Python Module of the Week

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About Python Module of the Week

PyMOTW is a series of blog posts written by Doug Hellmann (http://www.doughellmann.com/). It was started as a way to build the habit of writing something on a regular basis. The focus of the series is building a set of example code for the modules in the Python (http://www.python.org/) standard library.

Complete documentation for the standard library can be found on the Python web site at http://docs.python.org/library/contents.html.

Tools

The source text for PyMOTW is reStructuredText (http://docutils.sourceforge.net/) and the HTML and PDF output are created using Sphinx (http://sphinx.pocoo.org/).

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As new articles are written, they are posted to my blog (http://blog.doughellmann.com/). Updates are available by RSS (http://feeds.feedburner.com/PyMOTW) and email (http://www.feedburner.com/fb/a/emailverifySubmit?feedId=806224&amp;loc=en_US). See the project home page for details (http://www.doughellmann.com/PyMOTW/).

Translations and Other Versions

Junjie Cai and Yan Sheng have started a google code project called PyMOTWCN (http://code.google.com/p/pymotwcn/) and posted the completed translations at http://www.vbarter.cn/pymotw/.

Ralf Schönian is translating PyMOTW into German, following an alphabetical order. The results are available on his web site, http://schoenian-online.de/pymotw.html. Ralf is an active member of the pyCologne (http://wiki.python.de/User_Group_K%C3%B6ln?action=show&redirect=pyCologne) user group in Germany and author of pyVoc, the open source English/German vocabulary trainer (http://code.google.com/p/pyvoc/).

Roberto Pauletto is working on an Italian translation at http://robyp.x10hosting.com/. Roberto creates Windows applications with C# by day, and tinkers with Linux and Python at home. He has recently moved to Python from Perl for all of his system-administration scripting.

Ernesto Rico Schmidt (http://denklab.org/) provides a Spanish translation that follows the English version posts. Ernesto is in Bolivia, and is translating these examples as a way to contribute to the members of the Bolivian Free Software (http://www.softwarelibre.org.bo/) community who use Python. The full list of articles available in Spanish can be found at http://denklab.org/articles/category/pymotw/, and there is an RSS feed (http://denklab.org/feeds/articles/category/pymotw/).

Tetsuya Morimoto (http://d.hatena.ne.jp/t2y-1979/) is creating a Japanese translation. Tetsuya has used Python for 1.5 years. He has as experience at a Linux Distributor using Python with yum, anaconda, and rpm-tools while building RPM packages. Now, he uses it to make useful tools for himself, and is interested in application frameworks such as Django, mercurial and wxPython. Tetsuya is a member of Python Japan User's Group (http://www.python.jp/Zope/) and Python Code Reading (http://groups.google.co.jp/group/python-code-reading). The home page for his translation is http://d.hatena.ne.jp/t2y-1979/20090525/1243227350.

Gerard Flanagan is working on a "Python compendium" called The Hazel Tree (http://www.thehazeltree.org/). He is converting a collection of old and new of Python-related reference material into reStructuredText and then building a single searchable repository from the results. I am very pleased to have PyMOTW included with works from authors like Mark Pilgrim, Fredrik Lundh, Andrew Kuchling, and a growing list of others.

Other Contributors

Thank you to John Benediktsson for the original HTML-to-reST conversion.

Copyright

This section of the PyMOTW guide includes feature-based introductions to several modules in the standard library, organized by what your goal might be. Each article may include cross-references to several modules from different parts of the library, and show how they relate to one another.

CHAPTER

ONE

DATA PERSISTENCE AND EXCHANGE

Python provides several modules for storing data. There are basically two aspects to persistence: converting the in-memory object back and forth into a format for saving it, and working with the storage of the converted data.

1.1 Serializing Objects

Python includes two modules capable of converting objects into a transmittable or storable format (*serializing*): `pickle` and `json`. It is most common to use `pickle`, since there is a fast C implementation and it is integrated with some of the other standard library modules that actually store the serialized data, such as `shelve`. Web-based applications may want to examine `json`, however, since it integrates better with some of the existing web service storage applications.

1.2 Storing Serialized Objects

Once the in-memory object is converted to a storable format, the next step is to decide how to store the data. A simple flat-file with serialized objects written one after the other works for data that does not need to be indexed in any way. But Python includes a collection of modules for storing key-value pairs in a simple database using one of the DBM format variants.

The simplest interface to take advantage of the DBM format is provided by `shelve`. Simply open the shelve file, and access it through a dictionary-like API. Objects saved to the shelve are automatically pickled and saved without any extra work on your part.

One drawback of shelve is that with the default interface you can't guarantee which DBM format will be used. That won't matter if your application doesn't need to share the database files between hosts with different libraries, but if that is needed you can use one of the classes in the module to ensure a specific format is selected (*Specific Shelf Types*).

If you're going to be passing a lot of data around via JSON anyway, using `json` and `anydbm` can provide another persistence mechanism. Since the DBM database keys and values must be strings, however, the objects won't be automatically re-created when you access the value in the database.

1.3 Relational Databases

The excellent `sqlite3` in-process relational database is available with most Python distributions. It stores its database in memory or in a local file, and all access is from within the same process, so there is no network lag. The compact nature of `sqlite3` makes it especially well suited for embedding in desktop applications or development versions of web apps.

All access to the database is through the Python DBI 2.0 API, by default, as no object relational mapper (ORM) is included. The most popular general purpose ORM is SQLAlchemy (http://www.sqlalchemy.org/), but others such as Django's native ORM layer also support SQLite. SQLAlchemy is easy to install and set up, but if your objects aren't very complicated and you are worried about overhead, you may want to use the DBI interface directly.

1.4 Data Exchange Through Standard Formats

Although not usually considered a true persistence format `csv`, or comma-separated-value, files can be an effective way to migrate data between applications. Most spreadsheet programs and databases support both export and import using CSV, so dumping data to a CSV file is frequently the simplest way to move data out of your application and into an analysis tool.

CHAPTER

TWO

IN-MEMORY DATA STRUCTURES

Python includes several standard programming data structures as built-in types (http://docs.python.org/library/stdtypes.html) (list, tuple, dictionary, and set). Most applications won't need any other structures, but when they do the standard library delivers.

2.1 array

For large amounts of data, it may be more efficient to use an `array` instead of a `list`. Since the array is limited to a single data type, it can use a more compact memory representation than a general purpose list. As an added benefit, arrays can be manipulated using many of the same methods as a list, so it may be possible to replaces lists with arrays in to your application without a lot of other changes.

2.2 Sorting

If you need to maintain a sorted list as you add and remove values, check out `heapq`. By using the functions in `heapq` to add or remove items from a list, you can maintain the sort order of the list with low overhead.

Another option for building sorted lists or arrays is `bisect`. bisect uses a binary search to find the insertion point for new items, and is an alternative to repeatedly sorting a list that changes frequently.

2.3 Queue

Although the built-in list can simulate a queue using the `insert()` and `pop()` methods, it isn't thread-safe. For true ordered communication between threads you should use a `Queue`. `multiprocessing` includes a version of a Queue that works between processes, making it easier to port between the modules.

2.4 collections

`collections` includes implementations of several data structures that extend those found in other modules. For example, Deque is a double-ended queue, and allows you to add or remove items from either end. The `defaultdict` is a dictionary that responds with a default value if a key is missing. And `namedtuple` extends the normal tuple to give each member item an attribute name in addition to a numerical index.

2.5 Decoding Data

If you are working with data from another application, perhaps coming from a binary file or stream of data, you will find `struct` useful for decoding the data into Python's native types for easier manipulation.

2.6 Custom Variations

And finally, if the available types don't give you what you need, you may want to subclass one of the native types and customize it. You can also start from scratch by using the abstract base classes defined in `collections`.

CHAPTER

THREE

FILE ACCESS

Python's standard library includes a large range of tools for working with files, filenames, and file contents.

3.1 Filenames

The first step in working with files is to get the name of the file so you can operate on it. Python represents filenames as simple strings, but provides tools for building them from standard, platform-independent, components in `os.path`. List the contents of a directory with `listdir()` from `os`, or use `glob` to build a list of filenames from a pattern. Finer grained filtering of filenames is possible with `fnmatch`.

3.2 Meta-data

Once you know the name of the file, you may want to check other characteristics such as permissions or the file size using `os.stat()` and the constants in `stat`.

3.3 Reading Files

If you're writing a filter application that processes text input line-by-line, `fileinput` provides an easy framework to get started. The fileinput API calls for you to iterate over the `input()` generator, processing each line as it is yielded. The generator handles parsing command line arguments for file names, or falling back to reading directly from `sys.stdin`. The result is a flexible tool your users can run directly on a file or as part of a pipeline.

If your app needs random access to files, `linecache` makes it easy to read lines by their line number. The contents of the file are maintained in a cache, so be careful of memory consumption.

3.4 Temporary Files

For cases where you need to create scratch files to hold data temporarily, or before moving it to a permanent location, `tempfile` will be very useful. It provides classes to create temporary files and directories safely and securely. Names are guaranteed not to collide, and include random components so they are not easily guessable.

3.5 Files and Directories

Frequently you need to work on a file as a whole, without worrying about what is in it. The `shutil` module includes high-level file operations such as copying files and directories, setting permissions, etc.

CHAPTER

FOUR

TEXT PROCESSING TOOLS

The string class is the most obvious text processing tool available to Python programmers, but there are plenty of other tools in the standard library to make text manipulation simpler.

4.1 string module

Old-style code will use functions from the `string` module, instead of methods of string objects. There is an equivalent method for each function from the module, and use of the functions is deprecated for new code.

Newer code may use a `string.Template` as a simple way to parameterize strings beyond the features of the string or unicode classes. While not as feature-rich as templates defined by many of the web frameworks or extension modules available on PyPI, `string.Template` is a good middle ground for user-modifiable templates where dynamic values need to be inserted into otherwise static text.

4.2 Text Input

Reading from a file is easy enough, but if you're writing a line-by-line filter the `fileinput` module is even easier. The fileinput API calls for you to iterate over the `input()` generator, processing each line as it is yielded. The generator handles parsing command line arguments for file names, or falling back to reading directly from `sys.stdin`. The result is a flexible tool your users can run directly on a file or as part of a pipeline.

4.3 Text Output

The `textwrap` module includes tools for formatting text from paragraphs by limiting the width of output, adding indentation, and inserting line breaks to wrap lines consistently.

4.4 Comparing Values

The standard library includes two modules related to comparing text values beyond the built-in equality and sort comparison supported by string objects. `re` provides a complete regular expression library, implemented largely in C for performance. Regular expressions are well-suited for finding substrings within a larger data set, comparing strings against a pattern (rather than another fixed string), and mild parsing.

`difflib`, on the other hand, shows you the actual differences between sequences of text in terms of the parts added, removed, or changed. The output of the comparison functions in `difflib` can be used to provide more detailed feedback to user about where changes occur in two inputs, how a document has changed over time, etc.

CHAPTER

FIVE

BUILT-IN OBJECTS

5.1 exceptions – Built-in error classes

Purpose The exceptions module defines the built-in errors used throughout the standard library and by the interpreter.

Available In 1.5 and later

5.1.1 Description

In the past, Python has supported simple string messages as exceptions as well as classes. Since 1.5, all of the standard library modules use classes for exceptions. Starting with Python 2.5, string exceptions result in a DeprecationWarning, and support for string exceptions will be removed in the future.

5.1.2 Base Classes

The exception classes are defined in a hierarchy, described in the standard library documentation. In addition to the obvious organizational benefits, exception inheritance is useful because related exceptions can be caught by catching their base class. In most cases, these base classes are not intended to be raised directly.

BaseException

Base class for all exceptions. Implements logic for creating a string representation of the exception using str() from the arguments passed to the constructor.

Exception

Base class for exceptions that do not result in quitting the running application. All user-defined exceptions should use Exception as a base class.

StandardError

Base class for built-in exceptions used in the standard library.

ArithmeticError

Base class for math-related errors.

LookupError

Base class for errors raised when something can’t be found.

EnvironmentError

Base class for errors that come from outside of Python (the operating system, filesystem, etc.).

5.1.3 Raised Exceptions

AssertionError

An AssertionError is raised by a failed `assert` statement.

```
assert False, 'The assertion failed'
```

```
$ python exceptions_AssertionError_assert.py

Traceback (most recent call last):
  File "exceptions_AssertionError_assert.py", line 12, in <module>
    assert False, 'The assertion failed'
AssertionError: The assertion failed
```

It is also used in the `unittest` module in methods like `failIf()`.

```
import unittest

class AssertionExample(unittest.TestCase):

    def test(self):
        self.failUnless(False)

unittest.main()
```

```
$ python exceptions_AssertionError_unittest.py

F
======================================================================
FAIL: test (__main__.AssertionExample)
----------------------------------------------------------------------
Traceback (most recent call last):
  File "exceptions_AssertionError_unittest.py", line 17, in test
    self.failUnless(False)
AssertionError: False is not true

----------------------------------------------------------------------
Ran 1 test in 0.000s

FAILED (failures=1)
```

AttributeError

When an attribute reference or assignment fails, AttributeError is raised. For example, when trying to reference an attribute that does not exist:

```
class NoAttributes(object):
    pass

o = NoAttributes()
print o.attribute
```

```
$ python exceptions_AttributeError.py

Traceback (most recent call last):
  File "exceptions_AttributeError.py", line 16, in <module>
    print o.attribute
AttributeError: 'NoAttributes' object has no attribute 'attribute'
```

Or when trying to modify a read-only attribute:

```
class MyClass(object):

    @property
    def attribute(self):
        return 'This is the attribute value'

o = MyClass()
print o.attribute
o.attribute = 'New value'
```

```
$ python exceptions_AttributeError_assignment.py

This is the attribute value
Traceback (most recent call last):
  File "exceptions_AttributeError_assignment.py", line 20, in <module>
    o.attribute = 'New value'
AttributeError: can't set attribute
```

EOFError

An EOFError is raised when a built-in function like `input()` or `raw_input()` do not read any data before encountering the end of their input stream. The file methods like `read()` return an empty string at the end of the file.

```
while True:
    data = raw_input('prompt:')
    print 'READ:', data
```

```
$ echo hello | python PyMOTW/exceptions/exceptions_EOFError.py
prompt:READ: hello
prompt:Traceback (most recent call last):
  File "PyMOTW/exceptions/exceptions_EOFError.py", line 13, in <module>
    data = raw_input('prompt:')
EOFError: EOF when reading a line
```

FloatingPointError

Raised by floating point operations that result in errors, when floating point exception control (fpectl) is turned on. Enabling `fpectl` requires an interpreter compiled with the `--with-fpectl` flag. Using `fpectl` is discouraged in the stdlib docs (http://docs.python.org/lib/module-fpectl.html).

```
import math
import fpectl

print 'Control off:', math.exp(1000)
fpectl.turnon_sigfpe()
print 'Control on:', math.exp(1000)
```

GeneratorExit

Raised inside a generator the generator's `close()` method is called.

```
def my_generator():
    try:
        for i in range(5):
            print 'Yielding', i
            yield i
    except GeneratorExit:
        print 'Exiting early'

g = my_generator()
print g.next()
g.close()
```

```
$ python exceptions_GeneratorExit.py

Yielding 0
0
Exiting early
```

IOError

Raised when input or output fails, for example if a disk fills up or an input file does not exist.

```
f = open('/does/not/exist', 'r')
```

```
$ python exceptions_IOError.py

Traceback (most recent call last):
  File "exceptions_IOError.py", line 12, in <module>
    f = open('/does/not/exist', 'r')
IOError: [Errno 2] No such file or directory: '/does/not/exist'
```

ImportError

Raised when a module, or member of a module, cannot be imported. There are a few conditions where an ImportError might be raised.

1. If a module does not exist.

```
import module_does_not_exist
```

```
$ python exceptions_ImportError_nomodule.py

Traceback (most recent call last):
  File "exceptions_ImportError_nomodule.py", line 12, in <module>
```

```
    import module_does_not_exist
ImportError: No module named module_does_not_exist
```

2. If `from X import Y` is used and Y cannot be found inside the module X, an ImportError is raised.

```
from exceptions import MadeUpName
```

```
$ python exceptions_ImportError_missingname.py

Traceback (most recent call last):
  File "exceptions_ImportError_missingname.py", line 12, in <module>
    from exceptions import MadeUpName
ImportError: cannot import name MadeUpName
```

IndexError

An IndexError is raised when a sequence reference is out of range.

```
my_seq = [ 0, 1, 2 ]
print my_seq[3]
```

```
$ python exceptions_IndexError.py

Traceback (most recent call last):
  File "exceptions_IndexError.py", line 13, in <module>
    print my_seq[3]
IndexError: list index out of range
```

KeyError

Similarly, a KeyError is raised when a value is not found as a key of a dictionary.

```
d = { 'a':1, 'b':2 }
print d['c']
```

```
$ python exceptions_KeyError.py

Traceback (most recent call last):
  File "exceptions_KeyError.py", line 13, in <module>
    print d['c']
KeyError: 'c'
```

KeyboardInterrupt

A KeyboardInterrupt occurs whenever the user presses Ctrl-C (or Delete) to stop a running program. Unlike most of the other exceptions, KeyboardInterrupt inherits directly from BaseException to avoid being caught by global exception handlers that catch Exception.

```
try:
    print 'Press Return or Ctrl-C:',
    ignored = raw_input()
except Exception, err:
    print 'Caught exception:', err
except KeyboardInterrupt, err:
    print 'Caught KeyboardInterrupt'
else:
    print 'No exception'
```

Pressing Ctrl-C at the prompt causes a KeyboardInterrupt exception.

```
$ python exceptions_KeyboardInterrupt.py
Press Return or Ctrl-C: ^CCaught KeyboardInterrupt
```

MemoryError

If your program runs out of memory and it is possible to recover (by deleting some objects, for example), a MemoryError is raised.

```
import itertools

# Try to create a MemoryError by allocating a lot of memory
l = []
for i in range(3):
    try:
        for j in itertools.count(1):
            print i, j
            l.append('*' * (2**30))
    except MemoryError:
        print '(error, discarding existing list)'
        l = []
```

```
$ python exceptions_MemoryError.py
python(49670) malloc: *** mmap(size=1073745920) failed (error code=12)
*** error: can't allocate region
*** set a breakpoint in malloc_error_break to debug
python(49670) malloc: *** mmap(size=1073745920) failed (error code=12)
*** error: can't allocate region
*** set a breakpoint in malloc_error_break to debug
python(49670) malloc: *** mmap(size=1073745920) failed (error code=12)
*** error: can't allocate region
*** set a breakpoint in malloc_error_break to debug
0 1
0 2
0 3
(error, discarding existing list)
1 1
1 2
1 3
(error, discarding existing list)
2 1
2 2
2 3
(error, discarding existing list)
```

NameError

NameErrors are raised when your code refers to a name that does not exist in the current scope. For example, an unqualified variable name.

```
def func():
    print unknown_name

func()
```

```
$ python exceptions_NameError.py

Traceback (most recent call last):
  File "exceptions_NameError.py", line 15, in <module>
    func()
  File "exceptions_NameError.py", line 13, in func
    print unknown_name
NameError: global name 'unknown_name' is not defined
```

NotImplementedError

User-defined base classes can raise NotImplementedError to indicate that a method or behavior needs to be defined by a subclass, simulating an *interface*.

```
class BaseClass(object):
    """Defines the interface"""
    def __init__(self):
        super(BaseClass, self).__init__()
    def do_something(self):
        """The interface, not implemented"""
        raise NotImplementedError(self.__class__.__name__ + '.do_something')

class SubClass(BaseClass):
    """Implementes the interface"""
    def do_something(self):
        """really does something"""
        print self.__class__.__name__ + ' doing something!'

SubClass().do_something()
BaseClass().do_something()
```

```
$ python exceptions_NotImplementedError.py

SubClass doing something!
Traceback (most recent call last):
  File "exceptions_NotImplementedError.py", line 27, in <module>
    BaseClass().do_something()
  File "exceptions_NotImplementedError.py", line 18, in do_something
    raise NotImplementedError(self.__class__.__name__ + '.do_something')
NotImplementedError: BaseClass.do_something
```

See also:

abc - Abstract base classes

OSError

OSError serves as the error class for the os module, and is raised when an error comes back from an os-specific function.

```
import os

for i in range(10):
    print i, os.ttyname(i)
```

```
$ python exceptions_OSError.py

0 /dev/ttys000
1
Traceback (most recent call last):
  File "exceptions_OSError.py", line 15, in <module>
    print i, os.ttyname(i)
OSError: [Errno 25] Inappropriate ioctl for device
```

OverflowError

When an arithmetic operation exceeds the limits of the variable type, an OverflowError is raise. Long integers allocate more space as values grow, so they end up raising MemoryError. Floating point exception handling is not standardized, so floats are not checked. Regular integers are converted to long values as needed.

```
import sys

print 'Regular integer: (maxint=%s)' % sys.maxint
try:
    i = sys.maxint * 3
    print 'No overflow for ', type(i), 'i =', i
except OverflowError, err:
    print 'Overflowed at ', i, err

print
print 'Long integer:'
for i in range(0, 100, 10):
    print '%2d' % i, 2L ** i

print
print 'Floating point values:'
try:
    f = 2.0**i
    for i in range(100):
        print i, f
        f = f ** 2
except OverflowError, err:
    print 'Overflowed after ', f, err
```

```
$ python exceptions_OverflowError.py

Regular integer: (maxint=9223372036854775807)
No overflow for  <type 'long'> i = 27670116110564327421

Long integer:
 0 1
10 1024
20 1048576
30 1073741824
40 1099511627776
50 1125899906842624
60 1152921504606846976
```

```
70 1180591620717411303424
80 1208925819614629174706176
90 1237940039285380274899124224

Floating point values:
0 1.23794003929e+27
1 1.53249554087e+54
2 2.34854258277e+108
3 5.5156522631e+216
Overflowed after  5.5156522631e+216 (34, 'Result too large')
```

ReferenceError

When a `weakref` proxy is used to access an object that has already been garbage collected, a ReferenceError occurs.

```
import gc
import weakref

class ExpensiveObject(object):
    def __init__(self, name):
        self.name = name
    def __del__(self):
        print '(Deleting %s)' % self

obj = ExpensiveObject('obj')
p = weakref.proxy(obj)

print 'BEFORE:', p.name
obj = None
print 'AFTER:', p.name
```

```
$ python exceptions_ReferenceError.py

BEFORE: obj
(Deleting <__main__.ExpensiveObject object at 0x10046e4d0>)
AFTER:
Traceback (most recent call last):
  File "exceptions_ReferenceError.py", line 26, in <module>
    print 'AFTER:', p.name
ReferenceError: weakly-referenced object no longer exists
```

RuntimeError

A RuntimeError exception is used when no other more specific exception applies. The interpreter does not raise this exception itself very often, but some user code does.

StopIteration

When an iterator is done, it's `next()` method raises StopIteration. This exception is not considered an error.

```
l=[0,1,2]
i=iter(l)

print i
print i.next()
print i.next()
print i.next()
print i.next()
```

```
$ python exceptions_StopIteration.py

<listiterator object at 0x10045f650>
0
1
2
Traceback (most recent call last):
  File "exceptions_StopIteration.py", line 19, in <module>
    print i.next()
StopIteration
```

SyntaxError

A SyntaxError occurs any time the parser finds source code it does not understand. This can be while importing a module, invoking `exec`, or calling `eval()`. Attributes of the exception can be used to find exactly what part of the input text caused the exception.

```
try:
    print eval('five times three')
except SyntaxError, err:
    print 'Syntax error %s (%s-%s): %s' % \
        (err.filename, err.lineno, err.offset, err.text)
    print err
```

```
$ python exceptions_SyntaxError.py

Syntax error <string> (1-10): five times three
invalid syntax (<string>, line 1)
```

SystemError

When an error occurs in the interpreter itself and there is some chance of continuing to run successfully, it raises a SystemError. SystemErrors probably indicate a bug in the interpreter and should be reported to the maintainer.

SystemExit

When `sys.exit()` is called, it raises SystemExit instead of exiting immediately. This allows cleanup code in `try:finally` blocks to run and special environments (like debuggers and test frameworks) to catch the exception and avoid exiting.

TypeError

TypeErrors are caused by combining the wrong type of objects, or calling a function with the wrong type of object.

```
result = ('tuple',) + 'string'
```

```
$ python exceptions_TypeError.py

Traceback (most recent call last):
  File "exceptions_TypeError.py", line 12, in <module>
    result = ('tuple',) + 'string'
TypeError: can only concatenate tuple (not "str") to tuple
```

UnboundLocalError

An UnboundLocalError is a type of NameError specific to local variable names.

```
def throws_global_name_error():
    print unknown_global_name

def throws_unbound_local():
    local_val = local_val + 1
    print local_val

try:
    throws_global_name_error()
except NameError, err:
    print 'Global name error:', err

try:
    throws_unbound_local()
except UnboundLocalError, err:
    print 'Local name error:', err
```

The difference between the global NameError and the UnboundLocal is the way the name is used. Because the name "local_val" appears on the left side of an expression, it is interpreted as a local variable name.

```
$ python exceptions_UnboundLocalError.py

Global name error: global name 'unknown_global_name' is not defined
Local name error: local variable 'local_val' referenced before assignment
```

UnicodeError

`UnicodeError` is a subclass of `ValueError` and is raised when a Unicode problem occurs. There are separate subclasses for `UnicodeEncodeError`, `UnicodeDecodeError`, and `UnicodeTranslateError`.

ValueError

A ValueError is used when a function receives a value that has the right type but an invalid value.

```
print chr(1024)
```

```
$ python exceptions_ValueError.py

Traceback (most recent call last):
  File "exceptions_ValueError.py", line 12, in <module>
    print chr(1024)
ValueError: chr() arg not in range(256)
```

ZeroDivisionError

When zero shows up in the denominator of a division operation, a ZeroDivisionError is raised.

```
print 1/0
```

```
$ python exceptions_ZeroDivisionError.py

Traceback (most recent call last):
  File "exceptions_ZeroDivisionError.py", line 12, in <module>
    print 1/0
ZeroDivisionError: integer division or modulo by zero
```

5.1.4 Warning Categories

There are also several exceptions defined for use with the `warnings` module.

Warning The base class for all warnings.

UserWarning Base class for warnings coming from user code.

DeprecationWarning Used for features no longer being maintained.

PendingDeprecationWarning Used for features that are soon going to be deprecated.

SyntaxWarning Used for questionable syntax.

RuntimeWarning Used for events that happen at runtime that might cause problems.

FutureWarning Warning about changes to the language or library that are coming at a later time.

ImportWarning Warn about problems importing a module.

UnicodeWarning Warn about problems with unicode text.

See also:

exceptions (http://docs.python.org/library/exceptions.html) The standard library documentation for this module.

`warnings` Non-error warning messages.

CHAPTER

SIX

STRING SERVICES

6.1 codecs – String encoding and decoding

Purpose Encoders and decoders for converting text between different representations.

Available In 2.1 and later

The codecs module provides stream and file interfaces for transcoding data in your program. It is most commonly used to work with Unicode text, but other encodings are also available for other purposes.

6.1.1 Unicode Primer

CPython 2.x supports two types of strings for working with text data. Old-style str instances use a single 8-bit byte to represent each character of the string using its ASCII code. In contrast, unicode strings are managed internally as a sequence of Unicode *code points*. The code point values are saved as a sequence of 2 or 4 bytes each, depending on the options given when Python was compiled. Both unicode and str are derived from a common base class, and support a similar API.

When unicode strings are output, they are encoded using one of several standard schemes so that the sequence of bytes can be reconstructed as the same string later. The bytes of the encoded value are not necessarily the same as the code point values, and the encoding defines a way to translate between the two sets of values. Reading Unicode data also requires knowing the encoding so that the incoming bytes can be converted to the internal representation used by the unicode class.

The most common encodings for Western languages are UTF-8 and UTF-16, which use sequences of one and two byte values respectively to represent each character. Other encodings can be more efficient for storing languages where most of the characters are represented by code points that do not fit into two bytes.

See also:

For more introductory information about Unicode, refer to the list of references at the end of this section. The Python Unicode HOWTO (http://docs.python.org/howto/unicode) is especially helpful.

Encodings

The best way to understand encodings is to look at the different series of bytes produced by encoding the same string in different ways. The examples below use this function to format the byte string to make it easier to read.

```
import binascii

def to_hex(t, nbytes):
    "Format text t as a sequence of nbyte long values separated by spaces."
    chars_per_item = nbytes * 2
    hex_version = binascii.hexlify(t)
    num_chunks = len(hex_version) / chars_per_item
    def chunkify():
        for start in xrange(0, len(hex_version), chars_per_item):
            yield hex_version[start:start + chars_per_item]
    return ' '.join(chunkify())

if __name__ == '__main__':
    print to_hex('abcdef', 1)
    print to_hex('abcdef', 2)
```

The function uses `binascii` to get a hexadecimal representation of the input byte string, then insert a space between every *nbytes* bytes before returning the value.

```
$ python codecs_to_hex.py

61 62 63 64 65 66
6162 6364 6566
```

The first encoding example begins by printing the text `'pi: π'` using the raw representation of the `unicode` class. The π character is replaced with the expression for the Unicode code point, `\u03c0`. The next two lines encode the string as UTF-8 and UTF-16 respectively, and show the hexadecimal values resulting from the encoding.

```
from codecs_to_hex import to_hex

text = u'pi: π'

print 'Raw   :', repr(text)
print 'UTF-8 :', to_hex(text.encode('utf-8'), 1)
print 'UTF-16:', to_hex(text.encode('utf-16'), 2)
```

The result of encoding a `unicode` string is a `str` object.

```
$ python codecs_encodings.py

Raw   : u'pi: \u03c0'
UTF-8 : 70 69 3a 20 cf 80
UTF-16: fffe 7000 6900 3a00 2000 c003
```

Given a sequence of encoded bytes as a `str` instance, the `decode()` method translates them to code points and returns the sequence as a `unicode` instance.

```
from codecs_to_hex import to_hex

text = u'pi: π'
encoded = text.encode('utf-8')
decoded = encoded.decode('utf-8')

print 'Original :', repr(text)
print 'Encoded  :', to_hex(encoded, 1), type(encoded)
print 'Decoded  :', repr(decoded), type(decoded)
```

The choice of encoding used does not change the output type.

```
$ python codecs_decode.py

Original : u'pi: \u03c0'
Encoded  : 70 69 3a 20 cf 80 <type 'str'>
Decoded  : u'pi: \u03c0' <type 'unicode'>
```

Note: The default encoding is set during the interpreter start-up process, when `site` is loaded. Refer to *Unicode Defaults* for a description of the default encoding settings accessible via `sys`.

6.1.2 Working with Files

Encoding and decoding strings is especially important when dealing with I/O operations. Whether you are writing to a file, socket, or other stream, you will want to ensure that the data is using the proper encoding. In general, all text data needs to be decoded from its byte representation as it is read, and encoded from the internal values to a specific representation as it is written. Your program can explicitly encode and decode data, but depending on the encoding used it can be non-trivial to determine whether you have read enough bytes in order to fully decode the data. `codecs` provides classes that manage the data encoding and decoding for you, so you don't have to create your own.

The simplest interface provided by `codecs` is a replacement for the built-in `open()` function. The new version works just like the built-in, but adds two new arguments to specify the encoding and desired error handling technique.

```python
from codecs_to_hex import to_hex

import codecs
import sys

encoding = sys.argv[1]
filename = encoding + '.txt'

print 'Writing to', filename
with codecs.open(filename, mode='wt', encoding=encoding) as f:
    f.write(u'pi: \u03c0')

# Determine the byte grouping to use for to_hex()
nbytes = { 'utf-8':1,
           'utf-16':2,
           'utf-32':4,
           }.get(encoding, 1)

# Show the raw bytes in the file
print 'File contents:'
with open(filename, mode='rt') as f:
    print to_hex(f.read(), nbytes)
```

Starting with a `unicode` string with the code point for π, this example saves the text to a file using an encoding specified on the command line.

```
$ python codecs_open_write.py utf-8

Writing to utf-8.txt
File contents:
70 69 3a 20 cf 80

$ python codecs_open_write.py utf-16

Writing to utf-16.txt
File contents:
fffe 7000 6900 3a00 2000 c003

$ python codecs_open_write.py utf-32

Writing to utf-32.txt
```

```
File contents:
fffe0000 70000000 69000000 3a000000 20000000 c0030000
```

Reading the data with `open()` is straightforward, with one catch: you must know the encoding in advance, in order to set up the decoder correctly. Some data formats, such as XML, let you specify the encoding as part of the file, but usually it is up to the application to manage. `codecs` simply takes the encoding as an argument and assumes it is correct.

```
import codecs
import sys

encoding = sys.argv[1]
filename = encoding + '.txt'

print 'Reading from', filename
with codecs.open(filename, mode='rt', encoding=encoding) as f:
    print repr(f.read())
```

This example reads the files created by the previous program, and prints the representation of the resulting `unicode` object to the console.

```
$ python codecs_open_read.py utf-8

Reading from utf-8.txt
u'pi: \u03c0'

$ python codecs_open_read.py utf-16

Reading from utf-16.txt
u'pi: \u03c0'

$ python codecs_open_read.py utf-32

Reading from utf-32.txt
u'pi: \u03c0'
```

6.1.3 Byte Order

Multi-byte encodings such as UTF-16 and UTF-32 pose a problem when transferring the data between different computer systems, either by copying the file directly or with network communication. Different systems use different ordering of the high and low order bytes. This characteristic of the data, known as its *endianness*, depends on factors such as the hardware architecture and choices made by the operating system and application developer. There isn't always a way to know in advance what byte order to use for a given set of data, so the multi-byte encodings include a *byte-order marker* (BOM) as the first few bytes of encoded output. For example, UTF-16 is defined in such a way that 0xFFFE and 0xFEFF are not valid characters, and can be used to indicate the byte order. `codecs` defines constants for the byte order markers used by UTF-16 and UTF-32.

```
import codecs
from codecs_to_hex import to_hex

for name in [ 'BOM', 'BOM_BE', 'BOM_LE',
              'BOM_UTF8',
              'BOM_UTF16', 'BOM_UTF16_BE', 'BOM_UTF16_LE',
              'BOM_UTF32', 'BOM_UTF32_BE', 'BOM_UTF32_LE',
              ]:
    print '{:12} : {}'.format(name, to_hex(getattr(codecs, name), 2))
```

BOM, BOM_UTF16, and BOM_UTF32 are automatically set to the appropriate big-endian or little-endian values depending on the current system's native byte order.

```
$ python codecs_bom.py

BOM          : fffe
BOM_BE       : feff
BOM_LE       : fffe
BOM_UTF8     : efbb bf
BOM_UTF16    : fffe
BOM_UTF16_BE : feff
BOM_UTF16_LE : fffe
BOM_UTF32    : fffe 0000
BOM_UTF32_BE : 0000 feff
BOM_UTF32_LE : fffe 0000
```

Byte ordering is detected and handled automatically by the decoders in codecs, but you can also choose an explicit ordering for the encoding.

```
import codecs
from codecs_to_hex import to_hex

# Pick the non-native version of UTF-16 encoding
if codecs.BOM_UTF16 == codecs.BOM_UTF16_BE:
    bom = codecs.BOM_UTF16_LE
    encoding = 'utf_16_le'
else:
    bom = codecs.BOM_UTF16_BE
    encoding = 'utf_16_be'

print 'Native order  :', to_hex(codecs.BOM_UTF16, 2)
print 'Selected order:', to_hex(bom, 2)

# Encode the text.
encoded_text = u'pi: \u03c0'.encode(encoding)
print '{:14}: {}'.format(encoding, to_hex(encoded_text, 2))

with open('non-native-encoded.txt', mode='wb') as f:
    # Write the selected byte-order marker.  It is not included in the
    # encoded text because we were explicit about the byte order when
    # selecting the encoding.
    f.write(bom)
    # Write the byte string for the encoded text.
    f.write(encoded_text)
```

codecs_bom_create_file.py figures out the native byte ordering, then uses the alternate form explicitly so the next example can demonstrate auto-detection while reading.

```
$ python codecs_bom_create_file.py

Native order  : fffe
Selected order: feff
utf_16_be     : 0070 0069 003a 0020 03c0
```

codecs_bom_detection.py does not specify a byte order when opening the file, so the decoder uses the BOM value in the first two bytes of the file to determine it.

```
import codecs
from codecs_to_hex import to_hex
```

```
# Look at the raw data
with open('non-native-encoded.txt', mode='rb') as f:
    raw_bytes = f.read()

print 'Raw    :', to_hex(raw_bytes, 2)

# Re-open the file and let codecs detect the BOM
with codecs.open('non-native-encoded.txt', mode='rt', encoding='utf-16') as f:
    decoded_text = f.read()

print 'Decoded:', repr(decoded_text)
```

Since the first two bytes of the file are used for byte order detection, they are not included in the data returned by `read()`.

```
$ python codecs_bom_detection.py

Raw    : feff 0070 0069 003a 0020 03c0
Decoded: u'pi: \u03c0'
```

6.1.4 Error Handling

The previous sections pointed out the need to know the encoding being used when reading and writing Unicode files. Setting the encoding correctly is important for two reasons. If the encoding is configured incorrectly while reading from a file, the data will be interpreted wrong and may be corrupted or simply fail to decode. Not all Unicode characters can be represented in all encodings, so if the wrong encoding is used while writing an error will be generated and data may be lost.

`codecs` uses the same five error handling options that are provided by the `encode()` method of `unicode` and the `decode()` method of `str`.

Error Mode	Description
`strict`	Raises an exception if the data cannot be converted.
`replace`	Substitutes a special marker character for data that cannot be encoded.
`ignore`	Skips the data.
`xmlcharrefreplace`	XML character (encoding only)
`backslashreplace`	escape sequence (encoding only)

Encoding Errors

The most common error condition is receiving a *UnicodeEncodeError* when writing Unicode data to an ASCII output stream, such as a regular file or *sys.stdout*. This sample program can be used to experiment with the different error handling modes.

```
import codecs
import sys

error_handling = sys.argv[1]

text = u'pi: \u03c0'

try:
    # Save the data, encoded as ASCII, using the error
    # handling mode specified on the command line.
    with codecs.open('encode_error.txt', 'w',
                    encoding='ascii',
                    errors=error_handling) as f:
        f.write(text)

except UnicodeEncodeError, err:
    print 'ERROR:', err

else:
    # If there was no error writing to the file,
    # show what it contains.
    with open('encode_error.txt', 'rb') as f:
        print 'File contents:', repr(f.read())
```

While `strict` mode is safest for ensuring your application explicitly sets the correct encoding for all I/O operations, it can lead to program crashes when an exception is raised.

```
$ python codecs_encode_error.py strict

ERROR: 'ascii' codec can't encode character u'\u03c0' in position 4: ordinal not in range(128)
```

Some of the other error modes are more flexible. For example, `replace` ensures that no error is raised, at the expense of possibly losing data that cannot be converted to the requested encoding. The Unicode character for pi still cannot be encoded in ASCII, but instead of raising an exception the character is replaced with `?` in the output.

```
$ python codecs_encode_error.py replace

File contents: 'pi: ?'
```

To skip over problem data entirely, use `ignore`. Any data that cannot be encoded is simply discarded.

```
$ python codecs_encode_error.py ignore

File contents: 'pi: '
```

There are two lossless error handling options, both of which replace the character with an alternate representation defined by a standard separate from the encoding. `xmlcharrefreplace` uses an XML character reference as a substitute (the list of character references is specified in the W3C XML Entity Definitions for Characters (http://www.w3.org/TR/xml-entity-names/)).

```
$ python codecs_encode_error.py xmlcharrefreplace

File contents: 'pi: &#960;'
```

The other lossless error handling scheme is `backslashreplace` which produces an output format like the value you get when you print the `repr()` of a `unicode` object. Unicode characters are replaced with `\u` followed by the hexadecimal value of the code point.

```
$ python codecs_encode_error.py backslashreplace

File contents: 'pi: \\u03c0'
```

Decoding Errors

It is also possible to see errors when decoding data, especially if the wrong encoding is used.

```
import codecs
import sys
```

```
from codecs_to_hex import to_hex

error_handling = sys.argv[1]

text = u'pi: \u03c0'
print 'Original     :', repr(text)

# Save the data with one encoding
with codecs.open('decode_error.txt', 'w', encoding='utf-16') as f:
    f.write(text)

# Dump the bytes from the file
with open('decode_error.txt', 'rb') as f:
    print 'File contents:', to_hex(f.read(), 1)

# Try to read the data with the wrong encoding
with codecs.open('decode_error.txt', 'r',
                 encoding='utf-8',
                 errors=error_handling) as f:
    try:
        data = f.read()
    except UnicodeDecodeError, err:
        print 'ERROR:', err
    else:
        print 'Read         :', repr(data)
```

As with encoding, `strict` error handling mode raises an exception if the byte stream cannot be properly decoded. In this case, a *UnicodeDecodeError* results from trying to convert part of the UTF-16 BOM to a character using the UTF-8 decoder.

```
$ python codecs_decode_error.py strict

Original     : u'pi: \u03c0'
File contents: ff fe 70 00 69 00 3a 00 20 00 c0 03
ERROR: 'utf8' codec can't decode byte 0xff in position 0: invalid start byte
```

Switching to `ignore` causes the decoder to skip over the invalid bytes. The result is still not quite what is expected, though, since it includes embedded null bytes.

```
$ python codecs_decode_error.py ignore

Original     : u'pi: \u03c0'
File contents: ff fe 70 00 69 00 3a 00 20 00 c0 03
Read         : u'p\x00i\x00:\x00 \x00\x03'
```

In `replace` mode invalid bytes are replaced with `\uFFFD`, the official Unicode replacement character, which looks like a diamond with a black background containing a white question mark (�).

```
$ python codecs_decode_error.py replace

Original     : u'pi: \u03c0'
File contents: ff fe 70 00 69 00 3a 00 20 00 c0 03
Read         : u'\ufffd\ufffdp\x00i\x00:\x00 \x00\ufffd\x03'
```

6.1.5 Standard Input and Output Streams

The most common cause of *UnicodeEncodeError* exceptions is code that tries to print `unicode` data to the console or a Unix pipeline when *sys.stdout* is not configured with an encoding.

```
import codecs
import sys

text = u'pi: π'

# Printing to stdout may cause an encoding error
print 'Default encoding:', sys.stdout.encoding
print 'TTY:', sys.stdout.isatty()
print text
```

Problems with the default encoding of the standard I/O channels can be difficult to debug because the program works as expected when the output goes to the console, but cause encoding errors when it is used as part of a pipeline and the output includes Unicode characters above the ASCII range. This difference in behavior is caused by Python's initialization code, which sets the default encoding for each standard I/O channel *only if* the channel is connected to a terminal (`isatty()` returns `True`). If there is no terminal, Python assumes the program will configure the encoding explicitly, and leaves the I/O channel alone.

```
$ python codecs_stdout.py
Default encoding: utf-8
TTY: True
pi: π

$ python codecs_stdout.py | cat -
Default encoding: None
TTY: False
Traceback (most recent call last):
  File "codecs_stdout.py", line 18, in <module>
    print text
UnicodeEncodeError: 'ascii' codec can't encode character u'\u03c0' in
 position 4: ordinal not in range(128)
```

To explicitly set the encoding on the standard output channel, use `getwriter()` to get a stream encoder class for a specific encoding. Instantiate the class, passing `sys.stdout` as the only argument.

```
import codecs
import sys

text = u'pi: π'

# Wrap sys.stdout with a writer that knows how to handle encoding
# Unicode data.
wrapped_stdout = codecs.getwriter('UTF-8')(sys.stdout)
wrapped_stdout.write(u'Via write: ' + text + '\n')

# Replace sys.stdout with a writer
sys.stdout = wrapped_stdout

print u'Via print:', text
```

Writing to the wrapped version of `sys.stdout` passes the Unicode text through an encoder before sending the encoded bytes to stdout. Replacing `sys.stdout` means that any code used by your application that prints to standard output will be able to take advantage of the encoding writer.

```
$ python codecs_stdout_wrapped.py

Via write: pi: π
Via print: pi: π
```

The next problem to solve is how to know which encoding should be used. The proper encoding varies based on location, language, and user or system configuration, so hard-coding a fixed value is not a good idea. It would also be annoying for a user to need to pass explicit arguments to every program setting the input and output encodings. Fortunately, there is a global way to get a reasonable default encoding, using `locale`.

```
import codecs
import locale
import sys

text = u'pi: π'

# Configure locale from the user's environment settings.
locale.setlocale(locale.LC_ALL, '')

# Wrap stdout with an encoding-aware writer.
lang, encoding = locale.getdefaultlocale()
print 'Locale encoding    :', encoding
sys.stdout = codecs.getwriter(encoding)(sys.stdout)

print 'With wrapped stdout:', text
```

`getdefaultlocale()` returns the language and preferred encoding based on the system and user configuration settings in a form that can be used with `getwriter()`.

```
$ python codecs_stdout_locale.py

Locale encoding    : UTF-8
With wrapped stdout: pi: π
```

The encoding also needs to be set up when working with *sys.stdin*. Use `getreader()` to get a reader capable of decoding the input bytes.

```
import codecs
import locale
import sys

# Configure locale from the user's environment settings.
locale.setlocale(locale.LC_ALL, '')

# Wrap stdin with an encoding-aware reader.
lang, encoding = locale.getdefaultlocale()
sys.stdin = codecs.getreader(encoding)(sys.stdin)

print 'From stdin:', repr(sys.stdin.read())
```

Reading from the wrapped handle returns `unicode` objects instead of `str` instances.

```
$ python codecs_stdout_locale.py | python codecs_stdin.py

From stdin: u'Locale encoding    : UTF-8\nWith wrapped stdout: pi: \u03c0\n'
```

6.1.6 Network Communication

Network sockets are also byte-streams, and so Unicode data must be encoded into bytes before it is written to a socket.

```
import sys
import SocketServer


class Echo(SocketServer.BaseRequestHandler):

    def handle(self):
        # Get some bytes and echo them back to the client.
        data = self.request.recv(1024)
        self.request.send(data)
        return


if __name__ == '__main__':
    import codecs
    import socket
    import threading

    address = ('localhost', 0) # let the kernel give us a port
    server = SocketServer.TCPServer(address, Echo)
    ip, port = server.server_address # find out what port we were given

    t = threading.Thread(target=server.serve_forever)
    t.setDaemon(True) # don't hang on exit
    t.start()

    # Connect to the server
    s = socket.socket(socket.AF_INET, socket.SOCK_STREAM)
    s.connect((ip, port))

    # Send the data
    text = u'pi: π'
    len_sent = s.send(text)

    # Receive a response
    response = s.recv(len_sent)
    print repr(response)

    # Clean up
    s.close()
    server.socket.close()
```

You could encode the data explicitly, before sending it, but miss one call to `send()` and your program would fail with an encoding error.

```
   $ python codecs_socket_fail.py
   Traceback (most recent call last):
     File "codecs_socket_fail.py", line 43, in <module>
       len_sent = s.send(text)
   UnicodeEncodeError: 'ascii' codec can't encode character u'\u03c0' in
position 4: ordinal not in range(128)
```

By using `makefile()` to get a file-like handle for the socket, and then wrapping that with a stream-based reader or writer, you will be able to pass Unicode strings and know they are encoded on the way in to and out of the socket.

```
import sys
import SocketServer


class Echo(SocketServer.BaseRequestHandler):

    def handle(self):
        # Get some bytes and echo them back to the client.  There is
        # no need to decode them, since they are not used.
        data = self.request.recv(1024)
        self.request.send(data)
        return


class PassThrough(object):

    def __init__(self, other):
        self.other = other

    def write(self, data):
        print 'Writing :', repr(data)
        return self.other.write(data)

    def read(self, size=-1):
        print 'Reading :',
        data = self.other.read(size)
        print repr(data)
        return data

    def flush(self):
        return self.other.flush()

    def close(self):
        return self.other.close()


if __name__ == '__main__':
    import codecs
    import socket
    import threading

    address = ('localhost', 0) # let the kernel give us a port
    server = SocketServer.TCPServer(address, Echo)
    ip, port = server.server_address # find out what port we were given

    t = threading.Thread(target=server.serve_forever)
    t.setDaemon(True) # don't hang on exit
    t.start()

    # Connect to the server
    s = socket.socket(socket.AF_INET, socket.SOCK_STREAM)
    s.connect((ip, port))

    # Wrap the socket with a reader and writer.
    incoming = codecs.getreader('utf-8')(PassThrough(s.makefile('r')))
    outgoing = codecs.getwriter('utf-8')(PassThrough(s.makefile('w')))

    # Send the data
    text = u'pi: π'
    print 'Sending :', repr(text)
    outgoing.write(text)
    outgoing.flush()

    # Receive a response
    response = incoming.read()
    print 'Received:', repr(response)

    # Clean up
    s.close()
    server.socket.close()
```

This example uses `PassThrough` to show that the data is encoded before being sent, and the response is decoded after it is received in the client.

```
$ python codecs_socket.py
Sending : u'pi: \u03c0'
Writing : 'pi: \xcf\x80'
Reading : 'pi: \xcf\x80'
Received: u'pi: \u03c0'
```

6.1.7 Encoding Translation

Although most applications will work with `unicode` data internally, decoding or encoding it as part of an I/O operation, there are times when changing a file's encoding without holding on to that intermediate data format is useful. `EncodedFile()` takes an open file handle using one encoding and wraps it with a class that translates the data to another encoding as the I/O occurs.

```
from codecs_to_hex import to_hex

import codecs
from cStringIO import StringIO

# Raw version of the original data.
data = u'pi: \u03c0'

# Manually encode it as UTF-8.
utf8 = data.encode('utf-8')
print 'Start as UTF-8   :', to_hex(utf8, 1)

# Set up an output buffer, then wrap it as an EncodedFile.
output = StringIO()
encoded_file = codecs.EncodedFile(output, data_encoding='utf-8',
                                  file_encoding='utf-16')
encoded_file.write(utf8)

# Fetch the buffer contents as a UTF-16 encoded byte string
utf16 = output.getvalue()
print 'Encoded to UTF-16:', to_hex(utf16, 2)

# Set up another buffer with the UTF-16 data for reading,
# and wrap it with another EncodedFile.
buffer = StringIO(utf16)
encoded_file = codecs.EncodedFile(buffer, data_encoding='utf-8',
                                  file_encoding='utf-16')
```

```
# Read the UTF-8 encoded version of the data.
recoded = encoded_file.read()
print 'Back to UTF-8    :', to_hex(recoded, 1)
```

This example shows reading from and writing to separate handles returned by `EncodedFile()`. No matter whether the handle is used for reading or writing, the *file_encoding* always refers to the encoding in use by the open file handle passed as the first argument, and *data_encoding* value refers to the encoding in use by the data passing through the `read()` and `write()` calls.

```
$ python codecs_encodedfile.py

Start as UTF-8   : 70 69 3a 20 cf 80
Encoded to UTF-16: fffe 7000 6900 3a00 2000 c003
Back to UTF-8    : 70 69 3a 20 cf 80
```

6.1.8 Non-Unicode Encodings

Although most of the earlier examples use Unicode encodings, `codecs` can be used for many other data translations. For example, Python includes codecs for working with base-64, bzip2, ROT-13, ZIP, and other data formats.

```
import codecs
from cStringIO import StringIO

buffer = StringIO()
stream = codecs.getwriter('rot_13')(buffer)

text = 'abcdefghijklmnopqrstuvwxyz'

stream.write(text)
stream.flush()

print 'Original:', text
print 'ROT-13  :', buffer.getvalue()
```

Any transformation that can be expressed as a function taking a single input argument and returning a byte or Unicode string can be registered as a codec.

```
$ python codecs_rot13.py

Original: abcdefghijklmnopqrstuvwxyz
ROT-13  : nopqrstuvwxyzabcdefghijklm
```

Using `codecs` to wrap a data stream provides a simpler interface than working directly with `zlib`.

```
import codecs
from cStringIO import StringIO

from codecs_to_hex import to_hex

buffer = StringIO()
stream = codecs.getwriter('zlib')(buffer)

text = 'abcdefghijklmnopqrstuvwxyz\n' * 50

stream.write(text)
stream.flush()
```

```
print 'Original length :', len(text)
compressed_data = buffer.getvalue()
print 'ZIP compressed  :', len(compressed_data)

buffer = StringIO(compressed_data)
stream = codecs.getreader('zlib')(buffer)

first_line = stream.readline()
print 'Read first line :', repr(first_line)

uncompressed_data = first_line + stream.read()
print 'Uncompressed    :', len(uncompressed_data)
print 'Same            :', text == uncompressed_data
```

Not all of the compression or encoding systems support reading a portion of the data through the stream interface using `readline()` or `read()` because they need to find the end of a compressed segment to expand it. If your program cannot hold the entire uncompressed data set in memory, use the incremental access features of the compression library instead of `codecs`.

```
$ python codecs_zlib.py

Original length : 1350
ZIP compressed  : 48
Read first line : 'abcdefghijklmnopqrstuvwxyz\n'
Uncompressed    : 1350
Same            : True
```

6.1.9 Incremental Encoding

Some of the encodings provided, especially `bz2` and `zlib`, may dramatically change the length of the data stream as they work on it. For large data sets, these encodings operate better incrementally, working on one small chunk of data at a time. The `IncrementalEncoder` and `IncrementalDecoder` API is designed for this purpose.

```
import codecs
import sys

from codecs_to_hex import to_hex

text = 'abcdefghijklmnopqrstuvwxyz\n'
repetitions = 50

print 'Text length :', len(text)
print 'Repetitions :', repetitions
print 'Expected len:', len(text) * repetitions

# Encode the text several times build up a large amount of data
encoder = codecs.getincrementalencoder('bz2')()
encoded = []

print
print 'Encoding:',
for i in range(repetitions):
    en_c = encoder.encode(text, final = (i==repetitions-1))
    if en_c:
        print '\nEncoded : {} bytes'.format(len(en_c))
        encoded.append(en_c)
    else:
        sys.stdout.write('.')

bytes = ''.join(encoded)
print
print 'Total encoded length:', len(bytes)
print

# Decode the byte string one byte at a time
decoder = codecs.getincrementaldecoder('bz2')()
decoded = []

print 'Decoding:',
for i, b in enumerate(bytes):
    final= (i+1) == len(text)
    c = decoder.decode(b, final)
    if c:
        print '\nDecoded : {} characters'.format(len(c))
        print 'Decoding:',
        decoded.append(c)
    else:
        sys.stdout.write('.')
print

restored = u''.join(decoded)

print
print 'Total uncompressed length:', len(restored)
```

Each time data is passed to the encoder or decoder its internal state is updated. When the state is consistent (as defined by the codec), data is returned and the state resets. Until that point, calls to `encode()` or `decode()` will not return any data. When the last bit of data is passed in, the argument *final* should be set to `True` so the codec knows to flush any remaining buffered data.

```
$ python codecs_incremental_bz2.py

Text length : 27
Repetitions : 50
Expected len: 1350

Encoding:.................................................
Encoded : 99 bytes

Total encoded length: 99

Decoding:............................................................
............................
Decoded : 1350 characters
Decoding:..........

Total uncompressed length: 1350
```

6.1.10 Defining Your Own Encoding

Since Python comes with a large number of standard codecs already, it is unlikely that you will need to define your own. If you do, there are several base classes in `codecs` to make the process easier.

The first step is to understand the nature of the transformation described by the encoding. For example, an "invertcaps" encoding converts uppercase letters to lowercase, and lowercase letters to uppercase. Here is a simple definition of an encoding function that performs this transformation on an input string:

```
import string

def invertcaps(text):
    """Return new string with the case of all letters switched.
    """
    return ''.join( c.upper() if c in string.ascii_lowercase
                    else c.lower() if c in string.ascii_uppercase
                    else c
                    for c in text
                    )

if __name__ == '__main__':
    print invertcaps('ABC.def')
    print invertcaps('abc.DEF')
```

In this case, the encoder and decoder are the same function (as with `ROT-13`).

```
$ python codecs_invertcaps.py

abc.DEF
ABC.def
```

Although it is easy to understand, this implementation is not efficient, especially for very large text strings. Fortunately, `codecs` includes some helper functions for creating *character map* based codecs such as invertcaps. A character map encoding is made up of two dictionaries. The *encoding map* converts character values from the input string to byte values in the output and the *decoding map* goes the other way. Create your decoding map first, and then use `make_encoding_map()` to convert it to an encoding map. The C functions `charmap_encode()` and `charmap_decode()` use the maps to convert their input data efficiently.

```
import codecs
import string

# Map every character to itself
decoding_map = codecs.make_identity_dict(range(256))

# Make a list of pairs of ordinal values for the lower and upper case
# letters
pairs = zip([ ord(c) for c in string.ascii_lowercase],
            [ ord(c) for c in string.ascii_uppercase])

# Modify the mapping to convert upper to lower and lower to upper.
decoding_map.update( dict( (upper, lower) for (lower, upper) in pairs) )
decoding_map.update( dict( (lower, upper) for (lower, upper) in pairs) )

# Create a separate encoding map.
encoding_map = codecs.make_encoding_map(decoding_map)

if __name__ == '__main__':
    print codecs.charmap_encode('abc.DEF', 'strict', encoding_map)
    print codecs.charmap_decode('abc.DEF', 'strict', decoding_map)
    print encoding_map == decoding_map
```

Although the encoding and decoding maps for invertcaps are the same, that may not always be the case. `make_encoding_map()` detects situations where more than one input character is encoded to the same output byte and replaces the encoding value with `None` to mark the encoding as undefined.

```
$ python codecs_invertcaps_charmap.py

('ABC.def', 7)
(u'ABC.def', 7)
True
```

The character map encoder and decoder support all of the standard error handling methods described earlier, so you do not need to do any extra work to comply with that part of the API.

```
import codecs
from codecs_invertcaps_charmap import encoding_map

text = u'pi: π'

for error in [ 'ignore', 'replace', 'strict' ]:
    try:
        encoded = codecs.charmap_encode(text, error, encoding_map)
    except UnicodeEncodeError, err:
        encoded = str(err)
    print '{:7}: {}'.format(error, encoded)
```

Because the Unicode code point for π is not in the encoding map, the strict error handling mode raises an exception.

```
$ python codecs_invertcaps_error.py

ignore : ('PI: ', 5)
replace: ('PI: ?', 5)
strict : 'charmap' codec can't encode character u'\u03c0' in position
 4: character maps to <undefined>
```

After that the encoding and decoding maps are defined, you need to set up a few additional classes and register the encoding. `register()` adds a search function to the registry so that when a user wants to use your encoding `codecs` can locate it. The search function must take a single string argument with the name of the encoding, and return a `CodecInfo` object if it knows the encoding, or `None` if it does not.

```
import codecs
import encodings

def search1(encoding):
    print 'search1: Searching for:', encoding
    return None

def search2(encoding):
    print 'search2: Searching for:', encoding
    return None

codecs.register(search1)
codecs.register(search2)

utf8 = codecs.lookup('utf-8')
print 'UTF-8:', utf8

try:
    unknown = codecs.lookup('no-such-encoding')
except LookupError, err:
    print 'ERROR:', err
```

You can register multiple search functions, and each will be called in turn until one returns a `CodecInfo` or the list is exhausted. The internal search function registered by `codecs` knows how to load the standard codecs such as UTF-8 from encodings, so those names will never be passed to your search function.

```
$ python codecs_register.py

UTF-8: <codecs.CodecInfo object for encoding utf-8 at 0x100452ae0>
search1: Searching for: no-such-encoding
search2: Searching for: no-such-encoding
ERROR: unknown encoding: no-such-encoding
```

The CodecInfo instance returned by the search function tells codecs how to encode and decode using all of the different mechanisms supported: stateless, incremental, and stream. codecs includes base classes that make setting up a character map encoding easy. This example puts all of the pieces together to register a search function that returns a CodecInfo instance configured for the invertcaps codec.

```
import codecs

from codecs_invertcaps_charmap import encoding_map, decoding_map

# Stateless encoder/decoder

class InvertCapsCodec(codecs.Codec):
    def encode(self, input, errors='strict'):
        return codecs.charmap_encode(input, errors, encoding_map)

    def decode(self, input, errors='strict'):
        return codecs.charmap_decode(input, errors, decoding_map)

# Incremental forms

class InvertCapsIncrementalEncoder(codecs.IncrementalEncoder):
    def encode(self, input, final=False):
        return codecs.charmap_encode(input, self.errors, encoding_map)[0]

class InvertCapsIncrementalDecoder(codecs.IncrementalDecoder):
    def decode(self, input, final=False):
        return codecs.charmap_decode(input, self.errors, decoding_map)[0]

# Stream reader and writer

class InvertCapsStreamReader(InvertCapsCodec, codecs.StreamReader):
    pass

class InvertCapsStreamWriter(InvertCapsCodec, codecs.StreamWriter):
    pass

# Register the codec search function

def find_invertcaps(encoding):
    """Return the codec for 'invertcaps'.
    """
    if encoding == 'invertcaps':
        return codecs.CodecInfo(
            name='invertcaps',
            encode=InvertCapsCodec().encode,
            decode=InvertCapsCodec().decode,
            incrementalencoder=InvertCapsIncrementalEncoder,
            incrementaldecoder=InvertCapsIncrementalDecoder,
            streamreader=InvertCapsStreamReader,
            streamwriter=InvertCapsStreamWriter,
            )
    return None

codecs.register(find_invertcaps)

if __name__ == '__main__':

    # Stateless encoder/decoder
    encoder = codecs.getencoder('invertcaps')
    text = 'abc.DEF'
    encoded_text, consumed = encoder(text)
    print 'Encoder converted "{}" to "{}", consuming {} characters'.format(
        text, encoded_text, consumed)

    # Stream writer
    import sys
    writer = codecs.getwriter('invertcaps')(sys.stdout)
    print 'StreamWriter for stdout: ',
    writer.write('abc.DEF')
    print

    # Incremental decoder
    decoder_factory = codecs.getincrementaldecoder('invertcaps')
    decoder = decoder_factory()
    decoded_text_parts = []
    for c in encoded_text:
        decoded_text_parts.append(decoder.decode(c, final=False))
    decoded_text_parts.append(decoder.decode('', final=True))
    decoded_text = ''.join(decoded_text_parts)
    print 'IncrementalDecoder converted "{}" to "{}"'.format(
        encoded_text, decoded_text)
```

The stateless encoder/decoder base class is `Codec`. Override `encode()` and `decode()` with your implementation (in this case, calling `charmap_encode()` and `charmap_decode()` respectively). Each method must return a tuple containing the transformed data and the number of the input bytes or characters consumed. Conveniently, `charmap_encode()` and `charmap_decode()` already return that information.

`IncrementalEncoder` and `IncrementalDecoder` serve as base classes for the incremental interfaces. The `encode()` and `decode()` methods of the incremental classes are defined in such a way that they only return the actual transformed data. Any information about buffering is maintained as internal state. The invertcaps encoding does not need to buffer data (it uses a one-to-one mapping). For encodings that produce a different amount of output depending on the data being processed, such as compression algorithms, `BufferedIncrementalEncoder` and `BufferedIncrementalDecoder` are more appropriate base classes, since they manage the unprocessed portion of the input for you.

`StreamReader` and `StreamWriter` need `encode()` and `decode()` methods, too, and since they are expected to return the same value as the version from `Codec` you can use multiple inheritance for the implementation.

```
$ python codecs_invertcaps_register.py

Encoder converted "abc.DEF" to "ABC.def", consuming 7 characters
StreamWriter for stdout: ABC.def
IncrementalDecoder converted "ABC.def" to "abc.DEF"
```

See also:

codecs (http://docs.python.org/library/codecs.html) The standard library documentation for this module.

`locale` Accessing and managing the localization-based configuration settings and behaviors.

io The io module includes file and stream wrappers that handle encoding and decoding, too.

SocketServer For a more detailed example of an echo server, see the SocketServer module.

encodings Package in the standard library containing the encoder/decoder implementations provided by Python..

Unicode HOWTO (http://docs.python.org/howto/unicode) The official guide for using Unicode with Python 2.x.

Python Unicode Objects (http://effbot.org/zone/unicode-objects.htm) Fredrik Lundh's article about using non-ASCII character sets in Python 2.0.

How to Use UTF-8 with Python (http://evanjones.ca/python-utf8.html) Evan Jones' quick guide to working with Unicode, including XML data and the Byte-Order Marker.

On the Goodness of Unicode (http://www.tbray.org/ongoing/When/200x/2003/04/06/Unicode) Introduction to internationalization and Unicode by Tim Bray.

On Character Strings (http://www.tbray.org/ongoing/When/200x/2003/04/13/Strings) A look at the history of string processing in programming languages, by Tim Bray.

Characters vs. Bytes (http://www.tbray.org/ongoing/When/200x/2003/04/26/UTF) Part one of Tim Bray's "essay on modern character string processing for computer programmers." This installment covers in-memory representation of text in formats other than ASCII bytes.

The Absolute Minimum Every Software Developer Absolutely, Positively Must Know About Unicode and Character Sets (No E An introduction to Unicode by Joel Spolsky.

Endianness (http://en.wikipedia.org/wiki/Endianness) Explanation of endianness in Wikipedia.

6.2 difflib – Compare sequences

Purpose Compare sequences, especially lines of text.

Available In 2.1 and later

The difflib module contains tools for computing and working with differences between sequences. It is especially useful for comparing text, and includes functions that produce reports using several common difference formats.

The examples below will all use this common test data in the difflib_data.py module:

```
text1 = """Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Integer
eu lacus accumsan arcu fermentum euismod. Donec pulvinar porttitor
tellus. Aliquam venenatis. Donec facilisis pharetra tortor.  In nec
mauris eget magna consequat convallis. Nam sed sem vitae odio
pellentesque interdum. Sed consequat viverra nisl. Suspendisse arcu
metus, blandit quis, rhoncus ac, pharetra eget, velit. Mauris
urna. Morbi nonummy molestie orci. Praesent nisi elit, fringilla ac,
suscipit non, tristique vel, mauris. Curabitur vel lorem id nisl porta
adipiscing. Suspendisse eu lectus. In nunc. Duis vulputate tristique
enim. Donec quis lectus a justo imperdiet tempus."""
text1_lines = text1.splitlines()

text2 = """Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Integer
eu lacus accumsan arcu fermentum euismod. Donec pulvinar, porttitor
tellus. Aliquam venenatis. Donec facilisis pharetra tortor. In nec
mauris eget magna consequat convallis. Nam cras vitae mi vitae odio
pellentesque interdum. Sed consequat viverra nisl. Suspendisse arcu
metus, blandit quis, rhoncus ac, pharetra eget, velit. Mauris
urna. Morbi nonummy molestie orci. Praesent nisi elit, fringilla ac,
suscipit non, tristique vel, mauris. Curabitur vel lorem id nisl porta
adipiscing. Duis vulputate tristique enim. Donec quis lectus a justo
```

```
imperdiet tempus. Suspendisse eu lectus. In nunc. """
text2_lines = text2.splitlines()
```

6.2.1 Comparing Bodies of Text

The `Differ` class works on sequences of text lines and produces human-readable *deltas*, or change instructions, including differences within individual lines.

The default output produced by `Differ` is similar to the **diff** command line tool is simple with the `Differ` class. It includes the original input values from both lists, including common values, and markup data to indicate what changes were made.

- Lines prefixed with - indicate that they were in the first sequence, but not the second.
- Lines prefixed with + were in the second sequence, but not the first.
- If a line has an incremental difference between versions, an extra line prefixed with `?` is used to highlight the change within the new version.
- If a line has not changed, it is printed with an extra blank space on the left column so that it it lines up with the other lines that may have differences.

To compare text, break it up into a sequence of individual lines and pass the sequences to `compare()`.

```
import difflib
from difflib_data import *

d = difflib.Differ()
diff = d.compare(text1_lines, text2_lines)
print '\n'.join(diff)
```

The beginning of both text segments in the sample data is the same, so the first line is printed without any extra annotation.

```
1:   Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Integer
```

The second line of the data has been changed to include a comma in the modified text. Both versions of the line are printed, with the extra information on line 4 showing the column where the text was modified, including the fact that the `,` character was added.

```
2: - eu lacus accumsan arcu fermentum euismod. Donec pulvinar porttitor
3: + eu lacus accumsan arcu fermentum euismod. Donec pulvinar, porttitor
4: ?                                                        +
5:
```

Lines 6-9 of the output shows where an extra space was removed.

```
6: - tellus. Aliquam venenatis. Donec facilisis pharetra tortor.  In nec
7: ?                                                             -
8:
9: + tellus. Aliquam venenatis. Donec facilisis pharetra tortor. In nec
```

Next a more complex change was made, replacing several words in a phrase.

```
10: - mauris eget magna consequat convallis. Nam sed sem vitae odio
11: ?                                          - --
12:
13: + mauris eget magna consequat convallis. Nam cras vitae mi vitae odio
14: ?                                        +++ +++++   +
15:
```

The last sentence in the paragraph was changed significantly, so the difference is represented by simply removing the old version and adding the new (lines 20-23).

```
16:   pellentesque interdum. Sed consequat viverra nisl. Suspendisse arcu
17:   metus, blandit quis, rhoncus ac, pharetra eget, velit. Mauris
18:   urna. Morbi nonummy molestie orci. Praesent nisi elit, fringilla ac,
19:   suscipit non, tristique vel, mauris. Curabitur vel lorem id nisl porta
20: - adipiscing. Suspendisse eu lectus. In nunc. Duis vulputate tristique
21: - enim. Donec quis lectus a justo imperdiet tempus.
22: + adipiscing. Duis vulputate tristique enim. Donec quis lectus a justo
23: + imperdiet tempus. Suspendisse eu lectus. In nunc.
```

The `ndiff()` function produces essentially the same output.

```
import difflib
from difflib_data import *

diff = difflib.ndiff(text1_lines, text2_lines)
print '\n'.join(list(diff))
```

The processing is specifically tailored for working with text data and eliminating “noise” in the input.

```
$ python difflib_ndiff.py

  Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Integer
- eu lacus accumsan arcu fermentum euismod. Donec pulvinar porttitor
+ eu lacus accumsan arcu fermentum euismod. Donec pulvinar, porttitor
?                                                         +

- tellus. Aliquam venenatis. Donec facilisis pharetra tortor.  In nec
?                                                             -

+ tellus. Aliquam venenatis. Donec facilisis pharetra tortor. In nec
- mauris eget magna consequat convallis. Nam sed sem vitae odio
?                                             ------

+ mauris eget magna consequat convallis. Nam cras vitae mi vitae odio
?                                            +++        +++++++++

  pellentesque interdum. Sed consequat viverra nisl. Suspendisse arcu
  metus, blandit quis, rhoncus ac, pharetra eget, velit. Mauris
  urna. Morbi nonummy molestie orci. Praesent nisi elit, fringilla ac,
  suscipit non, tristique vel, mauris. Curabitur vel lorem id nisl porta
- adipiscing. Suspendisse eu lectus. In nunc. Duis vulputate tristique
- enim. Donec quis lectus a justo imperdiet tempus.
+ adipiscing. Duis vulputate tristique enim. Donec quis lectus a justo
+ imperdiet tempus. Suspendisse eu lectus. In nunc.
```

Other Output Formats

While the `Differ` class shows all of the input lines, a *unified diff* only includes modified lines and a bit of context. In Python 2.3, the `unified_diff()` function was added to produce this sort of output:

```
import difflib
from difflib_data import *

diff = difflib.unified_diff(text1_lines, text2_lines, lineterm='')
print '\n'.join(list(diff))
```

The output should look familiar to users of subversion or other version control tools:

```
$ python difflib_unified.py

---
+++
@@ -1,10 +1,10 @@
 Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Integer
-eu lacus accumsan arcu fermentum euismod. Donec pulvinar porttitor
-tellus. Aliquam venenatis. Donec facilisis pharetra tortor.  In nec
-mauris eget magna consequat convallis. Nam sed sem vitae odio
+eu lacus accumsan arcu fermentum euismod. Donec pulvinar, porttitor
+tellus. Aliquam venenatis. Donec facilisis pharetra tortor. In nec
+mauris eget magna consequat convallis. Nam cras vitae mi vitae odio
 pellentesque interdum. Sed consequat viverra nisl. Suspendisse arcu
 metus, blandit quis, rhoncus ac, pharetra eget, velit. Mauris
 urna. Morbi nonummy molestie orci. Praesent nisi elit, fringilla ac,
 suscipit non, tristique vel, mauris. Curabitur vel lorem id nisl porta
-adipiscing. Suspendisse eu lectus. In nunc. Duis vulputate tristique
-enim. Donec quis lectus a justo imperdiet tempus.
+adipiscing. Duis vulputate tristique enim. Donec quis lectus a justo
+imperdiet tempus. Suspendisse eu lectus. In nunc.
```

Using `context_diff()` produces similar readable output:

```
$ python difflib_context.py

***
---
***************
*** 1,10 ****
  Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Integer
! eu lacus accumsan arcu fermentum euismod. Donec pulvinar porttitor
! tellus. Aliquam venenatis. Donec facilisis pharetra tortor.  In nec
! mauris eget magna consequat convallis. Nam sed sem vitae odio
  pellentesque interdum. Sed consequat viverra nisl. Suspendisse arcu
  metus, blandit quis, rhoncus ac, pharetra eget, velit. Mauris
  urna. Morbi nonummy molestie orci. Praesent nisi elit, fringilla ac,
  suscipit non, tristique vel, mauris. Curabitur vel lorem id nisl porta
! adipiscing. Suspendisse eu lectus. In nunc. Duis vulputate tristique
! enim. Donec quis lectus a justo imperdiet tempus.
--- 1,10 ----
  Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Integer
! eu lacus accumsan arcu fermentum euismod. Donec pulvinar, porttitor
! tellus. Aliquam venenatis. Donec facilisis pharetra tortor. In nec
! mauris eget magna consequat convallis. Nam cras vitae mi vitae odio
  pellentesque interdum. Sed consequat viverra nisl. Suspendisse arcu
  metus, blandit quis, rhoncus ac, pharetra eget, velit. Mauris
  urna. Morbi nonummy molestie orci. Praesent nisi elit, fringilla ac,
  suscipit non, tristique vel, mauris. Curabitur vel lorem id nisl porta
! adipiscing. Duis vulputate tristique enim. Donec quis lectus a justo
! imperdiet tempus. Suspendisse eu lectus. In nunc.
```

HTML Output

`HtmlDiff` produces HTML output with the same information as `Diff`.

```
import difflib
from difflib_data import *

d = difflib.HtmlDiff()
print d.make_table(text1_lines, text2_lines)
```

This example uses `make_table()`, which only returns the `table` tag containing the difference information. The `make_file()` method produces a fully-formed HTML file as output.

Note: The output is not included here because it is very verbose.

6.2.2 Junk Data

All of the functions that produce difference sequences accept arguments to indicate which lines should be ignored, and which characters within a line should be ignored. These parameters can be used to skip over markup or whitespace changes in two versions of a file, for example.

```
# This example is taken from the source for difflib.py.

from difflib import SequenceMatcher

A = " abcd"
B = "abcd abcd"

print 'A = %r' % A
print 'B = %r' % B

print '\nWithout junk detection:'

s = SequenceMatcher(None, A, B)
i, j, k = s.find_longest_match(0, 5, 0, 9)
print '  i = %d' % i
print '  j = %d' % j
print '  k = %d' % k
print '  A[i:i+k] = %r' % A[i:i+k]
print '  B[j:j+k] = %r' % B[j:j+k]

print '\nTreat spaces as junk:'

s = SequenceMatcher(lambda x: x==" ", A, B)
i, j, k = s.find_longest_match(0, 5, 0, 9)
print '  i = %d' % i
print '  j = %d' % j
print '  k = %d' % k
print '  A[i:i+k] = %r' % A[i:i+k]
print '  B[j:j+k] = %r' % B[j:j+k]
```

The default for `Differ` is to not ignore any lines or characters explicitly, but to rely on the ability of `SequenceMatcher` to detect noise. The default for `ndiff()` is to ignore space and tab characters.

```
$ python difflib_junk.py

A = ' abcd'
B = 'abcd abcd'

Without junk detection:
  i = 0
  j = 4
  k = 5
  A[i:i+k] = ' abcd'
  B[j:j+k] = ' abcd'

Treat spaces as junk:
  i = 1
  j = 0
  k = 4
  A[i:i+k] = 'abcd'
  B[j:j+k] = 'abcd'
```

6.2.3 Comparing Arbitrary Types

The `SequenceMatcher` class compares two sequences of any types, as long as the values are hashable. It uses an algorithm to identify the longest contiguous matching blocks from the sequences, eliminating "junk" values that do not contribute to the real data.

```
import difflib
from difflib_data import *

s1 = [ 1, 2, 3, 5, 6, 4 ]
s2 = [ 2, 3, 5, 4, 6, 1 ]

print 'Initial data:'
print 's1 =', s1
print 's2 =', s2
print 's1 == s2:', s1==s2
print

matcher = difflib.SequenceMatcher(None, s1, s2)
for tag, i1, i2, j1, j2 in reversed(matcher.get_opcodes()):

    if tag == 'delete':
        print 'Remove %s from positions [%d:%d]' % (s1[i1:i2], i1, i2)
        del s1[i1:i2]

    elif tag == 'equal':
        print 'The sections [%d:%d] of s1 and [%d:%d] of s2 are the same' % \
            (i1, i2, j1, j2)

    elif tag == 'insert':
        print 'Insert %s from [%d:%d] of s2 into s1 at %d' % \
            (s2[j1:j2], j1, j2, i1)
        s1[i1:i2] = s2[j1:j2]

    elif tag == 'replace':
        print 'Replace %s from [%d:%d] of s1 with %s from [%d:%d] of s2' % (
            s1[i1:i2], i1, i2, s2[j1:j2], j1, j2)
        s1[i1:i2] = s2[j1:j2]

    print 's1 =', s1
    print 's2 =', s2
    print

print 's1 == s2:', s1==s2
```

This example compares two lists of integers and uses `get_opcodes()` to derive the instructions for converting the original list into the newer version. The modifications are applied in reverse order so that the list indexes remain accurate after items are added and removed.

```
$ python difflib_seq.py

Initial data:
s1 = [1, 2, 3, 5, 6, 4]
s2 = [2, 3, 5, 4, 6, 1]
s1 == s2: False

Replace [4] from [5:6] of s1 with [1] from [5:6] of s2
s1 = [1, 2, 3, 5, 6, 1]
s2 = [2, 3, 5, 4, 6, 1]

The sections [4:5] of s1 and [4:5] of s2 are the same
s1 = [1, 2, 3, 5, 6, 1]
s2 = [2, 3, 5, 4, 6, 1]

Insert [4] from [3:4] of s2 into s1 at 4
s1 = [1, 2, 3, 5, 4, 6, 1]
s2 = [2, 3, 5, 4, 6, 1]

The sections [1:4] of s1 and [0:3] of s2 are the same
s1 = [1, 2, 3, 5, 4, 6, 1]
s2 = [2, 3, 5, 4, 6, 1]

Remove [1] from positions [0:1]
s1 = [2, 3, 5, 4, 6, 1]
s2 = [2, 3, 5, 4, 6, 1]

s1 == s2: True
```

`SequenceMatcher` works with custom classes, as well as built-in types, as long as they are hashable.

See also:

difflib (http://docs.python.org/library/difflib.html) The standard library documentation for this module.

Pattern Matching: The Gestalt Approach (http://www.ddj.com/documents/s=1103/ddj8807c/) Discussion of a similar algorithm by John W. Ratcliff and D. E. Metzener published in Dr. Dobb's Journal in July, 1988.

Text Processing Tools

6.3 string – Working with text

Purpose Contains constants and classes for working with text.

Available In 2.5

The `string` module dates from the earliest versions of Python. In version 2.0, many of the functions previously implemented only in the module were moved to methods of `str` and `unicode` objects. Legacy versions of those functions are still available, but their use is deprecated and they will be dropped in Python 3.0. The `string` module still contains several useful constants and classes for working with string and unicode objects, and this discussion will concentrate on them.

6.3.1 Constants

The constants in the string module can be used to specify categories of characters such as `ascii_letters` and `digits`. Some of the constants, such as `lowercase`, are locale-dependent so the value changes to reflect the language settings of the user. Others, such as `hexdigits`, do not change when the locale changes.

```python
import string

for n in dir(string):
    if n.startswith('_'):
        continue
    v = getattr(string, n)
    if isinstance(v, basestring):
        print '%s=%s' % (n, repr(v))
        print
```

Most of the names for the constants are self-explanatory.

```
$ python string_constants.py

ascii_letters='abcdefghijklmnopqrstuvwxyzABCDEFGHIJKLMNOPQRSTUVWXYZ'

ascii_lowercase='abcdefghijklmnopqrstuvwxyz'

ascii_uppercase='ABCDEFGHIJKLMNOPQRSTUVWXYZ'

digits='0123456789'

hexdigits='0123456789abcdefABCDEF'

letters='abcdefghijklmnopqrstuvwxyzABCDEFGHIJKLMNOPQRSTUVWXYZ'

lowercase='abcdefghijklmnopqrstuvwxyz'

octdigits='01234567'

printable='0123456789abcdefghijklmnopqrstuvwxyzABCDEFGHIJKLMNOPQRSTUVWXYZ!"#$%&\'()*+,-./:;<=>?@[\\]

punctuation='!"#$%&\'()*+,-./:;<=>?@[\\]^_`{|}~'

uppercase='ABCDEFGHIJKLMNOPQRSTUVWXYZ'

whitespace='\t\n\x0b\x0c\r '
```

6.3.2 Functions

There are two functions not moving from the string module. `capwords()` capitalizes all of the words in a string.

```python
import string

s = 'The quick brown fox jumped over the lazy dog.'

print s
print string.capwords(s)
```

The results are the same as if you called `split()`, capitalized the words in the resulting list, then called `join()` to combine the results.

```
$ python string_capwords.py

The quick brown fox jumped over the lazy dog.
The Quick Brown Fox Jumped Over The Lazy Dog.
```

The other function creates translation tables that can be used with the `translate()` method to change one set of characters to another.

```
import string

leet = string.maketrans('abegiloprstz', '463611092572')

s = 'The quick brown fox jumped over the lazy dog.'

print s
print s.translate(leet)
```

In this example, some letters are replaced by their l33t (http://en.wikipedia.org/wiki/Leet) number alternatives.

```
$ python string_maketrans.py

The quick brown fox jumped over the lazy dog.
Th3 qu1ck 620wn f0x jum93d 0v32 7h3 142y d06.
```

6.3.3 Templates

String templates were added in Python 2.4 as part of **PEP 292** (http://www.python.org/dev/peps/pep-0292) and are intended as an alternative to the built-in interpolation syntax. With `string.Template` interpolation, variables are identified by name prefixed with `$` (e.g., `$var`) or, if necessary to set them off from surrounding text, they can also be wrapped with curly braces (e.g., `${var}`).

This example compares a simple template with a similar string interpolation setup.

```
import string

values = { 'var':'foo' }

t = string.Template("""
$var
$$
${var}iable
""")

print 'TEMPLATE:', t.substitute(values)

s = """
%(var)s
%%
%(var)siable
"""

print 'INTERPLOATION:', s % values
```

As you see, in both cases the trigger character (`$` or `%`) is escaped by repeating it twice.

```
$ python string_template.py

TEMPLATE:
```

```
foo
$
fooiable

INTERPLOATION:
foo
%
fooiable
```

One key difference between templates and standard string interpolation is that the type of the arguments is not taken into account. The values are converted to strings, and the strings are inserted into the result. No formatting options are available. For example, there is no way to control the number of digits used to represent a floating point value.

A benefit, though, is that by using the `safe_substitute()` method, it is possible to avoid exceptions if not all of the values needed by the template are provided as arguments.

```
import string

values = { 'var':'foo' }

t = string.Template("$var is here but $missing is not provided")

try:
    print 'TEMPLATE:', t.substitute(values)
except KeyError, err:
    print 'ERROR:', str(err)

print 'TEMPLATE:', t.safe_substitute(values)
```

Since there is no value for missing in the values dictionary, a *KeyError* is raised by `substitute()`. Instead of raising the error, `safe_substitute()` catches it and leaves the variable expression alone in the text.

```
$ python string_template_missing.py

TEMPLATE: ERROR: 'missing'
TEMPLATE: foo is here but $missing is not provided
```

6.3.4 Advanced Templates

If the default syntax for `string.Template` is not to your liking, you can change the behavior by adjusting the regular expression patterns it uses to find the variable names in the template body. A simple way to do that is to change the *delimiter* and *idpattern* class attributes.

```
import string

class MyTemplate(string.Template):
    delimiter = '%'
    idpattern = '[a-z]+_[a-z]+'

t = MyTemplate('%% %with_underscore %notunderscored')
d = { 'with_underscore':'replaced',
      'notunderscored':'not replaced',
      }

print t.safe_substitute(d)
```

In this example, variable ids must include an underscore somewhere in the middle, so `%notunderscored` is not replaced by anything.

```
$ python string_template_advanced.py

% replaced %notunderscored
```

For more complex changes, you can override the *pattern* attribute and define an entirely new regular expression. The pattern provided must contain four named groups for capturing the escaped delimiter, the named variable, a braced version of the variable name, and invalid delimiter patterns.

Let's look at the default pattern:

```
import string

t = string.Template('$var')
print t.pattern.pattern
```

Since `t.pattern` is a compiled regular expression, we have to access its pattern attribute to see the actual string.

```
$ python string_template_defaultpattern.py


    \$(?:
      (?P<escaped>\$) |   # Escape sequence of two delimiters
      (?P<named>[_a-z][_a-z0-9]*)      |   # delimiter and a Python identifier
      {(?P<braced>[_a-z][_a-z0-9]*)}   |   # delimiter and a braced identifier
      (?P<invalid>)              # Other ill-formed delimiter exprs
    )
```

If we wanted to create a new type of template using, for example, `{{var}}` as the variable syntax, we could use a pattern like this:

```
import re
import string

class MyTemplate(string.Template):
    delimiter = '{{'
    pattern = r'''
    \{\{(?:
    (?P<escaped>\{\{)|
    (?P<named>[_a-z][_a-z0-9]*)\}\}|
    (?P<braced>[_a-z][_a-z0-9]*)\}\}|
    (?P<invalid>)
    )
    '''

t = MyTemplate('''
{{{{
{{var}}
''')

print 'MATCHES:', t.pattern.findall(t.template)
print 'SUBSTITUTED:', t.safe_substitute(var='replacement')
```

We still have to provide both the named and braced patterns, even though they are the same. Here's the output:

```
$ python string_template_newsyntax.py

MATCHES: [('{{', '', '', ''), ('', 'var', '', '')]
SUBSTITUTED:
{{
replacement
```

6.3.5 Deprecated Functions

For information on the deprecated functions moved to the string and unicode classes, refer to String Methods (http://docs.python.org/lib/string-methods.html#string-methods) in the manual.

See also:

string (http://docs.python.org/lib/module-string.html) Standard library documentation for this module.

PEP 292 (http://www.python.org/dev/peps/pep-0292) Simpler String Substitutions

Text Processing Tools

6.4 StringIO and cStringIO – Work with text buffers using file-like API

Purpose Work with text buffers using file-like API

Available In StringIO: 1.4, cStringIO: 1.5

`StringIO` provides a convenient means of working with text in memory using the file API (read, write. etc.). There are two separate implementations. The `cStringIO` version is written in C for speed, while `StringIO` is written in Python for portability. Using `cStringIO` to build large strings can offer performance savings over some other string conctatenation techniques.

6.4.1 Example

Here are some pretty standard, simple, examples of using `StringIO` buffers:

```
# Find the best implementation available on this platform
try:
    from cStringIO import StringIO
except:
    from StringIO import StringIO

# Writing to a buffer
output = StringIO()
output.write('This goes into the buffer. ')
print >>output, 'And so does this.'

# Retrieve the value written
print output.getvalue()

output.close() # discard buffer memory

# Initialize a read buffer
input = StringIO('Inital value for read buffer')

# Read from the buffer
print input.read()
```

This example uses `read()`, but the `readline()` and `readlines()` methods are also available. The `StringIO` class also provides a `seek()` method so it is possible to jump around in a buffer while reading, which can be useful for rewinding if you are using some sort of look-ahead parsing algorithm.

```
$ python stringio_examples.py

This goes into the buffer. And so does this.
```

```
Inital value for read buffer
```

Real world applications of `StringIO` include a web application stack where various parts of the stack may add text to the response, or testing the output generated by parts of a program which typically write to a file.

The application we are building at work includes a shell scripting interface in the form of several command line programs. Some of these programs are responsible for pulling data from the database and dumping it on the console (either to show the user, or so the text can serve as input to another command). The commands share a set of formatter plugins to produce a text representation of an object in a variety of ways (XML, bash syntax, human readable, etc.). Since the formatters normally write to standard output, testing the results would be a little tricky without the StringIO module. Using StringIO to intercept the output of the formatter gives us an easy way to collect the output in memory to compare against expected results.

See also:

StringIO (http://docs.python.org/lib/module-StringIO.html) Standard library documentation for this module.

The StringIO module ::: www.effbot.org (http://effbot.org/librarybook/stringio.htm) effbot's examples with StringIO

Efficient String Concatenation in Python (http://www.skymind.com/%7Eocrow/python_string/) Examines various methods of combining strings and their relative merits.

6.5 re – Regular Expressions

Purpose Searching within and changing text using formal patterns.

Available In 1.5 and later

Regular expressions are text matching patterns described with a formal syntax. The patterns are interpreted as a set of instructions, which are then executed with a string as input to produce a matching subset or modified version of the original. The term "regular expressions" is frequently shortened to as "regex" or "regexp" in conversation. Expressions can include literal text matching, repetition, pattern-composition, branching, and other sophisticated rules. A large number of parsing problems are easier to solve with a regular expression than by creating a special-purpose lexer and parser.

Regular expressions are typically used in applications that involve a lot of text processing. For example, they are commonly used as search patterns in text editing programs used by developers, including vi, emacs, and modern IDEs. They are also an integral part of Unix command line utilities such as sed, grep, and awk. Many programming languages include support for regular expressions in the language syntax (Perl, Ruby, Awk, and Tcl). Other languages, such as C, C++, and Python supports regular expressions through extension libraries.

There are multiple open source implementations of regular expressions, each sharing a common core syntax but with different extensions or modifications to their advanced features. The syntax used in Python's `re` module is based on the syntax used for regular expressions in Perl, with a few Python-specific enhancements.

Note: Although the formal definition of "regular expression" is limited to expressions that describe regular languages, some of the extensions supported by `re` go beyond describing regular languages. The term "regular expression" is used here in a more general sense to mean any expression that can be evaluated by Python's `re` module.

6.5.1 Finding Patterns in Text

The most common use for `re` is to search for patterns in text. This example looks for two literal strings, `'this'` and `'that'`, in a text string.

```
import re

patterns = [ 'this', 'that' ]
text = 'Does this text match the pattern?'

for pattern in patterns:
    print 'Looking for "%s" in "%s" ->' % (pattern, text),

    if re.search(pattern,  text):
        print 'found a match!'
    else:
        print 'no match'
```

`search()` takes the pattern and text to scan, and returns a `Match` object when the pattern is found. If the pattern is not found, `search()` returns `None`.

```
$ python re_simple.py

Looking for "this" in "Does this text match the pattern?" -> found a match!
Looking for "that" in "Does this text match the pattern?" -> no match
```

The `Match` object returned by `search()` holds information about the nature of the match, including the original input string, the regular expression used, and the location within the original string where the pattern occurs.

```
import re

pattern = 'this'
text = 'Does this text match the pattern?'

match = re.search(pattern, text)

s = match.start()
e = match.end()

print 'Found "%s" in "%s" from %d to %d ("%s")' % \
    (match.re.pattern, match.string, s, e, text[s:e])
```

The `start()` and `end()` methods give the integer indexes into the string showing where the text matched by the pattern occurs.

```
$ python re_simple_match.py

Found "this" in "Does this text match the pattern?" from 5 to 9 ("this")
```

6.5.2 Compiling Expressions

`re` includes module-level functions for working with regular expressions as text strings, but it is usually more efficient to *compile* the expressions your program uses frequently. The `compile()` function converts an expression string into a `RegexObject`.

```
import re

# Pre-compile the patterns
regexes = [ re.compile(p) for p in [ 'this',
                                     'that',
                                     ]
            ]
```

```
text = 'Does this text match the pattern?'

for regex in regexes:
    print 'Looking for "%s" in "%s" ->' % (regex.pattern, text),

    if regex.search(text):
        print 'found a match!'
    else:
        print 'no match'
```

The module-level functions maintain a cache of compiled expressions, but the size of the cache is limited and using compiled expressions directly means you can avoid the cache lookup overhead. By pre-compiling any expressions your module uses when the module is loaded you shift the compilation work to application startup time, instead of a point where the program is responding to a user action.

```
$ python re_simple_compiled.py

Looking for "this" in "Does this text match the pattern?" -> found a match!
Looking for "that" in "Does this text match the pattern?" -> no match
```

6.5.3 Multiple Matches

So far the example patterns have all used `search()` to look for single instances of literal text strings. The `findall()` function returns all of the substrings of the input that match the pattern without overlapping.

```
import re

text = 'abbaaabbbbaaaaa'

pattern = 'ab'

for match in re.findall(pattern, text):
    print 'Found "%s"' % match
```

There are two instances of `ab` in the input string.

```
$ python re_findall.py

Found "ab"
Found "ab"
```

`finditer()` returns an iterator that produces `Match` instances instead of the strings returned by `findall()`.

```
import re

text = 'abbaaabbbbaaaaa'

pattern = 'ab'

for match in re.finditer(pattern, text):
    s = match.start()
    e = match.end()
    print 'Found "%s" at %d:%d' % (text[s:e], s, e)
```

This example finds the same two occurrences of `ab`, and the `Match` instance shows where they are in the original input.

```
$ python re_finditer.py

Found "ab" at 0:2
Found "ab" at 5:7
```

6.5.4 Pattern Syntax

Regular expressions support more powerful patterns than simple literal text strings. Patterns can repeat, can be anchored to different logical locations within the input, and can be expressed in compact forms that don't require every literal character be present in the pattern. All of these features are used by combining literal text values with *metacharacters* that are part of the regular expression pattern syntax implemented by `re`. The following examples will use this test program to explore variations in patterns.

```
import re

def test_patterns(text, patterns=[]):
    """Given source text and a list of patterns, look for
    matches for each pattern within the text and print
    them to stdout.
    """
    # Show the character positions and input text
    print
    print ''.join(str(i/10 or ' ') for i in range(len(text)))
    print ''.join(str(i%10) for i in range(len(text)))
    print text

    # Look for each pattern in the text and print the results
    for pattern in patterns:
        print
        print 'Matching "%s"' % pattern
        for match in re.finditer(pattern, text):
            s = match.start()
            e = match.end()
            print '  %2d : %2d = "%s"' % \
                (s, e-1, text[s:e])
    return

if __name__ == '__main__':
    test_patterns('abbaaabbbbaaaaa', ['ab'])
```

The output of `test_patterns()` shows the input text, including the character positions, as well as the substring range from each portion of the input that matches the pattern.

```
$ python re_test_patterns.py


          11111
012345678901234
abbaaabbbbaaaaa

Matching "ab"
   0 :  1 = "ab"
   5 :  6 = "ab"
```

Repetition

There are five ways to express repetition in a pattern. A pattern followed by the metacharacter `*` is repeated zero or more times (allowing a pattern to repeat zero times means it does not need to appear at all to match). Replace the `*` with `+` and the pattern must appear at least once. Using `?` means the pattern appears zero or one time. For a specific number of occurrences, use `{m}` after the pattern, where *m* is replaced with the number of times the pattern should repeat. And finally, to allow a variable but limited number of repetitions, use `{m,n}` where *m* is the minimum number of repetitions and *n* is the maximum. Leaving out *n* (`{m,}`) means the value appears at least *m* times, with no maximum.

```
from re_test_patterns import test_patterns

test_patterns('abbaaabbbbaaaaa',
              [ 'ab*',     # a followed by zero or more b
                'ab+',     # a followed by one or more b
                'ab?',     # a followed by zero or one b
                'ab{3}',   # a followed by three b
                'ab{2,3}', # a followed by two to three b
                ])
```

Notice how many more matches there are for `ab*` and `ab?` than `ab+`.

```
$ python re_repetition.py


          11111
012345678901234
abbaaabbbbaaaaa

Matching "ab*"
   0 :  2 = "abb"
   3 :  3 = "a"
   4 :  4 = "a"
   5 :  9 = "abbbb"
  10 : 10 = "a"
  11 : 11 = "a"
  12 : 12 = "a"
  13 : 13 = "a"
  14 : 14 = "a"

Matching "ab+"
   0 :  2 = "abb"
   5 :  9 = "abbbb"

Matching "ab?"
   0 :  1 = "ab"
   3 :  3 = "a"
   4 :  4 = "a"
   5 :  6 = "ab"
  10 : 10 = "a"
  11 : 11 = "a"
  12 : 12 = "a"
  13 : 13 = "a"
  14 : 14 = "a"

Matching "ab{3}"
   5 :  8 = "abbb"
```

```
Matching "ab{2,3}"
   0 :  2 = "abb"
   5 :  8 = "abbb"
```

The normal processing for a repetition instruction is to consume as much of the input as possible while matching the pattern. This so-called *greedy* behavior may result in fewer individual matches, or the matches may include more of the input text than intended. Greediness can be turned off by following the repetition instruction with `?`.

```
from re_test_patterns import test_patterns

test_patterns('abbaaabbbbaaaaa',
              [ 'ab*?',     # a followed by zero or more b
                'ab+?',     # a followed by one or more b
                'ab??',     # a followed by zero or one b
                'ab{3}?',   # a followed by three b
                'ab{2,3}?', # a followed by two to three b
                ])
```

Disabling greedy consumption of the input for any of the patterns where zero occurences of `b` are allowed means the matched substring does not include any `b` characters.

```
$ python re_repetition_non_greedy.py


          11111
012345678901234
abbaaabbbbaaaaa

Matching "ab*?"
   0 :  0 = "a"
   3 :  3 = "a"
   4 :  4 = "a"
   5 :  5 = "a"
  10 : 10 = "a"
  11 : 11 = "a"
  12 : 12 = "a"
  13 : 13 = "a"
  14 : 14 = "a"

Matching "ab+?"
   0 :  1 = "ab"
   5 :  6 = "ab"

Matching "ab??"
   0 :  0 = "a"
   3 :  3 = "a"
   4 :  4 = "a"
   5 :  5 = "a"
  10 : 10 = "a"
  11 : 11 = "a"
  12 : 12 = "a"
  13 : 13 = "a"
  14 : 14 = "a"

Matching "ab{3}?"
   5 :  8 = "abbb"

Matching "ab{2,3}?"
   0 :  2 = "abb"
   5 :  7 = "abb"
```

Character Sets

A *character set* is a group of characters, any one of which can match at that point in the pattern. For example, `[ab]` would match either `a` or `b`.

```
from re_test_patterns import test_patterns

test_patterns('abbaaabbbbaaaaa',
              [ '[ab]',    # either a or b
                'a[ab]+',  # a followed by one or more a or b
                'a[ab]+?', # a followed by one or more a or b, not greedy
                ])
```

The greedy form of the expression, `a[ab]+`, consumes the entire string because the first letter is `a` and every subsequent character is either `a` or `b`.

```
$ python re_charset.py


          11111
012345678901234
abbaaabbbbaaaaa

Matching "[ab]"
   0 :  0 = "a"
   1 :  1 = "b"
   2 :  2 = "b"
   3 :  3 = "a"
   4 :  4 = "a"
   5 :  5 = "a"
   6 :  6 = "b"
   7 :  7 = "b"
   8 :  8 = "b"
   9 :  9 = "b"
  10 : 10 = "a"
  11 : 11 = "a"
  12 : 12 = "a"
  13 : 13 = "a"
  14 : 14 = "a"

Matching "a[ab]+"
   0 : 14 = "abbaaabbbbaaaaa"

Matching "a[ab]+?"
   0 :  1 = "ab"
   3 :  4 = "aa"
   5 :  6 = "ab"
  10 : 11 = "aa"
  12 : 13 = "aa"
```

A character set can also be used to exclude specific characters. The special marker `^` means to look for characters not in the set following.

```
from re_test_patterns import test_patterns

test_patterns('This is some text -- with punctuation.',
              [ '[^-. ]+',  # sequences without -, ., or space
                ])
```

This pattern finds all of the substrings that do not contain the characters `-`, `.`, or a space.

```
$ python re_charset_exclude.py


          1111111111222222222233333333
01234567890123456789012345678901234567
This is some text -- with punctuation.

Matching "[^-. ]+"
   0 :  3 = "This"
   5 :  6 = "is"
   8 : 11 = "some"
  13 : 16 = "text"
  21 : 24 = "with"
  26 : 36 = "punctuation"
```

As character sets grow larger, typing every character that should (or should not) match becomes tedious. A more compact format using *character ranges* lets you define a character set to include all of the contiguous characters between a start and stop point.

```
from re_test_patterns import test_patterns

test_patterns('This is some text -- with punctuation.',
              [ '[a-z]+',      # sequences of lower case letters
                '[A-Z]+',      # sequences of upper case letters
                '[a-zA-Z]+',   # sequences of lower or upper case letters
                '[A-Z][a-z]+', # one upper case letter followed by lower case letters
                ])
```

Here the range `a-z` includes the lower case ASCII letters, and the range `A-Z` includes the upper case ASCII letters. The ranges can also be combined into a single character set.

```
$ python re_charset_ranges.py


          1111111111222222222233333333
01234567890123456789012345678901234567
This is some text -- with punctuation.

Matching "[a-z]+"
   1 :  3 = "his"
   5 :  6 = "is"
   8 : 11 = "some"
  13 : 16 = "text"
  21 : 24 = "with"
  26 : 36 = "punctuation"

Matching "[A-Z]+"
   0 :  0 = "T"

Matching "[a-zA-Z]+"
   0 :  3 = "This"
   5 :  6 = "is"
   8 : 11 = "some"
  13 : 16 = "text"
  21 : 24 = "with"
  26 : 36 = "punctuation"

Matching "[A-Z][a-z]+"
   0 :  3 = "This"
```

As a special case of a character set the metacharacter dot, or period (`.`), indicates that the pattern should match any single character in that position.

```
from re_test_patterns import test_patterns

test_patterns('abbaaabbbbaaaaa',
              [ 'a.',   # a followed by any one character
                'b.',   # b followed by any one character
                'a.*b', # a followed by anything, ending in b
                'a.*?b', # a followed by anything, ending in b
                ])
```

Combining dot with repetition can result in very long matches, unless the non-greedy form is used.

```
$ python re_charset_dot.py


          11111
012345678901234
abbaaabbbbaaaaa

Matching "a."
   0 :  1 = "ab"
   3 :  4 = "aa"
   5 :  6 = "ab"
  10 : 11 = "aa"
  12 : 13 = "aa"

Matching "b."
   1 :  2 = "bb"
   6 :  7 = "bb"
   8 :  9 = "bb"

Matching "a.*b"
   0 :  9 = "abbaaabbbb"

Matching "a.*?b"
   0 :  1 = "ab"
   3 :  6 = "aaab"
```

Escape Codes

An even more compact representation uses escape codes for several pre-defined character sets. The escape codes recognized by `re` are:

Code	Meaning
`\d`	a digit
`\D`	a non-digit
`\s`	whitespace (tab, space, newline, etc.)
`\S`	non-whitespace
`\w`	alphanumeric
`\W`	non-alphanumeric

Note: Escapes are indicated by prefixing the character with a backslash (\). Unfortunately, a backslash must itself be escaped in normal Python strings, and that results in expressions that are difficult to read. Using *raw* strings, created by prefixing the literal value with `r`, for creating regular expressions eliminates this problem and maintains readability.

```
from re_test_patterns import test_patterns

test_patterns('This is a prime #1 example!',
              [ r'\d+', # sequence of digits
                r'\D+', # sequence of non-digits
                r'\s+', # sequence of whitespace
                r'\S+', # sequence of non-whitespace
                r'\w+', # alphanumeric characters
                r'\W+', # non-alphanumeric
                ])
```

These sample expressions combine escape codes with repetition to find sequences of like characters in the input string.

```
$ python re_escape_codes.py


          11111111112222222
012345678901234567890123456
This is a prime #1 example!

Matching "\d+"
  17 : 17 = "1"

Matching "\D+"
   0 : 16 = "This is a prime #"
  18 : 26 = " example!"

Matching "\s+"
   4 :  4 = " "
   7 :  7 = " "
   9 :  9 = " "
  15 : 15 = " "
  18 : 18 = " "

Matching "\S+"
   0 :  3 = "This"
   5 :  6 = "is"
   8 :  8 = "a"
  10 : 14 = "prime"
  16 : 17 = "#1"
  19 : 26 = "example!"

Matching "\w+"
   0 :  3 = "This"
   5 :  6 = "is"
   8 :  8 = "a"
  10 : 14 = "prime"
  17 : 17 = "1"
  19 : 25 = "example"

Matching "\W+"
   4 :  4 = " "
   7 :  7 = " "
   9 :  9 = " "
  15 : 16 = " #"
  18 : 18 = " "
  26 : 26 = "!"
```

To match the characters that are part of the regular expression syntax, escape the characters in the search pattern.

```
from re_test_patterns import test_patterns

test_patterns(r'\d+ \D+ \s+ \S+ \w+ \W+',
              [ r'\\d\+',
                r'\\D\+',
                r'\\s\+',
                r'\\S\+',
                r'\\w\+',
                r'\\W\+',
                ])
```

These patterns escape the backslash and plus characters, since as metacharacters both have special meaning in a regular expression.

```
$ python re_escape_escapes.py


          1111111111222
01234567890123456789012
\d+ \D+ \s+ \S+ \w+ \W+

Matching "\\d\+"
   0 :  2 = "\d+"

Matching "\\D\+"
   4 :  6 = "\D+"

Matching "\\s\+"
   8 : 10 = "\s+"

Matching "\\S\+"
  12 : 14 = "\S+"

Matching "\\w\+"
  16 : 18 = "\w+"

Matching "\\W\+"
  20 : 22 = "\W+"
```

Anchoring

In addition to describing the content of a pattern to match, you can also specify the relative location in the input text where the pattern should appear using *anchoring* instructions.

Code	Meaning
`^`	start of string, or line
`$`	end of string, or line
`\A`	start of string
`\Z`	end of string
`\b`	empty string at the beginning or end of a word
`\B`	empty string not at the beginning or end of a word

```
from re_test_patterns import test_patterns

test_patterns('This is some text -- with punctuation.',
              [ r'^\w+',      # word at start of string
                r'\A\w+',     # word at start of string
                r'\w+\S*$',   # word at end of string, with optional punctuation
                r'\w+\S*\Z',  # word at end of string, with optional punctuation
                r'\w*t\w*',   # word containing 't'
                r'\bt\w+',    # 't' at start of word
                r'\w+t\b',    # 't' at end of word
                r'\Bt\B',     # 't', not start or end of word
                ])
```

The patterns in the example for matching words at the beginning and end of the string are different because the word at the end of the string is followed by punctuation to terminate the sentence. The pattern `\w+$` would not match, since `.` is not considered an alphanumeric character.

```
$ python re_anchoring.py


          11111111112222222222333333333
012345678901234567890123456789012345678
This is some text -- with punctuation.

Matching "^\w+"
   0 :  3 = "This"

Matching "\A\w+"
   0 :  3 = "This"

Matching "\w+\S*$"
  26 : 37 = "punctuation."

Matching "\w+\S*\Z"
  26 : 37 = "punctuation."

Matching "\w*t\w*"
  13 : 16 = "text"
  21 : 24 = "with"
  26 : 36 = "punctuation"

Matching "\bt\w+"
  13 : 16 = "text"

Matching "\w+t\b"
  13 : 16 = "text"

Matching "\Bt\B"
  23 : 23 = "t"
  30 : 30 = "t"
  33 : 33 = "t"
```

6.5.5 Constraining the Search

In situations where you know in advance that only a subset of the full input should be searched, you can further constrain the regular expression match by telling `re` to limit the search range. For example, if your pattern must appear at the front of the input, then using `match()` instead of `search()` will anchor the search without having to explicitly include an anchor in the search pattern.

```
import re

text = 'This is some text -- with punctuation.'
pattern = 'is'

print 'Text    :', text
print 'Pattern:', pattern

m = re.match(pattern, text)
print 'Match   :', m
s = re.search(pattern, text)
print 'Search :', s
```

Since the literal text `is` does not appear at the start of the input text, it is not found using `match()`. The sequence appears two other times in the text, though, so `search()` finds it.

```
$ python re_match.py

Text    : This is some text -- with punctuation.
Pattern: is
Match   : None
Search : <_sre.SRE_Match object at 0x100452988>
```

The `search()` method of a compiled regular expression accepts optional *start* and *end* position parameters to limit the search to a substring of the input.

```
import re

text = 'This is some text -- with punctuation.'
pattern = re.compile(r'\b\w*is\w*\b')

print 'Text:', text
print

pos = 0
while True:
    match = pattern.search(text, pos)
    if not match:
        break
    s = match.start()
    e = match.end()
    print '   %2d : %2d = "%s"' % \
        (s, e-1, text[s:e])
    # Move forward in text for the next search
    pos = e
```

This example implements a less efficient form of `iterall()`. Each time a match is found, the end position of that match is used for the next search.

```
$ python re_search_substring.py

Text: This is some text -- with punctuation.

   0 :  3 = "This"
   5 :  6 = "is"
```

6.5.6 Dissecting Matches with Groups

Searching for pattern matches is the basis of the powerful capabilities provided by regular expressions. Adding *groups* to a pattern lets you isolate parts of the matching text, expanding those capabilities to create a parser. Groups are defined by enclosing patterns in parentheses ((and)).

```
from re_test_patterns import test_patterns

test_patterns('abbaaabbbbaaaaa',
              [ 'a(ab)',    # 'a' followed by literal 'ab'
                'a(a*b*)',  # 'a' followed by 0-n 'a' and 0-n 'b'
                'a(ab)*',   # 'a' followed by 0-n 'ab'
                'a(ab)+',   # 'a' followed by 1-n 'ab'
                ])
```

Any complete regular expression can be converted to a group and nested within a larger expression. All of the repetition modifiers can be applied to a group as a whole, requiring the entire group pattern to repeat.

```
$ python re_groups.py


          11111
012345678901234
abbaaabbbbaaaaa

Matching "a(ab)"
   4 :  6 = "aab"

Matching "a(a*b*)"
   0 :  2 = "abb"
   3 :  9 = "aaabbbb"
  10 : 14 = "aaaaa"

Matching "a(ab)*"
   0 :  0 = "a"
   3 :  3 = "a"
   4 :  6 = "aab"
  10 : 10 = "a"
  11 : 11 = "a"
  12 : 12 = "a"
  13 : 13 = "a"
  14 : 14 = "a"

Matching "a(ab)+"
   4 :  6 = "aab"
```

To access the substrings matched by the individual groups within a pattern, use the `groups()` method of the `Match` object.

```
import re

text = 'This is some text -- with punctuation.'

print text
print

for pattern in [ r'^(\w+)',           # word at start of string
                 r'(\w+)\S*$',        # word at end of string, with optional punctuation
                 r'(\bt\w+)\W+(\w+)', # word starting with 't' then another word
```

```
                r'(\w+t)\b',          # word ending with 't'
                ]:
    regex = re.compile(pattern)
    match = regex.search(text)
    print 'Matching "%s"' % pattern
    print '  ', match.groups()
    print
```

`Match.groups()` returns a sequence of strings in the order of the group within the expression that matches the string.

```
$ python re_groups_match.py

This is some text -- with punctuation.

Matching "^(\w+)"
   ('This',)

Matching "(\w+)\S*$"
   ('punctuation',)

Matching "(\bt\w+)\W+(\w+)"
   ('text', 'with')

Matching "(\w+t)\b"
   ('text',)
```

If you are using grouping to find parts of the string, but you don't need all of the parts matched by groups, you can ask for the match of only a single group with `group()`.

```
import re

text = 'This is some text -- with punctuation.'

print 'Input text            :', text

# word starting with 't' then another word
regex = re.compile(r'(\bt\w+)\W+(\w+)')
print 'Pattern               :', regex.pattern

match = regex.search(text)
print 'Entire match          :', match.group(0)
print 'Word starting with "t":', match.group(1)
print 'Word after "t" word   :', match.group(2)
```

Group `0` represents the string matched by the entire expression, and sub-groups are numbered starting with `1` in the order their left parenthesis appears in the expression.

```
$ python re_groups_individual.py

Input text            : This is some text -- with punctuation.
Pattern               : (\bt\w+)\W+(\w+)
Entire match          : text -- with
Word starting with "t": text
Word after "t" word   : with
```

Python extends the basic grouping syntax to add *named groups*. Using names to refer to groups makes it easier to modify the pattern over time, without having to also modify the code using the match results. To set the name of a group, use the syntax `(P?<name>pattern)`.

```
import re

text = 'This is some text -- with punctuation.'

print text
print

for pattern in [ r'^(?P<first_word>\w+)',
                 r'(?P<last_word>\w+)\S*$',
                 r'(?P<t_word>\bt\w+)\W+(?P<other_word>\w+)',
                 r'(?P<ends_with_t>\w+t)\b',
                 ]:
    regex = re.compile(pattern)
    match = regex.search(text)
    print 'Matching "%s"' % pattern
    print '   ', match.groups()
    print '   ', match.groupdict()
    print
```

Use `groupdict()` to retrieve the dictionary mapping group names to substrings from the match. Named patterns are included in the ordered sequence returned by `groups()`, as well.

```
$ python re_groups_named.py

This is some text -- with punctuation.

Matching "^(?P<first_word>\w+)"
   ('This',)
   {'first_word': 'This'}

Matching "(?P<last_word>\w+)\S*$"
   ('punctuation',)
   {'last_word': 'punctuation'}

Matching "(?P<t_word>\bt\w+)\W+(?P<other_word>\w+)"
   ('text', 'with')
   {'other_word': 'with', 't_word': 'text'}

Matching "(?P<ends_with_t>\w+t)\b"
   ('text',)
   {'ends_with_t': 'text'}
```

An updated version of `test_patterns()` that shows the numbered and named groups matched by a pattern will make the following examples easier to follow.

```
import re

def test_patterns(text, patterns=[]):
    """Given source text and a list of patterns, look for
    matches for each pattern within the text and print
    them to stdout.
    """
    # Show the character positions and input text
    print
    print ''.join(str(i/10 or ' ') for i in range(len(text)))
    print ''.join(str(i%10) for i in range(len(text)))
    print text

    # Look for each pattern in the text and print the results
    for pattern in patterns:
        print
        print 'Matching "%s"' % pattern
        for match in re.finditer(pattern, text):
            s = match.start()
            e = match.end()
            print '  %2d : %2d = "%s"' % \
                (s, e-1, text[s:e])
            print '    Groups:', match.groups()
            if match.groupdict():
                print '    Named groups:', match.groupdict()
            print
    return
```

Since a group is itself a complete regular expression, groups can be nested within other groups to build even more complicated expressions.

```
from re_test_patterns_groups import test_patterns

test_patterns('abbaaabbbbaaaaa',
              [r'a((a*)(b*))', # 'a' followed by 0-n 'a' and 0-n 'b'
               ])
```

In this case, the group `(a*)` matches an empty string, so the return value from `groups()` includes that empty string as the matched value.

```
$ python re_groups_nested.py


          11111
012345678901234
abbaaabbbbaaaaa

Matching "a((a*)(b*))"
   0 :  2 = "abb"
    Groups: ('bb', '', 'bb')

   3 :  9 = "aaabbbb"
    Groups: ('aabbbb', 'aa', 'bbbb')

  10 : 14 = "aaaaa"
    Groups: ('aaaa', 'aaaa', '')
```

Groups are also useful for specifying alternative patterns. Use `|` to indicate that one pattern or another should match. Consider the placement of the `|` carefully, though. The first expression in this example matches a sequence of `a` followed by a sequence consisting entirely of a single letter, `a` or `b`. The second pattern matches `a` followed by a sequence that may include *either* `a` or `b`. The patterns are similar, but the resulting matches are completely different.

```
from re_test_patterns_groups import test_patterns

test_patterns('abbaaabbbbaaaaa',
              [r'a((a+)|(b+))', # 'a' followed by a sequence of 'a' or sequence of 'b'
               r'a((a|b)+)',    # 'a' followed by a sequence of 'a' or 'b'
               ])
```

When an alternative group is not matched, but the entire pattern does match, the return value of `groups()` includes a `None` value at the point in the sequence where the alternative group should appear.

```
$ python re_groups_alternative.py


          11111
012345678901234
abbaaabbbbaaaaa

Matching "a((a+)|(b+))"
   0 :  2 = "abb"
    Groups: ('bb', None, 'bb')

   3 :  5 = "aaa"
    Groups: ('aa', 'aa', None)

  10 : 14 = "aaaaa"
    Groups: ('aaaa', 'aaaa', None)


Matching "a((a|b)+)"
   0 : 14 = "abbaaabbbbaaaaa"
    Groups: ('bbaaabbbbaaaaa', 'a')
```

Defining a group containing a sub-pattern is also useful in cases where the string matching the sub-pattern is not part of what you want to extract from the full text. These groups are called *non-capturing*. To create a non-capturing group, use the syntax `(?:pattern)`.

```
from re_test_patterns_groups import test_patterns

test_patterns('abbaaabbbbaaaaa',
              [r'a((a+)|(b+))',      # capturing form
               r'a((?:a+)|(?:b+))', # non-capturing
               ])
```

Compare the groups returned for the capturing and non-capturing forms of a pattern that matches the same results.

```
$ python re_groups_non_capturing.py


          11111
012345678901234
abbaaabbbbaaaaa

Matching "a((a+)|(b+))"
   0 :  2 = "abb"
    Groups: ('bb', None, 'bb')

   3 :  5 = "aaa"
    Groups: ('aa', 'aa', None)

  10 : 14 = "aaaaa"
    Groups: ('aaaa', 'aaaa', None)


Matching "a((?:a+)|(?:b+))"
   0 :  2 = "abb"
    Groups: ('bb',)

   3 :  5 = "aaa"
    Groups: ('aa',)
  10 : 14 = "aaaaa"
    Groups: ('aaaa',)
```

6.5.7 Search Options

You can change the way the matching engine processes an expression using option flags. The flags can be combined using a bitwise or operation, and passed to `compile()`, `search()`, `match()`, and other functions that accept a pattern for searching.

Case-insensitive Matching

`IGNORECASE` causes literal characters and character ranges in the pattern to match both upper and lower case characters.

```
import re

text = 'This is some text -- with punctuation.'
pattern = r'\bT\w+'
with_case = re.compile(pattern)
without_case = re.compile(pattern, re.IGNORECASE)

print 'Text              :', text
print 'Pattern           :', pattern
print 'Case-sensitive    :', with_case.findall(text)
print 'Case-insensitive:', without_case.findall(text)
```

Since the pattern includes the literal `T`, without setting `IGNORECASE` the only match is the word `This`. When case is ignored, `text` also matches.

```
$ python re_flags_ignorecase.py

Text            : This is some text -- with punctuation.
Pattern         : \bT\w+
Case-sensitive  : ['This']
Case-insensitive: ['This', 'text']
```

Input with Multiple Lines

There are two flags that effect how searching in multi-line input works. The `MULTILINE` flag controls how the pattern matching code processes anchoring instructions for text containing newline characters. When multiline mode is turned on, the anchor rules for `^` and `$` apply at the beginning and end of each line, in addition to the entire string.

```
import re

text = 'This is some text -- with punctuation.\nAnd a second line.'
pattern = r'(^\w+)|(\w+\S*$)'
single_line = re.compile(pattern)
multiline = re.compile(pattern, re.MULTILINE)

print 'Text        :', repr(text)
print 'Pattern     :', pattern
print 'Single Line :', single_line.findall(text)
print 'Multline    :', multiline.findall(text)
```

The pattern in the example matches the first or last word of the input. It matches `line.` at the end of the string, even though there is no newline.

```
$ python re_flags_multiline.py

Text        : 'This is some text -- with punctuation.\nAnd a second line.'
Pattern     : (^\w+)|(\w+\S*$)
Single Line : [('This', ''), ('', 'line.')]
Multline    : [('This', ''), ('', 'punctuation.'), ('And', ''), ('', 'line.')]
```

`DOTALL` is the other flag related to multiline text. Normally the dot character `.` matches everything in the input text except a newline character. The flag allows dot to match newlines as well.

```
import re

text = 'This is some text -- with punctuation.\nAnd a second line.'
pattern = r'.+'
no_newlines = re.compile(pattern)
dotall = re.compile(pattern, re.DOTALL)

print 'Text        :', repr(text)
print 'Pattern     :', pattern
print 'No newlines :', no_newlines.findall(text)
print 'Dotall      :', dotall.findall(text)
```

Without the flag, each line of the input text matches the pattern separately. Adding the flag causes the entire string to be consumed.

```
$ python re_flags_dotall.py

Text        : 'This is some text -- with punctuation.\nAnd a second line.'
Pattern     : .+
No newlines : ['This is some text -- with punctuation.', 'And a second line.']
Dotall      : ['This is some text -- with punctuation.\nAnd a second line.']
```

Unicode

Under Python 2, `str` objects use the ASCII character set, and regular expression processing assumes that the pattern and input text are both ASCII. The escape codes described earlier are defined in terms of ASCII by default. Those assumptions mean that the pattern `\w+` will match the word “French” but not “Français”, since the `ç` is not part of the ASCII character set. To enable Unicode matching in Python 2, add the `UNICODE` flag when compiling the pattern.

```
import re
import codecs
import sys

# Set standard output encoding to UTF-8.
sys.stdout = codecs.getwriter('UTF-8')(sys.stdout)

text = u'Français złoty Österreich'
pattern = ur'\w+'
ascii_pattern = re.compile(pattern)
unicode_pattern = re.compile(pattern, re.UNICODE)

print 'Text    :', text
print 'Pattern :', pattern
print 'ASCII   :', u', '.join(ascii_pattern.findall(text))
print 'Unicode :', u', '.join(unicode_pattern.findall(text))
```

The other escape sequences (\W, \b, \B, \d, \D, \s, and \S) are also processed differently for Unicode text. Instead of assuming the members of the character set identified by the escape sequence, the regular expression engine consults the Unicode database to find the properties of each character.

```
$ python re_flags_unicode.py

Text    : Français złoty Österreich
Pattern : \w+
ASCII   : Fran, ais, z, oty, sterreich
Unicode : Français, złoty, Österreich
```

Note: Python 3 uses Unicode for all strings by default, so the flag is not necessary.

Verbose Expression Syntax

The compact format of regular expression syntax can become a hindrance as expressions grow more complicated. As the number of groups in your expression increases, you will have trouble keeping track of why each element is needed and how exactly the parts of the expression interact. Using named groups helps mitigate these issues, but a better solution is to use *verbose mode* expressions, which allow you to add comments and extra whitespace.

A pattern to validate email addresses will illustrate how verbose mode makes working with regular expressions easier. The first version recognizes addresses that end in one of three top-level domains, .com, .org, and .edu.

```
import re

address = re.compile('[\w\d.+-]+@([\w\d.]+\.)+(com|org|edu)', re.UNICODE)

candidates = [
    u'first.last@example.com',
    u'first.last+category@gmail.com',
    u'valid-address@mail.example.com',
    u'not-valid@example.foo',
    ]

for candidate in candidates:
    print
    print 'Candidate:', candidate
    match = address.search(candidate)
    if match:
        print '  Matches'
    else:
        print '  No match'
```

This expression is already complex. There are several character classes, groups, and repetition expressions.

```
$ python re_email_compact.py


Candidate: first.last@example.com
  Matches

Candidate: first.last+category@gmail.com
  Matches

Candidate: valid-address@mail.example.com
  Matches
```

```
Candidate: not-valid@example.foo
  No match
```

Converting the expression to a more verbose format will make it easier to extend.

```
import re

address = re.compile(
    '''
    [\w\d.+-]+       # username
    @
    ([\w\d.]+\.)+    # domain name prefix
    (com|org|edu)    # we should support more top-level domains
    ''',
    re.UNICODE | re.VERBOSE)

candidates = [
    u'first.last@example.com',
    u'first.last+category@gmail.com',
    u'valid-address@mail.example.com',
    u'not-valid@example.foo',
    ]

for candidate in candidates:
    print
    print 'Candidate:', candidate
    match = address.search(candidate)
    if match:
        print '  Matches'
    else:
        print '  No match'
```

The expression matches the same inputs, but in this extended format it is easier to read. The comments also help identify different parts of the pattern so that it can be expanded to match more inputs.

```
$ python re_email_verbose.py


Candidate: first.last@example.com
  Matches

Candidate: first.last+category@gmail.com
  Matches

Candidate: valid-address@mail.example.com
  Matches

Candidate: not-valid@example.foo
  No match
```

This expanded version parses inputs that include a person's name and email address, as might appear in an email header. The name comes first and stands on its own, and the email address follows surrounded by angle brackets (< and >).

```
import re

address = re.compile(
    '''
    # A name is made up of letters, and may include "." for title
    # abbreviations and middle initials.
    ((?P<name>
       ([\w.,]+\s+)*[\w.,]+)
       \s*
       # Email addresses are wrapped in angle brackets: < >
       # but we only want one if we found a name, so keep
       # the start bracket in this group.
       <
    )? # the entire name is optional

    # The address itself: username@domain.tld
    (?P<email>
      [\w\d.+-]+       # username
      @
      ([\w\d.]+\.)+    # domain name prefix
      (com|org|edu)    # limit the allowed top-level domains
    )

    >? # optional closing angle bracket
    ''',
    re.UNICODE | re.VERBOSE)

candidates = [
    u'first.last@example.com',
    u'first.last+category@gmail.com',
    u'valid-address@mail.example.com',
    u'not-valid@example.foo',
    u'First Last <first.last@example.com>',
    u'No Brackets first.last@example.com',
    u'First Last',
    u'First Middle Last <first.last@example.com>',
    u'First M. Last <first.last@example.com>',
    u'<first.last@example.com>',
    ]

for candidate in candidates:
    print
    print 'Candidate:', candidate
    match = address.search(candidate)
    if match:
        print '  Match name :', match.groupdict()['name']
        print '  Match email:', match.groupdict()['email']
    else:
        print '  No match'
```

As with other programming languages, the ability to insert comments into verbose regular expressions helps with their maintainability. This final version includes implementation notes to future maintainers and whitespace to separate the groups from each other and highlight their nesting level.

```
$ python re_email_with_name.py


Candidate: first.last@example.com
  Match name : None
  Match email: first.last@example.com

Candidate: first.last+category@gmail.com
```

```
  Match name : None
  Match email: first.last+category@gmail.com

Candidate: valid-address@mail.example.com
  Match name : None
  Match email: valid-address@mail.example.com

Candidate: not-valid@example.foo
  No match

Candidate: First Last <first.last@example.com>
  Match name : First Last
  Match email: first.last@example.com

Candidate: No Brackets first.last@example.com
  Match name : None
  Match email: first.last@example.com

Candidate: First Last
  No match

Candidate: First Middle Last <first.last@example.com>
  Match name : First Middle Last
  Match email: first.last@example.com

Candidate: First M. Last <first.last@example.com>
  Match name : First M. Last
  Match email: first.last@example.com

Candidate: <first.last@example.com>
  Match name : None
  Match email: first.last@example.com
```

Embedding Flags in Patterns

In situations where you cannot add flags when compiling an expression, such as when you are passing a pattern to a library function that will compile it later, you can embed the flags inside the expression string itself. For example, to turn case-insensitive matching on, add `(?i)` to the beginning of the expression.

```
import re

text = 'This is some text -- with punctuation.'
pattern = r'(?i)\bT\w+'
regex = re.compile(pattern)

print 'Text      :', text
print 'Pattern   :', pattern
print 'Matches   :', regex.findall(text)
```

Because the options control the way the entire expression is evaluated or parsed, they should always come at the beginning of the expression.

```
$ python re_flags_embedded.py

Text      : This is some text -- with punctuation.
Pattern   : (?i)\bT\w+
Matches   : ['This', 'text']
```

The abbreviations for all of the flags are:

Flag	Abbreviation
IGNORECASE	i
MULTILINE	m
DOTALL	s
UNICODE	u
VERBOSE	x

Embedded flags can be combined by placing them within the same group. For example, `(?imu)` turns on case-insensitive matching for multiline Unicode strings.

6.5.8 Looking Ahead, or Behind

There are many cases where it is useful to match a part of a pattern only if some other part will also match. For example, in the email parsing expression the angle brackets were each marked as optional. Really, though, the brackets should be paired, and the expression should only match if both are present, or neither are. This modified version of the expression uses a *positive look ahead* assertion to match the pair. The look ahead assertion syntax is `(?=pattern)`.

```
import re

address = re.compile(
    '''
    # A name is made up of letters, and may include "." for title
    # abbreviations and middle initials.
    ((?P<name>
       ([\w.,]+\s+)*[\w.,]+
     )
     \s+
    ) # name is no longer optional

    # LOOKAHEAD
    # Email addresses are wrapped in angle brackets, but we only want
    # the brackets if they are both there, or neither are.
    (?= (<.*>$)       # remainder wrapped in angle brackets
        |
        ([^<].*[^>]$) # remainder *not* wrapped in angle brackets
      )

    <? # optional opening angle bracket

    # The address itself: username@domain.tld
    (?P<email>
      [\w\d.+-]+       # username
      @
      ([\w\d.]+\.)+    # domain name prefix
      (com|org|edu)    # limit the allowed top-level domains
    )

    >? # optional closing angle bracket
    ''',
    re.UNICODE | re.VERBOSE)

candidates = [
    u'First Last <first.last@example.com>',
    u'No Brackets first.last@example.com',
    u'Open Bracket <first.last@example.com',
    u'Close Bracket first.last@example.com>',
    ]

for candidate in candidates:
    print
    print 'Candidate:', candidate
    match = address.search(candidate)
    if match:
        print '  Match name :', match.groupdict()['name']
        print '  Match email:', match.groupdict()['email']
    else:
        print '  No match'
```

There are several important changes in this version of the expression. First, the name portion is no longer optional. That means stand-alone addresses do not match, but it also prevents improperly formatted name/address combinations from matching. The positive look ahead rule after the "name" group asserts that the remainder of the string is either wrapped with a pair of angle brackets, or there is not a mismatched bracket; the brackets are either both present or neither is. The look ahead is expressed as a group, but the match for a look ahead group does not consume any of the input text, so the rest of the pattern picks up from the same spot after the look ahead matches.

```
$ python re_look_ahead.py


Candidate: First Last <first.last@example.com>
  Match name : First Last
  Match email: first.last@example.com

Candidate: No Brackets first.last@example.com
  Match name : No Brackets
  Match email: first.last@example.com

Candidate: Open Bracket <first.last@example.com
  No match

Candidate: Close Bracket first.last@example.com>
  No match
```

A *negative look ahead* assertion (`(?!pattern)`) says that the pattern does not match the text following the current point. For example, the email recognition pattern could be modified to ignore `noreply` mailing addresses commonly used by automated systems.

```
import re

address = re.compile(
    '''
    ^

    # An address: username@domain.tld

    # Ignore noreply addresses
    (?!noreply@.*$)

    [\w\d.+-]+       # username
    @
    ([\w\d.]+\.)+    # domain name prefix
    (com|org|edu)    # limit the allowed top-level domains

    $
    ''',
    re.UNICODE | re.VERBOSE)

candidates = [
    u'first.last@example.com',
    u'noreply@example.com',
    ]

for candidate in candidates:
    print
    print 'Candidate:', candidate
    match = address.search(candidate)
    if match:
        print '  Match:', candidate[match.start():match.end()]
    else:
        print '  No match'
```

The address starting `noreply` does not match the pattern, since the look ahead assertion fails.

```
$ python re_negative_look_ahead.py


Candidate: first.last@example.com
  Match: first.last@example.com

Candidate: noreply@example.com
  No match
```

Instead of looking ahead for `noreply` in the username portion of the email address, the pattern can also be written using a *negative look behind* assertion after the username is matched using the syntax `(?<!pattern)`.

```
import re

address = re.compile(
    '''
    ^

    # An address: username@domain.tld

    [\w\d.+-]+       # username

    # Ignore noreply addresses
    (?<!noreply)

    @
    ([\w\d.]+\.)+    # domain name prefix
    (com|org|edu)    # limit the allowed top-level domains

    $
    ''',
    re.UNICODE | re.VERBOSE)

candidates = [
    u'first.last@example.com',
    u'noreply@example.com',
    ]

for candidate in candidates:
    print
    print 'Candidate:', candidate
    match = address.search(candidate)
    if match:
        print '  Match:', candidate[match.start():match.end()]
    else:
        print '  No match'
```

Looking backwards works a little differently than looking ahead, in that the expression must use a fixed length pattern. Repetitions are allowed, as long as there is a fixed number (no wildcards or ranges).

```
$ python re_negative_look_behind.py


Candidate: first.last@example.com
  Match: first.last@example.com

Candidate: noreply@example.com
  No match
```

A *positive look behind* assertion can be used to find text following a pattern using the syntax `(?<=pattern)`. For example, this expression finds Twitter handles.

```
import re

twitter = re.compile(
    '''
    # A twitter handle: @username
    (?<=@)
    ([\w\d_]+)       # username
    ''',
    re.UNICODE | re.VERBOSE)

text = '''This text includes two Twitter handles.
One for @ThePSF, and one for the author, @doughellmann.
'''

print text
for match in twitter.findall(text):
    print 'Handle:', match
```

The pattern matches sequences of characters that can make up a Twitter handle, as long as they are preceded by an `@`.

```
$ python re_look_behind.py

This text includes two Twitter handles.
One for @ThePSF, and one for the author, @doughellmann.

Handle: ThePSF
Handle: doughellmann
```

6.5.9 Self-referencing Expressions

Matched values can be used in later parts of an expression. For example, the email example can be updated to match only addresses composed of the first and last name of the person by including back-references to those groups. The easiest way to achieve this is by referring to the previously matched group by id number, using `\num`.

```
import re

address = re.compile(
    r'''

    # The regular name
    (\w+)               # first name
    \s+
    (([\w.]+)\s+)?      # optional middle name or initial
    (\w+)               # last name

    \s+

    <

    # The address: first_name.last_name@domain.tld
    (?P<email>
      \1               # first name
      \.
      \4               # last name
      @
      ([\w\d.]+\.)+    # domain name prefix
      (com|org|edu)    # limit the allowed top-level domains
    )

    >
    ''',
    re.UNICODE | re.VERBOSE | re.IGNORECASE)

candidates = [
    u'First Last <first.last@example.com>',
    u'Different Name <first.last@example.com>',
    u'First Middle Last <first.last@example.com>',
    u'First M. Last <first.last@example.com>',
    ]

for candidate in candidates:
    print
    print 'Candidate:', candidate
    match = address.search(candidate)
    if match:
        print '  Match name :', match.group(1), match.group(4)
        print '  Match email:', match.group(5)
    else:
        print '  No match'
```

Although the syntax is simple, creating back-references by numerical id has a couple of disadvantages. From a practical standpoint, as the expression changes, you must count the groups again and possibly update every reference. The other disadvantage is that only 99 references can be made this way, because if the id number is three digits long it will be interpreted as an octal character value instead of a group reference. On the other hand, if you have more than 99 groups in your expression you will have more serious maintenance challenges than not being able to refer to some of the groups in the expression.

```
$ python re_refer_to_group.py


Candidate: First Last <first.last@example.com>
  Match name : First Last
  Match email: first.last@example.com

Candidate: Different Name <first.last@example.com>
  No match

Candidate: First Middle Last <first.last@example.com>
  Match name : First Last
  Match email: first.last@example.com

Candidate: First M. Last <first.last@example.com>
  Match name : First Last
  Match email: first.last@example.com
```

Python's expression parser includes an extension that uses `(?P=name)` to refer to the value of a named group matched earlier in the expression.

```
import re

address = re.compile(
    '''

    # The regular name
    (?P<first_name>\w+)
    \s+
    (([\w.]+)\s+)?      # optional middle name or initial
    (?P<last_name>\w+)

    \s+

    <

    # The address: first_name.last_name@domain.tld
    (?P<email>
      (?P=first_name)
      \.
      (?P=last_name)
      @
      ([\w\d.]+\.)+    # domain name prefix
      (com|org|edu)    # limit the allowed top-level domains
    )

    >
    ''',
    re.UNICODE | re.VERBOSE | re.IGNORECASE)

candidates = [
    u'First Last <first.last@example.com>',
    u'Different Name <first.last@example.com>',
    u'First Middle Last <first.last@example.com>',
    u'First M. Last <first.last@example.com>',
    ]

for candidate in candidates:
    print
    print 'Candidate:', candidate
    match = address.search(candidate)
    if match:
        print '  Match name :', match.groupdict()['first_name'], match.groupdict()['last_name']
        print '  Match email:', match.groupdict()['email']
    else:
        print '  No match'
```

The address expression is compiled with the `IGNORECASE` flag on, since proper names are normally capitalized but email addresses are not.

```
$ python re_refer_to_named_group.py


Candidate: First Last <first.last@example.com>
  Match name : First Last
  Match email: first.last@example.com

Candidate: Different Name <first.last@example.com>
  No match

Candidate: First Middle Last <first.last@example.com>
  Match name : First Last
  Match email: first.last@example.com

Candidate: First M. Last <first.last@example.com>
  Match name : First Last
  Match email: first.last@example.com
```

The other mechanism for using back-references in expressions lets you choose a different pattern based on whether or not a previous group matched. The email pattern can be corrected so that the angle brackets are required if a name is present, and not if the email address is by itself. The syntax for testing to see if a group has matched is `(?(id)yes-expression|no-expression)`, where *id* is the group name or number, *yes-expression* is the pattern to use if the group has a value and *no-expression* is the pattern to use otherwise.

```
import re

address = re.compile(
    '''
    ^

    # A name is made up of letters, and may include "." for title
    # abbreviations and middle initials.
    (?P<name>
       ([\w.]+\s+)*[\w.]+
     )?
    \s*

    # Email addresses are wrapped in angle brackets, but we only want
    # the brackets if we found a name.
    (?(name)
      # remainder wrapped in angle brackets because we have a name
      (?P<brackets>(?=(<.*>$)))
      |
      # remainder does not include angle brackets without name
      (?=([^<].*[^>]$))
     )

    # Only look for a bracket if our look ahead assertion found both
    # of them.
    (?(brackets)<|\s*)
    # The address itself: username@domain.tld
    (?P<email>
      [\w\d.+-]+       # username
      @
      ([\w\d.]+\.)+    # domain name prefix
      (com|org|edu)    # limit the allowed top-level domains
     )

    # Only look for a bracket if our look ahead assertion found both
    # of them.
    (?(brackets)>|\s*)

    $
    ''',
    re.UNICODE | re.VERBOSE)

candidates = [
    u'First Last <first.last@example.com>',
    u'No Brackets first.last@example.com',
    u'Open Bracket <first.last@example.com',
    u'Close Bracket first.last@example.com>',
    u'no.brackets@example.com',
    ]

for candidate in candidates:
    print
    print 'Candidate:', candidate
    match = address.search(candidate)
    if match:
        print '  Match name :', match.groupdict()['name']
        print '  Match email:', match.groupdict()['email']
    else:
        print '  No match'
```

This version of the email address parser uses two tests. If the `name` group matches, then the look ahead assertion requires both angle brackets and sets up the `brackets` group. If `name` is not matched, the assertion requires the rest of the text not have angle brackets around it. Later, if the `brackets` group is set, the actual pattern matching code consumes the brackets in the input using literal patterns, otherwise it consumes any blank space.

```
$ python re_id.py


Candidate: First Last <first.last@example.com>
  Match name : First Last
  Match email: first.last@example.com

Candidate: No Brackets first.last@example.com
  No match

Candidate: Open Bracket <first.last@example.com
  No match

Candidate: Close Bracket first.last@example.com>
  No match

Candidate: no.brackets@example.com
  Match name : None
  Match email: no.brackets@example.com
```

6.5.10 Modifying Strings with Patterns

In addition to searching through text, re also supports modifying text using regular expressions as the search mechanism, and the replacements can reference groups matched in the regex as part of the substitution text. Use sub() to replace all occurances of a pattern with another string.

```
import re

bold = re.compile(r'\*{2}(.*?)\*{2}', re.UNICODE)

text = 'Make this **bold**.  This **too**.'

print 'Text:', text
print 'Bold:', bold.sub(r'<b>\1</b>', text)
```

References to the text matched by the pattern can be inserted using the \num syntax used for back-references above.

```
$ python re_sub.py

Text: Make this **bold**.  This **too**.
Bold: Make this <b>bold</b>.  This <b>too</b>.
```

To use named groups in the substitution, use the syntax \g<name>.

```
import re

bold = re.compile(r'\*{2}(?P<bold_text>.*?)\*{2}', re.UNICODE)

text = 'Make this **bold**.  This **too**.'

print 'Text:', text
print 'Bold:', bold.sub(r'<b>\g<bold_text></b>', text)
```

The \g<name> syntax also works with numbered references, and using it eliminates any ambiguity between group numbers and surrounding literal digits.

```
$ python re_sub_named_groups.py

Text: Make this **bold**.  This **too**.
Bold: Make this <b>bold</b>.  This <b>too</b>.
```

Pass a value to *count* to limit the number of substitutions performed.

```
import re

bold = re.compile(r'\*{2}(.*?)\*{2}', re.UNICODE)

text = 'Make this **bold**.  This **too**.'

print 'Text:', text
print 'Bold:', bold.sub(r'<b>\1</b>', text, count=1)
```

Only the first substitution is made because *count* is 1.

```
$ python re_sub_count.py

Text: Make this **bold**.  This **too**.
Bold: Make this <b>bold</b>.  This **too**.
```

subn() works just like sub() except that it returns both the modified string and the count of substitutions made.

```
import re

bold = re.compile(r'\*{2}(.*?)\*{2}', re.UNICODE)

text = 'Make this **bold**.  This **too**.'

print 'Text:', text
print 'Bold:', bold.subn(r'<b>\1</b>', text)
```

The search pattern matches twice in the example.

```
$ python re_subn.py

Text: Make this **bold**.  This **too**.
Bold: ('Make this <b>bold</b>.  This <b>too</b>.', 2)
```

6.5.11 Splitting with Patterns

`str.split()` is one of the most frequently used methods for breaking apart strings to parse them. It only supports using literal values as separators, though, and sometimes a regular expression is necessary if the input is not consistently formatted. For example, many plain text markup languages define paragraph separators as two or more newline (`\n`) characters. In this case, `str.split()` cannot be used because of the "or more" part of the definition.

A strategy for identifying paragraphs using `findall()` would use a pattern like `(.+?)\n{2,}`.

```
import re

text = 'Paragraph one\non two lines.\n\nParagraph two.\n\n\nParagraph three.'

for num, para in enumerate(re.findall(r'(.+?)\n{2,}', text, flags=re.DOTALL)):
    print num, repr(para)
    print
```

That pattern fails for paragraphs at the end of the input text, as illustrated by the fact that "Paragraph three." is not part of the output.

```
$ python re_paragraphs_findall.py

0 'Paragraph one\non two lines.'

1 'Paragraph two.'
```

Extending the pattern to say that a paragraph ends with two or more newlines, or the end of input, fixes the problem but makes the pattern more complicated. Converting to `re.split()` instead of `re.findall()` handles the boundary condition automatically and keeps the pattern simple.

```
import re

text = 'Paragraph one\non two lines.\n\nParagraph two.\n\n\nParagraph three.'

print 'With findall:'
for num, para in enumerate(re.findall(r'(.+?)(\n{2,}|$)', text, flags=re.DOTALL)):
    print num, repr(para)
    print

print
print 'With split:'
```

```
for num, para in enumerate(re.split(r'\n{2,}', text)):
    print num, repr(para)
    print
```

The pattern argument to `split()` expresses the markup specification more precisely: Two or more newline characters mark a separator point between paragraphs in the input string.

```
$ python re_split.py

With findall:
0 ('Paragraph one\non two lines.', '\n\n')

1 ('Paragraph two.', '\n\n\n')

2 ('Paragraph three.', '')


With split:
0 'Paragraph one\non two lines.'

1 'Paragraph two.'

2 'Paragraph three.'
```

Enclosing the expression in parentheses to define a group causes `split()` to work more like `str.partition()`, so it returns the separator values as well as the other parts of the string.

```
import re

text = 'Paragraph one\non two lines.\n\nParagraph two.\n\n\nParagraph three.'

print
print 'With split:'
for num, para in enumerate(re.split(r'(\n{2,})', text)):
    print num, repr(para)
    print
```

The output now includes each paragraph, as well as the sequence of newlines separating them.

```
$ python re_split_groups.py


With split:
0 'Paragraph one\non two lines.'

1 '\n\n'

2 'Paragraph two.'

3 '\n\n\n'

4 'Paragraph three.'
```

See also:

re **(http://docs.python.org/library/re.html)** The standard library documentation for this module.

Regular Expression HOWTO **(http://docs.python.org/howto/regex.html)** Andrew Kuchling's introduction to regular expressions for Python developers.

Kodos (http://kodos.sourceforge.net/) An interactive regular expression testing tool by Phil Schwartz.

Python Regular Expression Testing Tool (http://www.pythonregex.com/) A web-based tool for testing regular expressions created by David Naffziger at BrandVerity.com. Inspired by Kodos.

Wikipedia: Regular expression (http://en.wikipedia.org/wiki/Regular_expressions) General introduction to regular expression concepts and techniques.

`locale` Use the `locale` module to set your language configuration when working with Unicode text.

`unicodedata` Programmatic access to the Unicode character property database.

6.6 struct – Working with Binary Data

Purpose Convert between strings and binary data.

Available In 1.4 and later

The `struct` module includes functions for converting between strings of bytes and native Python data types such as numbers and strings.

6.6.1 Functions vs. Struct Class

There are a set of module-level functions for working with structured values, and there is also the `Struct` class (new in Python 2.5). Format specifiers are converted from their string format to a compiled representation, similar to the way regular expressions are. The conversion takes some resources, so it is typically more efficient to do it once when creating a `Struct` instance and call methods on the instance instead of using the module-level functions. All of the examples below use the `Struct` class.

6.6.2 Packing and Unpacking

Structs support *packing* data into strings, and *unpacking* data from strings using format specifiers made up of characters representing the type of the data and optional count and endian-ness indicators. For complete details, refer to the standard library documentation (http://docs.python.org/library/struct.html).

In this example, the format specifier calls for an integer or long value, a two character string, and a floating point number. The spaces between the format specifiers are included here for clarity, and are ignored when the format is compiled.

```
import struct
import binascii

values = (1, 'ab', 2.7)
s = struct.Struct('I 2s f')
packed_data = s.pack(*values)

print 'Original values:', values
print 'Format string  :', s.format
print 'Uses           :', s.size, 'bytes'
print 'Packed Value   :', binascii.hexlify(packed_data)
```

The example converts the packed value to a sequence of hex bytes for printing with `binascii.hexlify()`, since some of the characters are nulls.

```
$ python struct_pack.py

Original values: (1, 'ab', 2.7)
Format string  : I 2s f
Uses           : 12 bytes
Packed Value   : 0100000061620000cdcc2c40
```

If we pass the packed value to `unpack()`, we get basically the same values back (note the discrepancy in the floating point value).

```
import struct
import binascii

packed_data = binascii.unhexlify('0100000061620000cdcc2c40')

s = struct.Struct('I 2s f')
unpacked_data = s.unpack(packed_data)
print 'Unpacked Values:', unpacked_data
```

```
$ python struct_unpack.py

Unpacked Values: (1, 'ab', 2.700000047683716)
```

6.6.3 Endianness

By default values are encoded using the native C library notion of "endianness". It is easy to override that choice by providing an explicit endianness directive in the format string.

```
import struct
import binascii

values = (1, 'ab', 2.7)
print 'Original values:', values

endianness = [
    ('@', 'native, native'),
    ('=', 'native, standard'),
    ('<', 'little-endian'),
    ('>', 'big-endian'),
    ('!', 'network'),
    ]

for code, name in endianness:
    s = struct.Struct(code + ' I 2s f')
    packed_data = s.pack(*values)
    print
    print 'Format string  :', s.format, 'for', name
    print 'Uses           :', s.size, 'bytes'
    print 'Packed Value   :', binascii.hexlify(packed_data)
    print 'Unpacked Value :', s.unpack(packed_data)
```

```
$ python struct_endianness.py

Original values: (1, 'ab', 2.7)

Format string  : @ I 2s f for native, native
Uses           : 12 bytes
```

```
Packed Value   : 0100000061620000cdcc2c40
Unpacked Value : (1, 'ab', 2.700000047683716)

Format string  : = I 2s f for native, standard
Uses           : 10 bytes
Packed Value   : 010000006162cdcc2c40
Unpacked Value : (1, 'ab', 2.700000047683716)

Format string  : < I 2s f for little-endian
Uses           : 10 bytes
Packed Value   : 010000006162cdcc2c40
Unpacked Value : (1, 'ab', 2.700000047683716)

Format string  : > I 2s f for big-endian
Uses           : 10 bytes
Packed Value   : 000000016162402ccccd
Unpacked Value : (1, 'ab', 2.700000047683716)

Format string  : ! I 2s f for network
Uses           : 10 bytes
Packed Value   : 000000016162402ccccd
Unpacked Value : (1, 'ab', 2.700000047683716)
```

6.6.4 Buffers

Working with binary packed data is typically reserved for highly performance sensitive situations or passing data into and out of extension modules. In such situations, you can optimize by avoiding the overhead of allocating a new buffer for each packed structure. The `pack_into()` and `unpack_from()` methods support writing to pre-allocated buffers directly.

```
import struct
import binascii

s = struct.Struct('I 2s f')
values = (1, 'ab', 2.7)
print 'Original:', values

print
print 'ctypes string buffer'

import ctypes
b = ctypes.create_string_buffer(s.size)
print 'Before  :', binascii.hexlify(b.raw)
s.pack_into(b, 0, *values)
print 'After   :', binascii.hexlify(b.raw)
print 'Unpacked:', s.unpack_from(b, 0)

print
print 'array'

import array
a = array.array('c', '\0' * s.size)
print 'Before  :', binascii.hexlify(a)
s.pack_into(a, 0, *values)
print 'After   :', binascii.hexlify(a)
print 'Unpacked:', s.unpack_from(a, 0)
```

The *size* attribute of the `Struct` tells us how big the buffer needs to be.

```
$ python struct_buffers.py

Original: (1, 'ab', 2.7)

ctypes string buffer
Before  : 000000000000000000000000
After   : 0100000061620000cdcc2c40
Unpacked: (1, 'ab', 2.700000047683716)

array
Before  : 000000000000000000000000
After   : 0100000061620000cdcc2c40
Unpacked: (1, 'ab', 2.700000047683716)
```

See also:

struct (http://docs.python.org/library/struct.html) The standard library documentation for this module.

`array` The array module, for working with sequences of fixed-type values.

`binascii` The binascii module, for producing ASCII representations of binary data.

WikiPedia: Endianness (http://en.wikipedia.org/wiki/Endianness) Explanation of byte order and endianness in encoding.

In-Memory Data Structures More tools for working with data structures.

6.7 textwrap – Formatting text paragraphs

Purpose Formatting text by adjusting where line breaks occur in a paragraph.

Available In 2.5

The `textwrap` module can be used to format text for output in situations where pretty-printing is desired. It offers programmatic functionality similar to the paragraph wrapping or filling features found in many text editors.

6.7.1 Example Data

The examples below use `textwrap_example.py`, which contains a string `sample_text`:

```
sample_text = '''
        The textwrap module can be used to format text for output in situations
        where pretty-printing is desired.  It offers programmatic functionality similar
        to the paragraph wrapping or filling features found in many text editors.
        '''
```

6.7.2 Filling Paragraphs

The `fill()` convenience function takes text as input and produces formatted text as output. Let's see what it does with the sample_text provided.

```
import textwrap
from textwrap_example import sample_text

print 'No dedent:\n'
print textwrap.fill(sample_text)
```

The results are something less than what we want:

```
$ python textwrap_fill.py

No dedent:

         The textwrap module can be used to format text for output in
situations         where pretty-printing is desired.  It offers
programmatic functionality similar         to the paragraph wrapping
or filling features found in many text editors.
```

6.7.3 Removing Existing Indentation

Notice the embedded tabs and extra spaces mixed into the middle of the output. It looks pretty rough. We can do better if we start by removing any common whitespace prefix from all of the lines in the sample text. This allows us to use docstrings or embedded multi-line strings straight from our Python code while removing the formatting of the code itself. The sample string has an artificial indent level introduced for illustrating this feature.

```
import textwrap
from textwrap_example import sample_text

dedented_text = textwrap.dedent(sample_text).strip()
print 'Dedented:\n'
print dedented_text
```

The results are starting to look better:

```
$ python textwrap_dedent.py

Dedented:

The textwrap module can be used to format text for output in situations
where pretty-printing is desired.  It offers programmatic functionality similar
to the paragraph wrapping or filling features found in many text editors.
```

Since “dedent” is the opposite of “indent”, the result is a block of text with the common initial whitespace from each line removed. If one line is already indented more than another, some of the whitespace will not be removed.

```
 One tab.
 Two tabs.
One tab.
```

becomes

```
One tab.
Two tabs.
One tab.
```

6.7.4 Combining Dedent and Fill

Next, let’s see what happens if we take the dedented text and pass it through `fill()` with a few different *width* values.

```
import textwrap
from textwrap_example import sample_text

dedented_text = textwrap.dedent(sample_text).strip()
for width in [ 20, 60, 80 ]:
        print
        print '%d Columns:\n' % width
        print textwrap.fill(dedented_text, width=width)
```

This gives several sets of output in the specified widths:

```
$ python textwrap_fill_width.py


20 Columns:

The textwrap module
can be used to
format text for
output in situations
where pretty-
printing is desired.
It offers
programmatic
functionality
similar to the
paragraph wrapping
or filling features
found in many text
editors.

60 Columns:

The textwrap module can be used to format text for output in
situations where pretty-printing is desired.  It offers
programmatic functionality similar to the paragraph wrapping
or filling features found in many text editors.

80 Columns:

The textwrap module can be used to format text for output in situations where
pretty-printing is desired.  It offers programmatic functionality similar to the
paragraph wrapping or filling features found in many text editors.
```

6.7.5 Hanging Indents

Besides the width of the output, you can control the indent of the first line independently of subsequent lines.

```
import textwrap
from textwrap_example import sample_text

dedented_text = textwrap.dedent(sample_text).strip()
print textwrap.fill(dedented_text, initial_indent='', subsequent_indent='    ')
```

This makes it relatively easy to produce a hanging indent, where the first line is indented less than the other lines.

```
$ python textwrap_hanging_indent.py

The textwrap module can be used to format text for output in
    situations where pretty-printing is desired.  It offers
    programmatic functionality similar to the paragraph wrapping or
    filling features found in many text editors.
```

The indent values can include non-whitespace characters, too, so the hanging indent can be prefixed with `*` to produce bullet points, etc. That came in handy when I converted my old zwiki content so I could import it into trac. I used the StructuredText package from Zope to parse the zwiki data, then created a formatter to produce trac's wiki markup as output. Using `textwrap`, I was able to format the output pages so almost no manual tweaking was needed after the conversion.

See also:

textwrap (http://docs.python.org/lib/module-textwrap.html) Standard library documentation for this module.

Text Processing Tools More tools for working with text.

CHAPTER

SEVEN

DATA TYPES

7.1 array – Sequence of fixed-type data

Purpose Manage sequences of fixed-type numerical data efficiently.

Available In 1.4 and later

The `array` module defines a sequence data structure that looks very much like a `list` except that all of the members have to be of the same type. The types supported are all numeric or other fixed-size primitive types such as bytes.

Code	Type	Minimum size (bytes)
`c`	character	1
`b`	int	1
`B`	int	1
`u`	Unicode character	2 or 4 (build-dependent)
`h`	int	2
`H`	int	2
`i`	int	2
`I`	long	2
`l`	int	4
`L`	long	4
`f`	float	4
`d`	float	8

7.1.1 array Initialization

An `array` is instantiated with an argument describing the type of data to be allowed, and possibly an initial sequence of data to store in the array.

```
import array
import binascii

s = 'This is the array.'
a = array.array('c', s)

print 'As string:', s
print 'As array :', a
print 'As hex   :', binascii.hexlify(a)
```

In this example, the array is configured to hold a sequence of bytes and is initialized with a simple string.

```
$ python array_string.py
```

```
As string: This is the array.
As array : array('c', 'This is the array.')
As hex   : 54686973206973207468652061727261792e
```

7.1.2 Manipulating Arrays

An `array` can be extended and otherwise manipulated in the same ways as other Python sequences.

```
import array

a = array.array('i', xrange(5))
print 'Initial :', a

a.extend(xrange(5))
print 'Extended:', a

print 'Slice   :', a[3:6]

print 'Iterator:', list(enumerate(a))
```

```
$ python array_sequence.py

Initial : array('i', [0, 1, 2, 3, 4])
Extended: array('i', [0, 1, 2, 3, 4, 0, 1, 2, 3, 4])
Slice   : array('i', [3, 4, 0])
Iterator: [(0, 0), (1, 1), (2, 2), (3, 3), (4, 4), (5, 0), (6, 1), (7, 2), (8, 3), (9, 4)]
```

7.1.3 Arrays and Files

The contents of an array can be written to and read from files using built-in methods coded efficiently for that purpose.

```
import array
import binascii
import tempfile

a = array.array('i', xrange(5))
print 'A1:', a

# Write the array of numbers to the file
output = tempfile.NamedTemporaryFile()
a.tofile(output.file) # must pass an *actual* file
output.flush()

# Read the raw data
input = open(output.name, 'rb')
raw_data = input.read()
print 'Raw Contents:', binascii.hexlify(raw_data)

# Read the data into an array
input.seek(0)
a2 = array.array('i')
a2.fromfile(input, len(a))
print 'A2:', a2
```

This example illustrates reading the data "raw", directly from the binary file, versus reading it into a new array and converting the bytes to the appropriate types.

```
$ python array_file.py

A1: array('i', [0, 1, 2, 3, 4])
Raw Contents: 0000000001000000020000000300000004000000
A2: array('i', [0, 1, 2, 3, 4])
```

7.1.4 Alternate Byte Ordering

If the data in the array is not in the native byte order, or needs to be swapped before being written to a file intended for a system with a different byte order, it is easy to convert the entire array without iterating over the elements from Python.

```
import array
import binascii

def to_hex(a):
    chars_per_item = a.itemsize * 2 # 2 hex digits
    hex_version = binascii.hexlify(a)
    num_chunks = len(hex_version) / chars_per_item
    for i in xrange(num_chunks):
        start = i*chars_per_item
        end = start + chars_per_item
        yield hex_version[start:end]

a1 = array.array('i', xrange(5))
a2 = array.array('i', xrange(5))
a2.byteswap()

fmt = '%10s %10s %10s %10s'
print fmt % ('A1 hex', 'A1', 'A2 hex', 'A2')
print fmt % (('-' * 10,) * 4)
for values in zip(to_hex(a1), a1, to_hex(a2), a2):
    print fmt % values
```

```
$ python array_byteswap.py

    A1 hex         A1     A2 hex         A2
---------- ---------- ---------- ----------
  00000000          0   00000000          0
  01000000          1   00000001   16777216
  02000000          2   00000002   33554432
  03000000          3   00000003   50331648
  04000000          4   00000004   67108864
```

See also:

array **(http://docs.python.org/library/array.html)** The standard library documentation for this module.

`struct` The struct module.

Numerical Python **(http://www.scipy.org)** NumPy is a Python library for working with large datasets efficiently.

In-Memory Data Structures

7.2 datetime – Date/time value manipulation

Purpose The datetime module includes functions and classes for doing date and time parsing, formatting, and arithmetic.

Available In 2.3 and later

`datetime` contains functions and classes for working with dates and times, separatley and together.

7.2.1 Times

Time values are represented with the `time` class. Times have attributes for hour, minute, second, and microsecond. They can also include time zone information. The arguments to initialize a `time` instance are optional, but the default of `0` is unlikely to be what you want.

```
import datetime

t = datetime.time(1, 2, 3)
print t
print 'hour  :', t.hour
print 'minute:', t.minute
print 'second:', t.second
print 'microsecond:', t.microsecond
print 'tzinfo:', t.tzinfo
```

```
$ python datetime_time.py

01:02:03
hour  : 1
minute: 2
second: 3
microsecond: 0
tzinfo: None
```

A time instance only holds values of time, and not a date associated with the time.

```
import datetime

print 'Earliest  :', datetime.time.min
print 'Latest    :', datetime.time.max
print 'Resolution:', datetime.time.resolution
```

The *min* and *max* class attributes reflect the valid range of times in a single day.

```
$ python datetime_time_minmax.py

Earliest  : 00:00:00
Latest    : 23:59:59.999999
Resolution: 0:00:00.000001
```

The resolution for time is limited to whole microseconds.

```
import datetime

for m in [ 1, 0, 0.1, 0.6 ]:
    try:
        print '%02.1f :' % m, datetime.time(0, 0, 0, microsecond=m)
    except TypeError, err:
        print 'ERROR:', err
```

In fact, using floating point numbers for the microsecond argument generates a *TypeError*.

```
$ python datetime_time_resolution.py

1.0 : 00:00:00.000001
0.0 : 00:00:00
0.1 : ERROR: integer argument expected, got float
0.6 : ERROR: integer argument expected, got float
```

7.2.2 Dates

Calendar date values are represented with the `date` class. Instances have attributes for year, month, and day. It is easy to create a date representing today's date using the `today()` class method.

```
import datetime

today = datetime.date.today()
print today
print 'ctime:', today.ctime()
print 'tuple:', today.timetuple()
print 'ordinal:', today.toordinal()
print 'Year:', today.year
print 'Mon :', today.month
print 'Day :', today.day
```

This example prints the current date in several formats:

```
$ python datetime_date.py

2013-02-21
ctime: Thu Feb 21 00:00:00 2013
tuple: time.struct_time(tm_year=2013, tm_mon=2, tm_mday=21, tm_hour=0, tm_min=0, tm_sec=0, tm_wday=3,
ordinal: 734920
Year: 2013
Mon : 2
Day : 21
```

There are also class methods for creating instances from integers (using proleptic Gregorian ordinal values, which starts counting from Jan. 1 of the year 1) or POSIX timestamp values.

```
import datetime
import time

o = 733114
print 'o:', o
print 'fromordinal(o):', datetime.date.fromordinal(o)
t = time.time()
print 't:', t
print 'fromtimestamp(t):', datetime.date.fromtimestamp(t)
```

This example illustrates the different value types used by `fromordinal()` and `fromtimestamp()`.

```
$ python datetime_date_fromordinal.py

o: 733114
```

```
fromordinal(o): 2008-03-13
t: 1361446545.52
fromtimestamp(t): 2013-02-21
```

As with `time`, the range of date values supported can be determined using the *min* and *max* attributes.

```
import datetime

print 'Earliest  :', datetime.date.min
print 'Latest    :', datetime.date.max
print 'Resolution:', datetime.date.resolution
```

The resolution for dates is whole days.

```
$ python datetime_date_minmax.py

Earliest  : 0001-01-01
Latest    : 9999-12-31
Resolution: 1 day, 0:00:00
```

Another way to create new date instances uses the `replace()` method of an existing date. For example, you can change the year, leaving the day and month alone.

```
import datetime

d1 = datetime.date(2008, 3, 12)
print 'd1:', d1

d2 = d1.replace(year=2009)
print 'd2:', d2
```

```
$ python datetime_date_replace.py

d1: 2008-03-12
d2: 2009-03-12
```

7.2.3 timedeltas

Using `replace()` is not the only way to calculate future/past dates. You can use `datetime` to perform basic arithmetic on date values via the `timedelta` class. Subtracting dates produces a `timedelta`, and a `timedelta` can be added or subtracted from a date to produce another date. The internal values for a `timedelta` are stored in days, seconds, and microseconds.

```
import datetime

print "microseconds:", datetime.timedelta(microseconds=1)
print "milliseconds:", datetime.timedelta(milliseconds=1)
print "seconds     :", datetime.timedelta(seconds=1)
print "minutes     :", datetime.timedelta(minutes=1)
print "hours       :", datetime.timedelta(hours=1)
print "days        :", datetime.timedelta(days=1)
print "weeks       :", datetime.timedelta(weeks=1)
```

Intermediate level values passed to the constructor are converted into days, seconds, and microseconds.

```
$ python datetime_timedelta.py

microseconds: 0:00:00.000001
```

```
milliseconds: 0:00:00.001000
seconds     : 0:00:01
minutes     : 0:01:00
hours       : 1:00:00
days        : 1 day, 0:00:00
weeks       : 7 days, 0:00:00
```

7.2.4 Date Arithmetic

Date math uses the standard arithmetic operators. This example with date objects illustrates using `timedelta` objects to compute new dates, and subtracting date instances to produce timedeltas (including a negative delta value).

```
import datetime

today = datetime.date.today()
print 'Today    :', today

one_day = datetime.timedelta(days=1)
print 'One day  :', one_day

yesterday = today - one_day
print 'Yesterday:', yesterday

tomorrow = today + one_day
print 'Tomorrow :', tomorrow

print 'tomorrow - yesterday:', tomorrow - yesterday
print 'yesterday - tomorrow:', yesterday - tomorrow
```

```
$ python datetime_date_math.py

Today    : 2013-02-21
One day  : 1 day, 0:00:00
Yesterday: 2013-02-20
Tomorrow : 2013-02-22
tomorrow - yesterday: 2 days, 0:00:00
yesterday - tomorrow: -2 days, 0:00:00
```

7.2.5 Comparing Values

Both date and time values can be compared using the standard operators to determine which is earlier or later.

```
import datetime
import time

print 'Times:'
t1 = datetime.time(12, 55, 0)
print '\tt1:', t1
t2 = datetime.time(13, 5, 0)
print '\tt2:', t2
print '\tt1 < t2:', t1 < t2

print 'Dates:'
d1 = datetime.date.today()
print '\td1:', d1
```

```
d2 = datetime.date.today() + datetime.timedelta(days=1)
print '\td2:', d2
print '\td1 > d2:', d1 > d2
```

```
$ python datetime_comparing.py

Times:
        t1: 12:55:00
        t2: 13:05:00
        t1 < t2: True
Dates:
        d1: 2013-02-21
        d2: 2013-02-22
        d1 > d2: False
```

7.2.6 Combining Dates and Times

Use the `datetime` class to hold values consisting of both date and time components. As with `date`, there are several convenient class methods to make creating `datetime` instances from other common values.

```
import datetime

print 'Now    :', datetime.datetime.now()
print 'Today  :', datetime.datetime.today()
print 'UTC Now:', datetime.datetime.utcnow()

d = datetime.datetime.now()
for attr in [ 'year', 'month', 'day', 'hour', 'minute', 'second', 'microsecond']:
    print attr, ':', getattr(d, attr)
```

As you might expect, the `datetime` instance has all of the attributes of both a date and a time object.

```
$ python datetime_datetime.py

Now    : 2013-02-21 06:35:45.658505
Today  : 2013-02-21 06:35:45.659381
UTC Now: 2013-02-21 11:35:45.659396
year : 2013
month : 2
day : 21
hour : 6
minute : 35
second : 45
microsecond : 659677
```

Just as with date, datetime provides convenient class methods for creating new instances. It also includes `fromordinal()` and `fromtimestamp()`. In addition, `combine()` can be useful if you already have a date instance and time instance and want to create a datetime.

```
import datetime

t = datetime.time(1, 2, 3)
print 't :', t

d = datetime.date.today()
print 'd :', d
```

```
dt = datetime.datetime.combine(d, t)
print 'dt:', dt
```

```
$ python datetime_datetime_combine.py

t : 01:02:03
d : 2013-02-21
dt: 2013-02-21 01:02:03
```

7.2.7 Formatting and Parsing

The default string representation of a datetime object uses the ISO 8601 (http://www.iso.org/iso/support/faqs/faqs_widely_used_standards/widely_used_standards_other/date_and_time_format.htm) format (`YYYY-MM-DDTHH:MM:SS.mmmmmm`). Alternate formats can be generated using `strftime()`. Similarly, if your input data includes timestamp values parsable with `time.strptime()`, then `datetime.strptime()` is a convenient way to convert them to datetime instances.

```
import datetime

format = "%a %b %d %H:%M:%S %Y"

today = datetime.datetime.today()
print 'ISO     :', today

s = today.strftime(format)
print 'strftime:', s

d = datetime.datetime.strptime(s, format)
print 'strptime:', d.strftime(format)
```

```
$ python datetime_datetime_strptime.py

ISO     : 2013-02-21 06:35:45.707450
strftime: Thu Feb 21 06:35:45 2013
strptime: Thu Feb 21 06:35:45 2013
```

7.2.8 Time Zones

Within `datetime`, time zones are represented by subclasses of `tzinfo`. Since `tzinfo` is an abstract base class, you need to define a subclass and provide appropriate implementations for a few methods to make it useful. Unfortunately, `datetime` does not include any actual implementations ready to be used, although the documentation does provide a few sample implementations. Refer to the standard library documentation page for examples using fixed offsets as well as a DST-aware class and more details about creating your own class. pytz (http://pytz.sourceforge.net/) is also a good source for time zone implementation details.

See also:

datetime (http://docs.python.org/lib/module-datetime.html) The standard library documentation for this module.

`calendar` The `calendar` module.

`time` The `time` module.

dateutil (http://labix.org/python-dateutil) dateutil from Labix extends the datetime module with additional features.

WikiPedia: Proleptic Gregorian calendar (http://en.wikipedia.org/wiki/Proleptic_Gregorian_calendar) A description of the Gregorian calendar system.

pytz (http://pytz.sourceforge.net/) World Time Zone database

ISO 8601 (http://www.iso.org/iso/support/faqs/faqs_widely_used_standards/widely_used_standards_other/date_and_time_form
The standard for numeric representation of Dates and Time

7.3 calendar – Work with dates

Purpose The calendar module implements classes for working with dates to manage year/month/week oriented values.

Available In 1.4, with updates in 2.5

The calendar module defines the Calendar class, which encapsulates calculations for values such as the dates of the weeks in a given month or year. In addition, the TextCalendar and HTMLCalendar classes can produce pre-formatted output.

7.3.1 Formatting Examples

A very simple example which produces formatted text output for a month using TextCalendar might use the prmonth() method.

```
import calendar

c = calendar.TextCalendar(calendar.SUNDAY)
c.prmonth(2007, 7)
```

The example configures TextCalendar to start weeks on Sunday, following the American convention. The default is to use the European convention of starting a week on Monday.

The output looks like:

```
$ python calendar_textcalendar.py

     July 2007
Su Mo Tu We Th Fr Sa
 1  2  3  4  5  6  7
 8  9 10 11 12 13 14
15 16 17 18 19 20 21
22 23 24 25 26 27 28
29 30 31
```

The HTML output for the same time period is slightly different, since there is no prmonth() method:

```
import calendar

c = calendar.HTMLCalendar(calendar.SUNDAY)
print c.formatmonth(2007, 7)
```

The rendered output looks roughly the same, but is wrapped with HTML tags. You can also see that each table cell has a class attribute corresponding to the day of the week.

```
$ python calendar_htmlcalendar.py

<table border="0" cellpadding="0" cellspacing="0" class="month">
<tr><th colspan="7" class="month">July 2007</th></tr>
<tr><th class="sun">Sun</th><th class="mon">Mon</th><th class="tue">Tue</th><th class="wed">Wed</th><
<tr><td class="sun">1</td><td class="mon">2</td><td class="tue">3</td><td class="wed">4</td><td clas
```

```
<tr><td class="sun">8</td><td class="mon">9</td><td class="tue">10</td><td class="wed">11</td><td cla
<tr><td class="sun">15</td><td class="mon">16</td><td class="tue">17</td><td class="wed">18</td><td c
<tr><td class="sun">22</td><td class="mon">23</td><td class="tue">24</td><td class="wed">25</td><td c
<tr><td class="sun">29</td><td class="mon">30</td><td class="tue">31</td><td class="noday">&nbsp;</tc
</table>
```

If you need to produce output in a format other than one of the available defaults, you can use `calendar` to calculate the dates and organize the values into week and month ranges, then iterate over the result yourself. The weekheader(), monthcalendar(), and yeardays2calendar() methods of Calendar are especially useful for that sort of work.

Calling yeardays2calendar() produces a sequence of "month row" lists. Each list includes the months as another list of weeks. The weeks are lists of tuples made up of day number (1-31) and weekday number (0-6). Days that fall outside of the month have a day number of 0.

```
import calendar
import pprint

pprint.pprint(calendar.Calendar(calendar.SUNDAY).yeardays2calendar(2007, 2))
```

Calling yeardays2calendar(2007, 2) returns data for 2007, organized with 2 months per row.

```
$ python calendar_yeardays2calendar.py

[[[[(0, 6), (1, 0), (2, 1), (3, 2), (4, 3), (5, 4), (6, 5)],
   [(7, 6), (8, 0), (9, 1), (10, 2), (11, 3), (12, 4), (13, 5)],
   [(14, 6), (15, 0), (16, 1), (17, 2), (18, 3), (19, 4), (20, 5)],
   [(21, 6), (22, 0), (23, 1), (24, 2), (25, 3), (26, 4), (27, 5)],
   [(28, 6), (29, 0), (30, 1), (31, 2), (0, 3), (0, 4), (0, 5)]],
  [[(0, 6), (0, 0), (0, 1), (0, 2), (1, 3), (2, 4), (3, 5)],
   [(4, 6), (5, 0), (6, 1), (7, 2), (8, 3), (9, 4), (10, 5)],
   [(11, 6), (12, 0), (13, 1), (14, 2), (15, 3), (16, 4), (17, 5)],
   [(18, 6), (19, 0), (20, 1), (21, 2), (22, 3), (23, 4), (24, 5)],
   [(25, 6), (26, 0), (27, 1), (28, 2), (0, 3), (0, 4), (0, 5)]]],
 [[[(0, 6), (0, 0), (0, 1), (0, 2), (1, 3), (2, 4), (3, 5)],
   [(4, 6), (5, 0), (6, 1), (7, 2), (8, 3), (9, 4), (10, 5)],
   [(11, 6), (12, 0), (13, 1), (14, 2), (15, 3), (16, 4), (17, 5)],
   [(18, 6), (19, 0), (20, 1), (21, 2), (22, 3), (23, 4), (24, 5)],
   [(25, 6), (26, 0), (27, 1), (28, 2), (29, 3), (30, 4), (31, 5)]],
  [[(1, 6), (2, 0), (3, 1), (4, 2), (5, 3), (6, 4), (7, 5)],
   [(8, 6), (9, 0), (10, 1), (11, 2), (12, 3), (13, 4), (14, 5)],
   [(15, 6), (16, 0), (17, 1), (18, 2), (19, 3), (20, 4), (21, 5)],
   [(22, 6), (23, 0), (24, 1), (25, 2), (26, 3), (27, 4), (28, 5)],
   [(29, 6), (30, 0), (0, 1), (0, 2), (0, 3), (0, 4), (0, 5)]]],
 [[[(0, 6), (0, 0), (1, 1), (2, 2), (3, 3), (4, 4), (5, 5)],
   [(6, 6), (7, 0), (8, 1), (9, 2), (10, 3), (11, 4), (12, 5)],
   [(13, 6), (14, 0), (15, 1), (16, 2), (17, 3), (18, 4), (19, 5)],
   [(20, 6), (21, 0), (22, 1), (23, 2), (24, 3), (25, 4), (26, 5)],
   [(27, 6), (28, 0), (29, 1), (30, 2), (31, 3), (0, 4), (0, 5)]],
  [[(0, 6), (0, 0), (0, 1), (0, 2), (0, 3), (1, 4), (2, 5)],
   [(3, 6), (4, 0), (5, 1), (6, 2), (7, 3), (8, 4), (9, 5)],
   [(10, 6), (11, 0), (12, 1), (13, 2), (14, 3), (15, 4), (16, 5)],
   [(17, 6), (18, 0), (19, 1), (20, 2), (21, 3), (22, 4), (23, 5)],
   [(24, 6), (25, 0), (26, 1), (27, 2), (28, 3), (29, 4), (30, 5)]]],
 [[[(1, 6), (2, 0), (3, 1), (4, 2), (5, 3), (6, 4), (7, 5)],
   [(8, 6), (9, 0), (10, 1), (11, 2), (12, 3), (13, 4), (14, 5)],
   [(15, 6), (16, 0), (17, 1), (18, 2), (19, 3), (20, 4), (21, 5)],
   [(22, 6), (23, 0), (24, 1), (25, 2), (26, 3), (27, 4), (28, 5)],
   [(29, 6), (30, 0), (31, 1), (0, 2), (0, 3), (0, 4), (0, 5)]],
  [[(0, 6), (0, 0), (0, 1), (1, 2), (2, 3), (3, 4), (4, 5)],
   [(5, 6), (6, 0), (7, 1), (8, 2), (9, 3), (10, 4), (11, 5)],
   [(12, 6), (13, 0), (14, 1), (15, 2), (16, 3), (17, 4), (18, 5)],
   [(19, 6), (20, 0), (21, 1), (22, 2), (23, 3), (24, 4), (25, 5)],
   [(26, 6), (27, 0), (28, 1), (29, 2), (30, 3), (31, 4), (0, 5)]]],
 [[[(0, 6), (0, 0), (0, 1), (0, 2), (0, 3), (0, 4), (1, 5)],
   [(2, 6), (3, 0), (4, 1), (5, 2), (6, 3), (7, 4), (8, 5)],
   [(9, 6), (10, 0), (11, 1), (12, 2), (13, 3), (14, 4), (15, 5)],
   [(16, 6), (17, 0), (18, 1), (19, 2), (20, 3), (21, 4), (22, 5)],
   [(23, 6), (24, 0), (25, 1), (26, 2), (27, 3), (28, 4), (29, 5)],
   [(30, 6), (0, 0), (0, 1), (0, 2), (0, 3), (0, 4), (0, 5)]],
  [[(0, 6), (1, 0), (2, 1), (3, 2), (4, 3), (5, 4), (6, 5)],
   [(7, 6), (8, 0), (9, 1), (10, 2), (11, 3), (12, 4), (13, 5)],
   [(14, 6), (15, 0), (16, 1), (17, 2), (18, 3), (19, 4), (20, 5)],
   [(21, 6), (22, 0), (23, 1), (24, 2), (25, 3), (26, 4), (27, 5)],
   [(28, 6), (29, 0), (30, 1), (31, 2), (0, 3), (0, 4), (0, 5)]]],
 [[[(0, 6), (0, 0), (0, 1), (0, 2), (1, 3), (2, 4), (3, 5)],
   [(4, 6), (5, 0), (6, 1), (7, 2), (8, 3), (9, 4), (10, 5)],
   [(11, 6), (12, 0), (13, 1), (14, 2), (15, 3), (16, 4), (17, 5)],
   [(18, 6), (19, 0), (20, 1), (21, 2), (22, 3), (23, 4), (24, 5)],
   [(25, 6), (26, 0), (27, 1), (28, 2), (29, 3), (30, 4), (0, 5)]],
  [[(0, 6), (0, 0), (0, 1), (0, 2), (0, 3), (0, 4), (1, 5)],
   [(2, 6), (3, 0), (4, 1), (5, 2), (6, 3), (7, 4), (8, 5)],
   [(9, 6), (10, 0), (11, 1), (12, 2), (13, 3), (14, 4), (15, 5)],
   [(16, 6), (17, 0), (18, 1), (19, 2), (20, 3), (21, 4), (22, 5)],
   [(23, 6), (24, 0), (25, 1), (26, 2), (27, 3), (28, 4), (29, 5)],
   [(30, 6), (31, 0), (0, 1), (0, 2), (0, 3), (0, 4), (0, 5)]]]]
```

This is equivalent to the data used by formatyear()

```
import calendar

print calendar.TextCalendar(calendar.SUNDAY).formatyear(2007, 2, 1, 1, 2)
```

which for the same arguments produces output like:

```
$ python calendar_formatyear.py

                   2007

      January                  February
Su Mo Tu We Th Fr Sa      Su Mo Tu We Th Fr Sa
    1  2  3  4  5  6                   1  2  3
 7  8  9 10 11 12 13       4  5  6  7  8  9 10
14 15 16 17 18 19 20      11 12 13 14 15 16 17
21 22 23 24 25 26 27      18 19 20 21 22 23 24
28 29 30 31               25 26 27 28

       March                    April
Su Mo Tu We Th Fr Sa      Su Mo Tu We Th Fr Sa
             1  2  3       1  2  3  4  5  6  7
 4  5  6  7  8  9 10       8  9 10 11 12 13 14
11 12 13 14 15 16 17      15 16 17 18 19 20 21
18 19 20 21 22 23 24      22 23 24 25 26 27 28
25 26 27 28 29 30 31      29 30

        May                      June
Su Mo Tu We Th Fr Sa      Su Mo Tu We Th Fr Sa
       1  2  3  4  5                      1  2
 6  7  8  9 10 11 12       3  4  5  6  7  8  9
```

```
13 14 15 16 17 18 19   10 11 12 13 14 15 16
20 21 22 23 24 25 26   17 18 19 20 21 22 23
27 28 29 30 31         24 25 26 27 28 29 30

        July                  August
Su Mo Tu We Th Fr Sa   Su Mo Tu We Th Fr Sa
 1  2  3  4  5  6  7             1  2  3  4
 8  9 10 11 12 13 14    5  6  7  8  9 10 11
15 16 17 18 19 20 21   12 13 14 15 16 17 18
22 23 24 25 26 27 28   19 20 21 22 23 24 25
29 30 31               26 27 28 29 30 31

     September              October
Su Mo Tu We Th Fr Sa   Su Mo Tu We Th Fr Sa
                   1       1  2  3  4  5  6
 2  3  4  5  6  7  8    7  8  9 10 11 12 13
 9 10 11 12 13 14 15   14 15 16 17 18 19 20
16 17 18 19 20 21 22   21 22 23 24 25 26 27
23 24 25 26 27 28 29   28 29 30 31
30

      November              December
Su Mo Tu We Th Fr Sa   Su Mo Tu We Th Fr Sa
             1  2  3                      1
 4  5  6  7  8  9 10    2  3  4  5  6  7  8
11 12 13 14 15 16 17    9 10 11 12 13 14 15
18 19 20 21 22 23 24   16 17 18 19 20 21 22
25 26 27 28 29 30      23 24 25 26 27 28 29
                       30 31
```

If you want to format the output yourself for some reason (such as including links in HTML output), you will find the day_name, day_abbr, month_name, and month_abbr module attributes useful. They are automatically configured correctly for the current locale.

7.3.2 Calculating Dates

Although the calendar module focuses mostly on printing full calendars in various formats, it also provides functions useful for working with dates in other ways, such as calculating dates for a recurring event. For example, the Python Atlanta User's Group meets the 2nd Thursday of every month. To calculate the dates for the meetings for a year, you could use the return value of monthcalendar().

```python
import calendar
import pprint

pprint.pprint(calendar.monthcalendar(2007, 7))
```

Notice that some days are 0. Those are days of the week that overlap with the given month but which are part of another month.

```
$ python calendar_monthcalendar.py

[[0, 0, 0, 0, 0, 0, 1],
 [2, 3, 4, 5, 6, 7, 8],
 [9, 10, 11, 12, 13, 14, 15],
 [16, 17, 18, 19, 20, 21, 22],
 [23, 24, 25, 26, 27, 28, 29],
 [30, 31, 0, 0, 0, 0, 0]]
```

As mentioned earlier, the first day of the week is Monday. It is possible to change that by calling setfirstweekday(). On the other hand, since the calendar module includes constants for indexing into the date ranges returned by monthcalendar(), it is more convenient to skip that step in this case.

To calculate the PyATL meeting dates for 2007, assuming the second Thursday of every month, we can use the 0 values to tell us whether the Thursday of the first week is included in the month (or if the month starts, for example on a Friday).

```
import calendar

# Show every month
for month in range(1, 13):

    # Compute the dates for each week that overlaps the month
    c = calendar.monthcalendar(2007, month)
    first_week = c[0]
    second_week = c[1]
    third_week = c[2]

    # If there is a Thursday in the first week, the second Thursday
    # is in the second week.  Otherwise the second Thursday must
    # be in the third week.
    if first_week[calendar.THURSDAY]:
        meeting_date = second_week[calendar.THURSDAY]
    else:
        meeting_date = third_week[calendar.THURSDAY]

    print '%3s: %2s' % (month, meeting_date)
```

So the PyATL meeting schedule for the year is:

```
$ python calendar_secondthursday.py

  1: 11
  2:  8
  3:  8
  4: 12
  5: 10
  6: 14
  7: 12
  8:  9
  9: 13
 10: 11
 11:  8
 12: 13
```

See also:

calendar **(http://docs.python.org/library/calendar.html)** The standard library documentation for this module.

`time` Lower-level time functions.

`datetime` Manipulate date values, including timestamps and time zones.

7.4 collections – Container data types

Purpose Container data types.

Available In 2.4 and later

The collections module includes container data types beyond the built-in types list, dict, and tuple.

7.4.1 Counter

A Counter is a container that keeps track of how many times equivalent values are added. It can be used to implement the same algorithms for which bag or multiset data structures are commonly used in other languages.

Initializing

Counter supports three forms of initialization. Its constructor can be called with a sequence of items, a dictionary containing keys and counts, or using keyword arguments mapping string names to counts.

```
import collections

print collections.Counter(['a', 'b', 'c', 'a', 'b', 'b'])
print collections.Counter({'a':2, 'b':3, 'c':1})
print collections.Counter(a=2, b=3, c=1)
```

The results of all three forms of initialization are the same.

```
$ python collections_counter_init.py

Counter({'b': 3, 'a': 2, 'c': 1})
Counter({'b': 3, 'a': 2, 'c': 1})
Counter({'b': 3, 'a': 2, 'c': 1})
```

An empty Counter can be constructed with no arguments and populated via the update() method.

```
import collections

c = collections.Counter()
print 'Initial :', c

c.update('abcdaab')
print 'Sequence:', c

c.update({'a':1, 'd':5})
print 'Dict    :', c
```

The count values are increased based on the new data, rather than replaced. In this example, the count for a goes from 3 to 4.

```
$ python collections_counter_update.py

Initial : Counter()
Sequence: Counter({'a': 3, 'b': 2, 'c': 1, 'd': 1})
Dict    : Counter({'d': 6, 'a': 4, 'b': 2, 'c': 1})
```

Accessing Counts

Once a Counter is populated, its values can be retrieved using the dictionary API.

```
import collections

c = collections.Counter('abcdaab')
```

```
for letter in 'abcde':
    print '%s : %d' % (letter, c[letter])
```

Counter does not raise *KeyError* for unknown items. If a value has not been seen in the input (as with e in this example), its count is 0.

```
$ python collections_counter_get_values.py

a : 3
b : 2
c : 1
d : 1
e : 0
```

The elements() method returns an iterator that produces all of the items known to the Counter.

```
import collections

c = collections.Counter('extremely')
c['z'] = 0
print c
print list(c.elements())
```

The order of elements is not guaranteed, and items with counts less than zero are not included.

```
$ python collections_counter_elements.py

Counter({'e': 3, 'm': 1, 'l': 1, 'r': 1, 't': 1, 'y': 1, 'x': 1, 'z': 0})
['e', 'e', 'e', 'm', 'l', 'r', 't', 'y', 'x']
```

Use most_common() to produce a sequence of the *n* most frequently encountered input values and their respective counts.

```
import collections

c = collections.Counter()
with open('/usr/share/dict/words', 'rt') as f:
    for line in f:
        c.update(line.rstrip().lower())

print 'Most common:'
for letter, count in c.most_common(3):
    print '%s: %7d' % (letter, count)
```

This example counts the letters appearing in all of the words in the system dictionary to produce a frequency distribution, then prints the three most common letters. Leaving out the argument to most_common() produces a list of all the items, in order of frequency.

```
$ python collections_counter_most_common.py

Most common:
e:  235331
i:  201032
a:  199554
```

Arithmetic

Counter instances support arithmetic and set operations for aggregating results.

```
import collections

c1 = collections.Counter(['a', 'b', 'c', 'a', 'b', 'b'])
c2 = collections.Counter('alphabet')

print 'C1:', c1
print 'C2:', c2

print '\nCombined counts:'
print c1 + c2

print '\nSubtraction:'
print c1 - c2

print '\nIntersection (taking positive minimums):'
print c1 & c2

print '\nUnion (taking maximums):'
print c1 | c2
```

Each time a new `Counter` is produced through an operation, any items with zero or negative counts are discarded. The count for `a` is the same in `c1` and `c2`, so subtraction leaves it at zero.

```
$ python collections_counter_arithmetic.py

C1: Counter({'b': 3, 'a': 2, 'c': 1})
C2: Counter({'a': 2, 'b': 1, 'e': 1, 'h': 1, 'l': 1, 'p': 1, 't': 1})

Combined counts:
Counter({'a': 4, 'b': 4, 'c': 1, 'e': 1, 'h': 1, 'l': 1, 'p': 1, 't': 1})

Subtraction:
Counter({'b': 2, 'c': 1})

Intersection (taking positive minimums):
Counter({'a': 2, 'b': 1})

Union (taking maximums):
Counter({'b': 3, 'a': 2, 'c': 1, 'e': 1, 'h': 1, 'l': 1, 'p': 1, 't': 1})
```

7.4.2 defaultdict

The standard dictionary includes the method `setdefault()` for retrieving a value and establishing a default if the value does not exist. By contrast, `defaultdict` lets the caller specify the default up front when the container is initialized.

```
import collections

def default_factory():
    return 'default value'

d = collections.defaultdict(default_factory, foo='bar')
print 'd:', d
print 'foo =>', d['foo']
print 'bar =>', d['bar']
```

This works well as long as it is appropriate for all keys to have the same default. It can be especially useful if the default is a type used for aggregating or accumulating values, such as a `list`, `set`, or even `int`. The standard library documentation includes several examples of using `defaultdict` this way.

```
$ python collections_defaultdict.py

d: defaultdict(<function default_factory at 0x100468c80>, {'foo': 'bar'})
foo => bar
bar => default value
```

See also:

defaultdict examples (http://docs.python.org/lib/defaultdict-examples.html) Examples of using defaultdict from the standard library documentation.

James Tauber: Evolution of Default Dictionaries in Python (http://jtauber.com/blog/2008/02/27/evolution_of_default_dictionari Discussion of how defaultdict relates to other means of initializing dictionaries.

7.4.3 Deque

A double-ended queue, or `deque`, supports adding and removing elements from either end. The more commonly used stacks and queues are degenerate forms of deques, where the inputs and outputs are restricted to a single end.

```
import collections

d = collections.deque('abcdefg')
print 'Deque:', d
print 'Length:', len(d)
print 'Left end:', d[0]
print 'Right end:', d[-1]

d.remove('c')
print 'remove(c):', d
```

Since deques are a type of sequence container, they support some of the same operations that lists support, such as examining the contents with `__getitem__()`, determining length, and removing elements from the middle by matching identity.

```
$ python collections_deque.py

Deque: deque(['a', 'b', 'c', 'd', 'e', 'f', 'g'])
Length: 7
Left end: a
Right end: g
remove(c): deque(['a', 'b', 'd', 'e', 'f', 'g'])
```

Populating

A deque can be populated from either end, termed “left” and “right” in the Python implementation.

```
import collections

# Add to the right
d = collections.deque()
d.extend('abcdefg')
print 'extend    :', d
d.append('h')
print 'append    :', d
```

```
# Add to the left
d = collections.deque()
d.extendleft('abcdefg')
print 'extendleft:', d
d.appendleft('h')
print 'appendleft:', d
```

Notice that `extendleft()` iterates over its input and performs the equivalent of an `appendleft()` for each item. The end result is the `deque` contains the input sequence in reverse order.

```
$ python collections_deque_populating.py

extend    : deque(['a', 'b', 'c', 'd', 'e', 'f', 'g'])
append    : deque(['a', 'b', 'c', 'd', 'e', 'f', 'g', 'h'])
extendleft: deque(['g', 'f', 'e', 'd', 'c', 'b', 'a'])
appendleft: deque(['h', 'g', 'f', 'e', 'd', 'c', 'b', 'a'])
```

Consuming

Similarly, the elements of the `deque` can be consumed from both or either end, depending on the algorithm being applied.

```
import collections

print 'From the right:'
d = collections.deque('abcdefg')
while True:
    try:
        print d.pop()
    except IndexError:
        break

print '\nFrom the left:'
d = collections.deque('abcdefg')
while True:
    try:
        print d.popleft()
    except IndexError:
        break
```

Use `pop()` to remove an item from the "right" end of the `deque` and `popleft()` to take from the "left" end.

```
$ python collections_deque_consuming.py

From the right:
g
f
e
d
c
b
a

From the left:
a
b
c
```

```
d
e
f
g
```

Since deques are thread-safe, the contents can even be consumed from both ends at the same time from separate threads.

```
import collections
import threading
import time

candle = collections.deque(xrange(11))

def burn(direction, nextSource):
    while True:
        try:
            next = nextSource()
        except IndexError:
            break
        else:
            print '%8s: %s' % (direction, next)
            time.sleep(0.1)
    print '%8s done' % direction
    return

left = threading.Thread(target=burn, args=('Left', candle.popleft))
right = threading.Thread(target=burn, args=('Right', candle.pop))

left.start()
right.start()

left.join()
right.join()
```

The threads in this example alternate between each end, removing items until the `deque` is empty.

```
$ python collections_deque_both_ends.py

    Left: 0
   Right: 10
   Right: 9
     Left: 1
   Right: 8
    Left: 2
   Right: 7
    Left: 3
   Right: 6
    Left: 4
   Right: 5
    Left done
   Right done
```

Rotating

Another useful capability of the `deque` is to rotate it in either direction, to skip over some items.

```
import collections

d = collections.deque(xrange(10))
print 'Normal        :', d

d = collections.deque(xrange(10))
d.rotate(2)
print 'Right rotation:', d

d = collections.deque(xrange(10))
d.rotate(-2)
print 'Left rotation :', d
```

Rotating the `deque` to the right (using a positive rotation) takes items from the right end and moves them to the left end. Rotating to the left (with a negative value) takes items from the left end and moves them to the right end. It may help to visualize the items in the deque as being engraved along the edge of a dial.

```
$ python collections_deque_rotate.py

Normal        : deque([0, 1, 2, 3, 4, 5, 6, 7, 8, 9])
Right rotation: deque([8, 9, 0, 1, 2, 3, 4, 5, 6, 7])
Left rotation : deque([2, 3, 4, 5, 6, 7, 8, 9, 0, 1])
```

See also:

WikiPedia: Deque (http://en.wikipedia.org/wiki/Deque) A discussion of the deque data structure.

Deque Recipes (http://docs.python.org/lib/deque-recipes.html) Examples of using deques in algorithms from the standard library documentation.

7.4.4 namedtuple

The standard `tuple` uses numerical indexes to access its members.

```
bob = ('Bob', 30, 'male')
print 'Representation:', bob

jane = ('Jane', 29, 'female')
print '\nField by index:', jane[0]

print '\nFields by index:'
for p in [ bob, jane ]:
    print '%s is a %d year old %s' % p
```

This makes `tuples` convenient containers for simple uses.

```
$ python collections_tuple.py

Representation: ('Bob', 30, 'male')

Field by index: Jane

Fields by index:
Bob is a 30 year old male
Jane is a 29 year old female
```

On the other hand, remembering which index should be used for each value can lead to errors, especially if the `tuple` has a lot of fields and is constructed far from where it is used. A `namedtuple` assigns names, as well as the numerical index, to each member.

Defining

`namedtuple` instances are just as memory efficient as regular tuples because they do not have per-instance dictionaries. Each kind of `namedtuple` is represented by its own class, created by using the `namedtuple()` factory function. The arguments are the name of the new class and a string containing the names of the elements.

```
import collections

Person = collections.namedtuple('Person', 'name age gender')

print 'Type of Person:', type(Person)

bob = Person(name='Bob', age=30, gender='male')
print '\nRepresentation:', bob

jane = Person(name='Jane', age=29, gender='female')
print '\nField by name:', jane.name

print '\nFields by index:'
for p in [ bob, jane ]:
    print '%s is a %d year old %s' % p
```

As the example illustrates, it is possible to access the fields of the `namedtuple` by name using dotted notation (`obj.attr`) as well as using the positional indexes of standard tuples.

```
$ python collections_namedtuple_person.py

Type of Person: <type 'type'>

Representation: Person(name='Bob', age=30, gender='male')

Field by name: Jane

Fields by index:
Bob is a 30 year old male
Jane is a 29 year old female
```

Invalid Field Names

As the field names are parsed, invalid values cause *ValueError* exceptions.

```
import collections

try:
    collections.namedtuple('Person', 'name class age gender')
except ValueError, err:
    print err

try:
    collections.namedtuple('Person', 'name age gender age')
except ValueError, err:
    print err
```

Names are invalid if they are repeated or conflict with Python keywords.

```
$ python collections_namedtuple_bad_fields.py

Type names and field names cannot be a keyword: 'class'
Encountered duplicate field name: 'age'
```

In situations where a `namedtuple` is being created based on values outside of the control of the programm (such as to represent the rows returned by a database query, where the schema is not known in advance), set the *rename* option to `True` so the fields are renamed.

```
import collections

with_class = collections.namedtuple('Person', 'name class age gender', rename=True)
print with_class._fields

two_ages = collections.namedtuple('Person', 'name age gender age', rename=True)
print two_ages._fields
```

The field with name `class` becomes `_1` and the duplicate `age` field is changed to `_3`.

```
$ python collections_namedtuple_rename.py

('name', '_1', 'age', 'gender')
('name', 'age', 'gender', '_3')
```

7.4.5 OrderedDict

An `OrderedDict` is a dictionary subclass that remembers the order in which its contents are added.

```
import collections

print 'Regular dictionary:'
d = {}
d['a'] = 'A'
d['b'] = 'B'
d['c'] = 'C'
d['d'] = 'D'
d['e'] = 'E'

for k, v in d.items():
    print k, v

print '\nOrderedDict:'
d = collections.OrderedDict()
d['a'] = 'A'
d['b'] = 'B'
d['c'] = 'C'
d['d'] = 'D'
d['e'] = 'E'

for k, v in d.items():
    print k, v
```

A regular `dict` does not track the insertion order, and iterating over it produces the values in an arbitrary order. In an `OrderedDict`, by contrast, the order the items are inserted is remembered and used when creating an iterator.

```
$ python collections_ordereddict_iter.py
```

```
Regular dictionary:
a A
c C
b B
e E
d D

OrderedDict:
a A
b B
c C
d D
e E
```

Equality

A regular `dict` looks at its contents when testing for equality. An `OrderedDict` also considers the order the items were added.

```
import collections

print 'dict       :',
d1 = {}
d1['a'] = 'A'
d1['b'] = 'B'
d1['c'] = 'C'
d1['d'] = 'D'
d1['e'] = 'E'

d2 = {}
d2['e'] = 'E'
d2['d'] = 'D'
d2['c'] = 'C'
d2['b'] = 'B'
d2['a'] = 'A'

print d1 == d2

print 'OrderedDict:',

d1 = collections.OrderedDict()
d1['a'] = 'A'
d1['b'] = 'B'
d1['c'] = 'C'
d1['d'] = 'D'
d1['e'] = 'E'

d2 = collections.OrderedDict()
d2['e'] = 'E'
d2['d'] = 'D'
d2['c'] = 'C'
d2['b'] = 'B'
d2['a'] = 'A'

print d1 == d2
```

In this case, since the two ordered dictionaries are created from values in a different order, they are considered to be different.

```
$ python collections_ordereddict_equality.py

dict       : True
OrderedDict: False
```

See also:

collections (http://docs.python.org/library/collections.html) The standard library documentation for this module.

7.5 heapq – In-place heap sort algorithm

Purpose The heapq implements a min-heap sort algorithm suitable for use with Python's lists.

Available In New in 2.3 with additions in 2.5

A *heap* is a tree-like data structure where the child nodes have a sort-order relationship with the parents. *Binary heaps* can be represented using a list or array organized so that the children of element N are at positions 2*N+1 and 2*N+2 (for zero-based indexes). This layout makes it possible to rearrange heaps in place, so it is not necessary to reallocate as much memory when adding or removing items.

A max-heap ensures that the parent is larger than or equal to both of its children. A min-heap requires that the parent be less than or equal to its children. Python's heapq module implements a min-heap.

7.5.1 Example Data

The examples below use this sample data:

```
# This data was generated with the random module.

data = [19, 9, 4, 10, 11, 8, 2]
```

The heap output is printed using `heapq_showtree.py`:

```
import math
from cStringIO import StringIO

def show_tree(tree, total_width=36, fill=' '):
    """Pretty-print a tree."""
    output = StringIO()
    last_row = -1
    for i, n in enumerate(tree):
        if i:
            row = int(math.floor(math.log(i+1, 2)))
        else:
            row = 0
        if row != last_row:
            output.write('\n')
        columns = 2**row
        col_width = int(math.floor((total_width * 1.0) / columns))
        output.write(str(n).center(col_width, fill))
        last_row = row
    print output.getvalue()
    print '-' * total_width
    print
    return
```

7.5.2 Creating a Heap

There are 2 basic ways to create a heap, `heappush()` and `heapify()`.

Using `heappush()`, the heap sort order of the elements is maintained as new items are added from a data source.

```
import heapq
from heapq_showtree import show_tree
from heapq_heapdata import data

heap = []
print 'random :', data
print

for n in data:
    print 'add %3d:' % n
    heapq.heappush(heap, n)
    show_tree(heap)
```

```
$ python heapq_heappush.py

random : [19, 9, 4, 10, 11, 8, 2]

add  19:

                 19
------------------------------------

add   9:

                 9
        19
------------------------------------

add   4:

                 4
        19                9
------------------------------------

add  10:

                 4
        10                9
    19
------------------------------------

add  11:

                 4
        10                9
    19       11
------------------------------------

add   8:

                 4
        10                8
    19       11       9
```

```
------------------------------------

add   2:

                 2
        10                 4
    19        11        9         8
------------------------------------
```

If the data is already in memory, it is more efficient to use `heapify()` to rearrange the items of the list in place.

```
import heapq
from heapq_showtree import show_tree
from heapq_heapdata import data

print 'random    :', data
heapq.heapify(data)
print 'heapified :'
show_tree(data)
```

```
$ python heapq_heapify.py

random    : [19, 9, 4, 10, 11, 8, 2]
heapified :

                 2
        9                  4
    10        11        8         19
------------------------------------
```

7.5.3 Accessing Contents of a Heap

Once the heap is organized correctly, use `heappop()` to remove the element with the lowest value. In this example, adapted from the stdlib documentation, `heapify()` and `heappop()` are used to sort a list of numbers.

```
import heapq
from heapq_showtree import show_tree
from heapq_heapdata import data

print 'random    :', data
heapq.heapify(data)
print 'heapified :'
show_tree(data)
print

inorder = []
while data:
    smallest = heapq.heappop(data)
    print 'pop    %3d:' % smallest
    show_tree(data)
    inorder.append(smallest)
print 'inorder   :', inorder
```

```
$ python heapq_heappop.py

random    : [19, 9, 4, 10, 11, 8, 2]
heapified :
```

```
                 2
         9                 4
    10       11       8         19
------------------------------------


pop      2:

                 4
         9                 8
    10       11       19
------------------------------------

pop      4:

                 8
         9                 19
    10       11
------------------------------------

pop      8:

                 9
         10                19
    11
------------------------------------

pop      9:

                 10
         11                19
------------------------------------

pop     10:

                 11
         19
------------------------------------

pop     11:

                 19
------------------------------------

pop     19:

------------------------------------

inorder   : [2, 4, 8, 9, 10, 11, 19]
```

To remove existing elements and replace them with new values in a single operation, use `heapreplace()`.

```
import heapq
from heapq_showtree import show_tree
from heapq_heapdata import data

heapq.heapify(data)
print 'start:'
```

```
show_tree(data)

for n in [0, 7, 13, 9, 5]:
    smallest = heapq.heapreplace(data, n)
    print 'replace %2d with %2d:' % (smallest, n)
    show_tree(data)
```

Replacing elements in place lets you maintain a fixed size heap, such as a queue of jobs ordered by priority.

```
$ python heapq_heapreplace.py

start:

                 2
        9                 4
    10       11       8        19
------------------------------------

replace  2 with  0:

                 0
        9                 4
    10       11       8        19
------------------------------------

replace  0 with  7:

                 4
        9                 7
    10       11       8        19
------------------------------------

replace  4 with 13:

                 7
        9                 8
    10       11       13       19
------------------------------------

replace  7 with  9:

                 8
        9                 9
    10       11       13       19
------------------------------------

replace  8 with  5:

                 5
        9                 9
    10       11       13       19
------------------------------------
```

7.5.4 Data Extremes

heapq also includes 2 functions to examine an iterable to find a range of the largest or smallest values it contains. Using nlargest() and nsmallest() are really only efficient for relatively small values of n > 1, but can still come in handy in a few cases.

```
import heapq
from heapq_heapdata import data

print 'all       :', data
print '3 largest :', heapq.nlargest(3, data)
print 'from sort :', list(reversed(sorted(data)[-3:]))
print '3 smallest:', heapq.nsmallest(3, data)
print 'from sort :', sorted(data)[:3]
```

```
$ python heapq_extremes.py

all       : [19, 9, 4, 10, 11, 8, 2]
3 largest : [19, 11, 10]
from sort : [19, 11, 10]
3 smallest: [2, 4, 8]
from sort : [2, 4, 8]
```

See also:

heapq **(http://docs.python.org/library/heapq.html)** The standard library documentation for this module.

WikiPedia: Heap (data structure) **(http://en.wikipedia.org/wiki/Heap_(data_structure))** A general description of heap data structures.

In-Memory Data Structures Other Python data structures.

Priority Queue A priority queue implementation from `Queue` in the standard library.

7.6 bisect – Maintain lists in sorted order

Purpose Maintains a list in sorted order without having to call sort each time an item is added to the list.

Available In 1.4

The bisect module implements an algorithm for inserting elements into a list while maintaining the list in sorted order. This can be much more efficient than repeatedly sorting a list, or explicitly sorting a large list after it is constructed.

7.6.1 Example

Let's look at a simple example using bisect.insort(), which inserts items into a list in sorted order.

```
import bisect
import random

# Use a constant see to ensure that we see
# the same pseudo-random numbers each time
# we run the loop.
random.seed(1)

# Generate 20 random numbers and
# insert them into a list in sorted
# order.
l = []
for i in range(1, 20):
    r = random.randint(1, 100)
    position = bisect.bisect(l, r)
    bisect.insort(l, r)
    print '%2d %2d' % (r, position), l
```

The output for that script is:

```
$ python bisect_example.py

14  0 [14]
85  1 [14, 85]
77  1 [14, 77, 85]
26  1 [14, 26, 77, 85]
50  2 [14, 26, 50, 77, 85]
45  2 [14, 26, 45, 50, 77, 85]
66  4 [14, 26, 45, 50, 66, 77, 85]
79  6 [14, 26, 45, 50, 66, 77, 79, 85]
10  0 [10, 14, 26, 45, 50, 66, 77, 79, 85]
 3  0 [3, 10, 14, 26, 45, 50, 66, 77, 79, 85]
84  9 [3, 10, 14, 26, 45, 50, 66, 77, 79, 84, 85]
44  4 [3, 10, 14, 26, 44, 45, 50, 66, 77, 79, 84, 85]
77  9 [3, 10, 14, 26, 44, 45, 50, 66, 77, 77, 79, 84, 85]
 1  0 [1, 3, 10, 14, 26, 44, 45, 50, 66, 77, 77, 79, 84, 85]
45  7 [1, 3, 10, 14, 26, 44, 45, 45, 50, 66, 77, 77, 79, 84, 85]
73 10 [1, 3, 10, 14, 26, 44, 45, 45, 50, 66, 73, 77, 77, 79, 84, 85]
23  4 [1, 3, 10, 14, 23, 26, 44, 45, 45, 50, 66, 73, 77, 77, 79, 84, 85]
95 17 [1, 3, 10, 14, 23, 26, 44, 45, 45, 50, 66, 73, 77, 77, 79, 84, 85, 95]
91 17 [1, 3, 10, 14, 23, 26, 44, 45, 45, 50, 66, 73, 77, 77, 79, 84, 85, 91, 95]
```

The first column shows the new random number. The second column shows the position where the number will be inserted into the list. The remainder of each line is the current sorted list.

This is a simple example, and for the amount of data we are manipulating it might be faster to simply build the list and then sort it once. But for long lists, significant time and memory savings can be achieved using an insertion sort algorithm such as this.

You probably noticed that the result set above includes a few repeated values (45 and 77). The bisect module provides 2 ways to handle repeats. New values can be inserted to the left of existing values, or to the right. The insort() function is actually an alias for insort_right(), which inserts after the existing value. The corresponding function insort_left() inserts before the existing value.

If we manipulate the same data using bisect_left() and insort_left(), we end up with the same sorted list but notice that the insert positions are different for the duplicate values.

```
import bisect
import random

# Reset the seed
random.seed(1)

# Use bisect_left and insort_left.
l = []
for i in range(1, 20):
    r = random.randint(1, 100)
    position = bisect.bisect_left(l, r)
    bisect.insort_left(l, r)
    print '%2d %2d' % (r, position), l
```

```
$ python bisect_example2.py

14  0 [14]
```

```
85  1 [14, 85]
77  1 [14, 77, 85]
26  1 [14, 26, 77, 85]
50  2 [14, 26, 50, 77, 85]
45  2 [14, 26, 45, 50, 77, 85]
66  4 [14, 26, 45, 50, 66, 77, 85]
79  6 [14, 26, 45, 50, 66, 77, 79, 85]
10  0 [10, 14, 26, 45, 50, 66, 77, 79, 85]
 3  0 [3, 10, 14, 26, 45, 50, 66, 77, 79, 85]
84  9 [3, 10, 14, 26, 45, 50, 66, 77, 79, 84, 85]
44  4 [3, 10, 14, 26, 44, 45, 50, 66, 77, 79, 84, 85]
77  8 [3, 10, 14, 26, 44, 45, 50, 66, 77, 77, 79, 84, 85]
 1  0 [1, 3, 10, 14, 26, 44, 45, 50, 66, 77, 77, 79, 84, 85]
45  6 [1, 3, 10, 14, 26, 44, 45, 45, 50, 66, 77, 77, 79, 84, 85]
73 10 [1, 3, 10, 14, 26, 44, 45, 45, 50, 66, 73, 77, 77, 79, 84, 85]
23  4 [1, 3, 10, 14, 23, 26, 44, 45, 45, 50, 66, 73, 77, 77, 79, 84, 85]
95 17 [1, 3, 10, 14, 23, 26, 44, 45, 45, 50, 66, 73, 77, 77, 79, 84, 85, 95]
91 17 [1, 3, 10, 14, 23, 26, 44, 45, 45, 50, 66, 73, 77, 77, 79, 84, 85, 91, 95]
```

In addition to the Python implementation, there is a faster C implementation available. If the C version is present, that implementation overrides the pure Python implementation automatically when you import the bisect module.

See also:

bisect **(http://docs.python.org/library/bisect.html)** The standard library documentation for this module.

WikiPedia: Insertion Sort **(http://en.wikipedia.org/wiki/Insertion_sort)** A description of the insertion sort algorithm.

In-Memory Data Structures

7.7 sched – Generic event scheduler.

Purpose Generic event scheduler.

Available In 1.4

The `sched` module implements a generic event scheduler for running tasks at specific times. The scheduler class uses a *time* function to learn the current time, and a *delay* function to wait for a specific period of time. The actual units of time are not important, which makes the interface flexible enough to be used for many purposes.

The *time* function is called without any arguments, and should return a number representing the current time. The *delay* function is called with a single integer argument, using the same scale as the time function, and should wait that many time units before returning. For example, the `time.time()` and `time.sleep()` functions meet these requirements.

To support multi-threaded applications, the delay function is called with argument 0 after each event is generated, to ensure that other threads also have a chance to run.

7.7.1 Running Events With a Delay

Events can be scheduled to run after a delay, or at a specific time. To schedule them with a delay, use the `enter()` method, which takes 4 arguments:

- A number representing the delay
- A priority value

- The function to call
- A tuple of arguments for the function

This example schedules 2 different events to run after 2 and 3 seconds respectively. When the event's time comes up, `print_event()` is called and prints the current time and the name argument passed to the event.

```
import sched
import time

scheduler = sched.scheduler(time.time, time.sleep)

def print_event(name):
    print 'EVENT:', time.time(), name

print 'START:', time.time()
scheduler.enter(2, 1, print_event, ('first',))
scheduler.enter(3, 1, print_event, ('second',))

scheduler.run()
```

The output will look something like this:

```
$ python sched_basic.py

START: 1361446599.49
EVENT: 1361446601.49 first
EVENT: 1361446602.49 second
```

The time printed for the first event is 2 seconds after start, and the time for the second event is 3 seconds after start.

7.7.2 Overlapping Events

The call to `run()` blocks until all of the events have been processed. Each event is run in the same thread, so if an event takes longer to run than the delay between events, there will be overlap. The overlap is resolved by postponing the later event. No events are lost, but some events may be called later than they were scheduled. In the next example, `long_event()` sleeps but it could just as easily delay by performing a long calculation or by blocking on I/O.

```
import sched
import time

scheduler = sched.scheduler(time.time, time.sleep)

def long_event(name):
    print 'BEGIN EVENT :', time.time(), name
    time.sleep(2)
    print 'FINISH EVENT:', time.time(), name

print 'START:', time.time()
scheduler.enter(2, 1, long_event, ('first',))
scheduler.enter(3, 1, long_event, ('second',))

scheduler.run()
```

The result is the second event is run immediately after the first finishes, since the first event took long enough to push the clock past the desired start time of the second event.

```
$ python sched_overlap.py
```

```
START: 1361446602.55
BEGIN EVENT : 1361446604.55 first
FINISH EVENT: 1361446606.55 first
BEGIN EVENT : 1361446606.55 second
FINISH EVENT: 1361446608.55 second
```

7.7.3 Event Priorities

If more than one event is scheduled for the same time their priority values are used to determine the order they are run.

```
import sched
import time

scheduler = sched.scheduler(time.time, time.sleep)

def print_event(name):
    print 'EVENT:', time.time(), name

now = time.time()
print 'START:', now
scheduler.enterabs(now+2, 2, print_event, ('first',))
scheduler.enterabs(now+2, 1, print_event, ('second',))

scheduler.run()
```

This example needs to ensure that they are scheduled for the exact same time, so the `enterabs()` method is used instead of `enter()`. The first argument to `enterabs()` is the time to run the event, instead of the amount of time to delay.

```
$ python sched_priority.py

START: 1361446608.62
EVENT: 1361446610.62 second
EVENT: 1361446610.62 first
```

7.7.4 Canceling Events

Both `enter()` and `enterabs()` return a reference to the event which can be used to cancel it later. Since `run()` blocks, the event has to be canceled in a different thread. For this example, a thread is started to run the scheduler and the main processing thread is used to cancel the event.

```
import sched
import threading
import time

scheduler = sched.scheduler(time.time, time.sleep)

# Set up a global to be modified by the threads
counter = 0

def increment_counter(name):
    global counter
    print 'EVENT:', time.time(), name
    counter += 1
    print 'NOW:', counter
print 'START:', time.time()
e1 = scheduler.enter(2, 1, increment_counter, ('E1',))
e2 = scheduler.enter(3, 1, increment_counter, ('E2',))

# Start a thread to run the events
t = threading.Thread(target=scheduler.run)
t.start()

# Back in the main thread, cancel the first scheduled event.
scheduler.cancel(e1)

# Wait for the scheduler to finish running in the thread
t.join()

print 'FINAL:', counter
```

Two events were scheduled, but the first was later canceled. Only the second event runs, so the counter variable is only incremented one time.

```
$ python sched_cancel.py

START: 1361446610.65
EVENT: 1361446613.66 E2
NOW: 1
FINAL: 1
```

See also:

sched **(http://docs.python.org/lib/module-sched.html)** Standard library documentation for this module.

`time` The time module.

7.8 Queue – A thread-safe FIFO implementation

Purpose Provides a thread-safe FIFO implementation

Available In at least 1.4

The `Queue` module provides a FIFO implementation suitable for multi-threaded programming. It can be used to pass messages or other data between producer and consumer threads safely. Locking is handled for the caller, so it is simple to have as many threads as you want working with the same Queue instance. A Queue's size (number of elements) may be restricted to throttle memory usage or processing.

Note: This discussion assumes you already understand the general nature of a queue. If you don't, you may want to read some of the references before continuing.

7.8.1 Basic FIFO Queue

The `Queue` class implements a basic first-in, first-out container. Elements are added to one "end" of the sequence using `put()`, and removed from the other end using `get()`.

```
import Queue

q = Queue.Queue()
```

```
for i in range(5):
    q.put(i)

while not q.empty():
    print q.get()
```

This example uses a single thread to illustrate that elements are removed from the queue in the same order they are inserted.

```
$ python Queue_fifo.py

0
1
2
3
4
```

7.8.2 LIFO Queue

In contrast to the standard FIFO implementation of `Queue`, the `LifoQueue` uses last-in, first-out ordering (normally associated with a stack data structure).

```
import Queue

q = Queue.LifoQueue()

for i in range(5):
    q.put(i)

while not q.empty():
    print q.get()
```

The item most recently `put()` into the queue is removed by `get()`.

```
$ python Queue_lifo.py

4
3
2
1
0
```

7.8.3 Priority Queue

Sometimes the processing order of the items in a queue needs to be based on characteristics of those items, rather than just the order they are created or added to the queue. For example, print jobs from the payroll department may take precedence over a code listing printed by a developer. `PriorityQueue` uses the sort order of the contents of the queue to decide which to retrieve.

```
import Queue

class Job(object):
    def __init__(self, priority, description):
        self.priority = priority
        self.description = description
        print 'New job:', description
        return
    def __cmp__(self, other):
        return cmp(self.priority, other.priority)

q = Queue.PriorityQueue()

q.put( Job(3, 'Mid-level job') )
q.put( Job(10, 'Low-level job') )
q.put( Job(1, 'Important job') )

while not q.empty():
    next_job = q.get()
    print 'Processing job:', next_job.description
```

In this single-threaded example, the jobs are pulled out of the queue in strictly priority order. If there were multiple threads consuming the jobs, they would be processed based on the priority of items in the queue at the time `get()` was called.

```
$ python Queue_priority.py

New job: Mid-level job
New job: Low-level job
New job: Important job
Processing job: Important job
Processing job: Mid-level job
Processing job: Low-level job
```

7.8.4 Using Queues with Threads

As an example of how to use the Queue class with multiple threads, we can create a very simplistic podcasting client. This client reads one or more RSS feeds, queues up the enclosures for download, and processes several downloads in parallel using threads. It is simplistic and unsuitable for actual use, but the skeleton implementation gives us enough code to work with to provide an example of using the Queue module.

```
# System modules
from Queue import Queue
from threading import Thread
import time

# Local modules
import feedparser

# Set up some global variables
num_fetch_threads = 2
enclosure_queue = Queue()

# A real app wouldn't use hard-coded data...
feed_urls = [ 'http://www.castsampler.com/cast/feed/rss/guest',
             ]


def downloadEnclosures(i, q):
    """This is the worker thread function.
    It processes items in the queue one after
    another.  These daemon threads go into an
    infinite loop, and only exit when
    the main thread ends.
    """
    while True:
        print '%s: Looking for the next enclosure' % i
        url = q.get()
        print '%s: Downloading:' % i, url
        # instead of really downloading the URL,
        # we just pretend and sleep
        time.sleep(i + 2)
        q.task_done()


# Set up some threads to fetch the enclosures
for i in range(num_fetch_threads):
    worker = Thread(target=downloadEnclosures, args=(i, enclosure_queue,))
    worker.setDaemon(True)
    worker.start()

# Download the feed(s) and put the enclosure URLs into
# the queue.
for url in feed_urls:
    response = feedparser.parse(url, agent='fetch_podcasts.py')
    for entry in response['entries']:
        for enclosure in entry.get('enclosures', []):
            print 'Queuing:', enclosure['url']
            enclosure_queue.put(enclosure['url'])

# Now wait for the queue to be empty, indicating that we have
# processed all of the downloads.
print '*** Main thread waiting'
enclosure_queue.join()
print '*** Done'
```

First, we establish some operating parameters. Normally these would come from user inputs (preferences, a database, whatever). For our example we hard code the number of threads to use and the list of URLs to fetch.

Next, we need to define the function `downloadEnclosures()` that will run in the worker thread, processing the downloads. Again, for illustration purposes this only simulates the download. To actually download the enclosure, you might use `urllib` or `urllib2`. In this example, we simulate a download delay by sleeping a variable amount of time, depending on the thread id.

Once the threads' target function is defined, we can start the worker threads. Notice that downloadEnclosures() will block on the statement `url = q.get()` until the queue has something to return, so it is safe to start the threads before there is anything in the queue.

The next step is to retrieve the feed contents (using Mark Pilgrim's feedparser (http://www.feedparser.org/) module) and enqueue the URLs of the enclosures. As soon as the first URL is added to the queue, one of the worker threads should pick it up and start downloading it. The loop below will continue to add items until the feed is exhausted, and the worker threads will take turns dequeuing URLs to download them.

And the only thing left to do is wait for the queue to empty out again, using `join()`.

If you run the sample script, you should see output something like this:

```
0: Looking for the next enclosure
1: Looking for the next enclosure
Queuing: http://http.earthcache.net/htc-01.media.globix.net/COMP009996MOD1/Danny_Meyer.mp3
Queuing: http://feeds.feedburner.com/~r/drmoldawer/~5/104445110/moldawerinthemorning_show34_032607.mp
Queuing: http://www.podtrac.com/pts/redirect.mp3/twit.cachefly.net/MBW-036.mp3
Queuing: http://media1.podtech.net/media/2007/04/PID_010848/Podtech_calacaniscast22_ipod.mp4
Queuing: http://media1.podtech.net/media/2007/03/PID_010592/Podtech_SXSW_KentBrewster_ipod.mp4
```

```
Queuing: http://media1.podtech.net/media/2007/02/PID_010171/Podtech_IDM_ChrisOBrien2.mp3
Queuing: http://feeds.feedburner.com/~r/drmoldawer/~5/96188661/moldawerinthemorning_show30_022607.mp3
*** Main thread waiting
0: Downloading: http://http.earthcache.net/htc-01.media.globix.net/COMP009996MOD1/Danny_Meyer.mp3
1: Downloading: http://feeds.feedburner.com/~r/drmoldawer/~5/104445110/moldawerinthemorning_show34_03
0: Looking for the next enclosure
0: Downloading: http://www.podtrac.com/pts/redirect.mp3/twit.cachefly.net/MBW-036.mp3
1: Looking for the next enclosure
1: Downloading: http://media1.podtech.net/media/2007/04/PID_010848/Podtech_calacaniscast22_ipod.mp4
0: Looking for the next enclosure
0: Downloading: http://media1.podtech.net/media/2007/03/PID_010592/Podtech_SXSW_KentBrewster_ipod.mp4
0: Looking for the next enclosure
0: Downloading: http://media1.podtech.net/media/2007/02/PID_010171/Podtech_IDM_ChrisOBrien2.mp3
1: Looking for the next enclosure
1: Downloading: http://feeds.feedburner.com/~r/drmoldawer/~5/96188661/moldawerinthemorning_show30_022
0: Looking for the next enclosure
1: Looking for the next enclosure
*** Done
```

The actual output will depend on whether anyone modifies the subscriptions in the guest account on http://www.CastSampler.com.

See also:

Queue (http://docs.python.org/lib/module-Queue.html) Standard library documentation for this module.

***Deque* from `collections`** collections includes a deque (double-ended queue) class

Wikipedia: Queue data structures http://en.wikipedia.org/wiki/Queue_(data_structure)

Wikipedia: FIFO http://en.wikipedia.org/wiki/FIFO

feedparser (http://www.feedparser.org/) Mark Pilgrim's feedparser module (http://www.feedparser.org/).

In-Memory Data Structures Other complex data structures in the standard library.

7.9 weakref – Garbage-collectable references to objects

Purpose Refer to an "expensive" object, but allow it to be garbage collected if there are no other non-weak references.

Available In Since 2.1

The `weakref` module supports weak references to objects. A normal reference increments the reference count on the object and prevents it from being garbage collected. This is not always desirable, either when a circular reference might be present or when building a cache of objects that should be deleted when memory is needed.

7.9.1 References

Weak references to your objects are managed through the `ref` class. To retrieve the original object, call the reference object.

```python
import weakref

class ExpensiveObject(object):
    def __del__(self):
        print '(Deleting %s)' % self
```

```
obj = ExpensiveObject()
r = weakref.ref(obj)

print 'obj:', obj
print 'ref:', r
print 'r():', r()

print 'deleting obj'
del obj
print 'r():', r()
```

In this case, since `obj` is deleted before the second call to the reference, the `ref` returns `None`.

```
$ python weakref_ref.py

obj: <__main__.ExpensiveObject object at 0x10046d410>
ref: <weakref at 0x100467838; to 'ExpensiveObject' at 0x10046d410>
r(): <__main__.ExpensiveObject object at 0x10046d410>
deleting obj
(Deleting <__main__.ExpensiveObject object at 0x10046d410>)
r(): None
```

7.9.2 Reference Callbacks

The `ref` constructor takes an optional second argument that should be a callback function to invoke when the referenced object is deleted.

```
import weakref

class ExpensiveObject(object):
    def __del__(self):
        print '(Deleting %s)' % self

def callback(reference):
    """Invoked when referenced object is deleted"""
    print 'callback(', reference, ')'

obj = ExpensiveObject()
r = weakref.ref(obj, callback)

print 'obj:', obj
print 'ref:', r
print 'r():', r()

print 'deleting obj'
del obj
print 'r():', r()
```

The callback receives the reference object as an argument, after the reference is "dead" and no longer refers to the original object. This lets you remove the weak reference object from a cache, for example.

```
$ python weakref_ref_callback.py

obj: <__main__.ExpensiveObject object at 0x10046c610>
ref: <weakref at 0x100468890; to 'ExpensiveObject' at 0x10046c610>
r(): <__main__.ExpensiveObject object at 0x10046c610>
deleting obj
```

```
callback( <weakref at 0x100468890; dead> )
(Deleting <__main__.ExpensiveObject object at 0x10046c610>)
r(): None
```

7.9.3 Proxies

Instead of using `ref` directly, it can be more convenient to use a proxy. Proxies can be used as though they were the original object, so you do not need to call the `ref` first to access the object.

```
import weakref

class ExpensiveObject(object):
    def __init__(self, name):
        self.name = name
    def __del__(self):
        print '(Deleting %s)' % self

obj = ExpensiveObject('My Object')
r = weakref.ref(obj)
p = weakref.proxy(obj)

print 'via obj:', obj.name
print 'via ref:', r().name
print 'via proxy:', p.name
del obj
print 'via proxy:', p.name
```

If the proxy is access after the referent object is removed, a `ReferenceError` exception is raised.

```
$ python weakref_proxy.py

via obj: My Object
via ref: My Object
via proxy: My Object
(Deleting <__main__.ExpensiveObject object at 0x10046b490>)
via proxy:
Traceback (most recent call last):
  File "weakref_proxy.py", line 26, in <module>
    print 'via proxy:', p.name
ReferenceError: weakly-referenced object no longer exists
```

7.9.4 Cyclic References

One use for weak references is to allow cyclic references without preventing garbage collection. This example illustrates the difference between using regular objects and proxies when a graph includes a cycle.

First, we need a `Graph` class that accepts any object given to it as the "next" node in the sequence. For the sake of brevity, this `Graph` supports a single outgoing reference from each node, which results in boring graphs but makes it easy to create cycles. The function `demo()` is a utility function to exercise the graph class by creating a cycle and then removing various references.

```
import gc
from pprint import pprint
import weakref

class Graph(object):
    def __init__(self, name):
        self.name = name
        self.other = None
    def set_next(self, other):
        print '%s.set_next(%s (%s))' % (self.name, other, type(other))
        self.other = other
    def all_nodes(self):
        "Generate the nodes in the graph sequence."
        yield self
        n = self.other
        while n and n.name != self.name:
            yield n
            n = n.other
        if n is self:
            yield n
        return
    def __str__(self):
        return '->'.join([n.name for n in self.all_nodes()])
    def __repr__(self):
        return '%s(%s)' % (self.__class__.__name__, self.name)
    def __del__(self):
        print '(Deleting %s)' % self.name
        self.set_next(None)

class WeakGraph(Graph):
    def set_next(self, other):
        if other is not None:
            # See if we should replace the reference
            # to other with a weakref.
            if self in other.all_nodes():
                other = weakref.proxy(other)
        super(WeakGraph, self).set_next(other)
        return

def collect_and_show_garbage():
    "Show what garbage is present."
    print 'Collecting...'
    n = gc.collect()
    print 'Unreachable objects:', n
    print 'Garbage:',
    pprint(gc.garbage)

def demo(graph_factory):
    print 'Set up graph:'
    one = graph_factory('one')
    two = graph_factory('two')
    three = graph_factory('three')
    one.set_next(two)
    two.set_next(three)
    three.set_next(one)

    print
    print 'Graphs:'
    print str(one)
    print str(two)
    print str(three)
    collect_and_show_garbage()
    print
    three = None
    two = None
    print 'After 2 references removed:'
    print str(one)
    collect_and_show_garbage()

    print
    print 'Removing last reference:'
    one = None
    collect_and_show_garbage()
```

Now we can set up a test program using the `gc` module to help us debug the leak. The `DEBUG_LEAK` flag causes `gc` to print information about objects that cannot be seen other than through the reference the garbage collector has to them.

```
import gc
from pprint import pprint
import weakref

from weakref_graph import Graph, demo, collect_and_show_garbage

gc.set_debug(gc.DEBUG_LEAK)

print 'Setting up the cycle'
print
demo(Graph)

print
print 'Breaking the cycle and cleaning up garbage'
print
gc.garbage[0].set_next(None)
while gc.garbage:
    del gc.garbage[0]
print
collect_and_show_garbage()
```

Even after deleting the local references to the `Graph` instances in `demo()`, the graphs all show up in the garbage list and cannot be collected. The dictionaries in the garbage list hold the attributes of the `Graph` instances. We can forcibly delete the graphs, since we know what they are:

```
$ python -u weakref_cycle.py

Setting up the cycle

Set up graph:
one.set_next(two (<class 'weakref_graph.Graph'>))
two.set_next(three (<class 'weakref_graph.Graph'>))
three.set_next(one->two->three (<class 'weakref_graph.Graph'>))

Graphs:
one->two->three->one
two->three->one->two
three->one->two->three
Collecting...
Unreachable objects: 0
Garbage:[]
```

```
After 2 references removed:
one->two->three->one
Collecting...
Unreachable objects: 0
Garbage:[]

Removing last reference:
Collecting...
gc: uncollectable <Graph 0x10046ff50>
gc: uncollectable <Graph 0x10046ff90>
gc: uncollectable <Graph 0x10046ffd0>
gc: uncollectable <dict 0x100363060>
gc: uncollectable <dict 0x100366460>
gc: uncollectable <dict 0x1003671f0>
Unreachable objects: 6
Garbage:[Graph(one),
 Graph(two),
 Graph(three),
 {'name': 'one', 'other': Graph(two)},
 {'name': 'two', 'other': Graph(three)},
 {'name': 'three', 'other': Graph(one)}]

Breaking the cycle and cleaning up garbage

one.set_next(None (<type 'NoneType'>))
(Deleting two)
two.set_next(None (<type 'NoneType'>))
(Deleting three)
three.set_next(None (<type 'NoneType'>))
(Deleting one)
one.set_next(None (<type 'NoneType'>))

Collecting...
Unreachable objects: 0
Garbage:[]
```

And now let's define a more intelligent `WeakGraph` class that knows not to create cycles using regular references, but to use a `ref` when a cycle is detected.

```
import gc
from pprint import pprint
import weakref

from weakref_graph import Graph, demo

class WeakGraph(Graph):
    def set_next(self, other):
        if other is not None:
            # See if we should replace the reference
            # to other with a weakref.
            if self in other.all_nodes():
                other = weakref.proxy(other)
        super(WeakGraph, self).set_next(other)
        return

demo(WeakGraph)
```

Since the `WeakGraph` instances use proxies to refer to objects that have already been seen, as `demo()` removes all local references to the objects, the cycle is broken and the garbage collector can delete the objects for us.

```
$ python weakref_weakgraph.py

Set up graph:
one.set_next(two (<class '__main__.WeakGraph'>))
two.set_next(three (<class '__main__.WeakGraph'>))
three.set_next(one->two->three (<type 'weakproxy'>))

Graphs:
one->two->three
two->three->one->two
three->one->two->three
Collecting...
Unreachable objects: 0
Garbage:[]

After 2 references removed:
one->two->three
Collecting...
Unreachable objects: 0
Garbage:[]

Removing last reference:
(Deleting one)
one.set_next(None (<type 'NoneType'>))
(Deleting two)
two.set_next(None (<type 'NoneType'>))
(Deleting three)
three.set_next(None (<type 'NoneType'>))
Collecting...
Unreachable objects: 0
Garbage:[]
```

7.9.5 Caching Objects

The `ref` and `proxy` classes are considered "low level". While they are useful for maintaining weak references to individual objects and allowing cycles to be garbage collected, if you need to create a cache of several objects the `WeakKeyDictionary` and `WeakValueDictionary` provide a more appropriate API.

As you might expect, the `WeakValueDictionary` uses weak references to the values it holds, allowing them to be garbage collected when other code is not actually using them.

To illustrate the difference between memory handling with a regular dictionary and `WeakValueDictionary`, let's go experiment with explicitly calling the garbage collector again:

```
import gc
from pprint import pprint
import weakref

gc.set_debug(gc.DEBUG_LEAK)

class ExpensiveObject(object):
    def __init__(self, name):
        self.name = name
    def __repr__(self):
        return 'ExpensiveObject(%s)' % self.name
    def __del__(self):
        print '(Deleting %s)' % self
```

```
def demo(cache_factory):
    # hold objects so any weak references
    # are not removed immediately
    all_refs = {}
    # the cache using the factory we're given
    print 'CACHE TYPE:', cache_factory
    cache = cache_factory()
    for name in [ 'one', 'two', 'three' ]:
        o = ExpensiveObject(name)
        cache[name] = o
        all_refs[name] = o
        del o # decref

    print 'all_refs =',
    pprint(all_refs)
    print 'Before, cache contains:', cache.keys()
    for name, value in cache.items():
        print '  %s = %s' % (name, value)
        del value # decref

    # Remove all references to our objects except the cache
    print 'Cleanup:'
    del all_refs
    gc.collect()

    print 'After, cache contains:', cache.keys()
    for name, value in cache.items():
        print '  %s = %s' % (name, value)
    print 'demo returning'
    return

demo(dict)
print
demo(weakref.WeakValueDictionary)
```

Notice that any loop variables that refer to the values we are caching must be cleared explicitly to decrement the reference count on the object. Otherwise the garbage collector would not remove the objects and they would remain in the cache. Similarly, the all_refs variable is used to hold references to prevent them from being garbage collected prematurely.

```
$ python weakref_valuedict.py

CACHE TYPE: <type 'dict'>
all_refs ={'one': ExpensiveObject(one),
 'three': ExpensiveObject(three),
 'two': ExpensiveObject(two)}
Before, cache contains: ['three', 'two', 'one']
  three = ExpensiveObject(three)
  two = ExpensiveObject(two)
  one = ExpensiveObject(one)
Cleanup:
After, cache contains: ['three', 'two', 'one']
  three = ExpensiveObject(three)
  two = ExpensiveObject(two)
  one = ExpensiveObject(one)
demo returning
(Deleting ExpensiveObject(three))
(Deleting ExpensiveObject(two))
```

```
(Deleting ExpensiveObject(one))

CACHE TYPE: weakref.WeakValueDictionary
all_refs ={'one': ExpensiveObject(one),
 'three': ExpensiveObject(three),
 'two': ExpensiveObject(two)}
Before, cache contains: ['three', 'two', 'one']
  three = ExpensiveObject(three)
  two = ExpensiveObject(two)
  one = ExpensiveObject(one)
Cleanup:
(Deleting ExpensiveObject(three))
(Deleting ExpensiveObject(two))
(Deleting ExpensiveObject(one))
After, cache contains: []
demo returning
```

The WeakKeyDictionary works similarly but uses weak references for the keys instead of the values in the dictionary.

The library documentation for weakref contains this warning:

Warning: Caution: Because a WeakValueDictionary is built on top of a Python dictionary, it must not change size when iterating over it. This can be difficult to ensure for a WeakValueDictionary because actions performed by the program during iteration may cause items in the dictionary to vanish "by magic" (as a side effect of garbage collection).

See also:

weakref (http://docs.python.org/lib/module-weakref.html) Standard library documentation for this module.

gc The gc module is the interface to the interpreter's garbage collector.

7.10 copy – Duplicate objects

Purpose Provides functions for duplicating objects using shallow or deep copy semantics.

Available In 1.4

The copy module includes 2 functions, copy() and deepcopy(), for duplicating existing objects.

7.10.1 Shallow Copies

The shallow copy created by copy() is a new container populated with references to the contents of the original object. For example, a new list is constructed and the elements of the original list are appended to it.

```python
import copy

class MyClass:
    def __init__(self, name):
        self.name = name
    def __cmp__(self, other):
        return cmp(self.name, other.name)

a = MyClass('a')
l = [ a ]
dup = copy.copy(l)
```

```
print 'l  :', l
print 'dup:', dup
print 'dup is l:', (dup is l)
print 'dup == l:', (dup == l)
print 'dup[0] is l[0]:', (dup[0] is l[0])
print 'dup[0] == l[0]:', (dup[0] == l[0])
```

For a shallow copy, the MyClass instance is not duplicated so the reference in the dup list is to the same object that is in the l list.

```
$ python copy_shallow.py

l  : [<__main__.MyClass instance at 0x100467d88>]
dup: [<__main__.MyClass instance at 0x100467d88>]
dup is l: False
dup == l: True
dup[0] is l[0]: True
dup[0] == l[0]: True
```

7.10.2 Deep Copies

The deep copy created by deepcopy() is a new container populated with copies of the contents of the original object. For example, a new list is constructed and the elements of the original list are copied, then the copies are appended to the new list.

By replacing the call to copy() with deepcopy(), the difference becomes apparent.

```
dup = copy.deepcopy(l)
```

Notice that the first element of the list is no longer the same object reference, but the two objects still evaluate as being equal.

```
$ python copy_deep.py

l  : [<__main__.MyClass instance at 0x100467d88>]
dup: [<__main__.MyClass instance at 0x100467dd0>]
dup is l: False
dup == l: True
dup[0] is l[0]: False
dup[0] == l[0]: True
```

7.10.3 Controlling Copy Behavior

It is possible to control how copies are made using the __copy__ and __deepcopy__ hooks.

- __copy__() is called without any arguments and should return a shallow copy of the object.
- __deepcopy__() is called with a memo dictionary, and should return a deep copy of the object. Any member attributes that need to be deep-copied should be passed to copy.deepcopy(), along with the memo dictionary, to control for recursion (see below).

This example illustrates how the methods are called:

```
import copy

class MyClass:
    def __init__(self, name):
        self.name = name
    def __cmp__(self, other):
        return cmp(self.name, other.name)
    def __copy__(self):
        print '__copy__()'
        return MyClass(self.name)
    def __deepcopy__(self, memo):
        print '__deepcopy__(%s)' % str(memo)
        return MyClass(copy.deepcopy(self.name, memo))

a = MyClass('a')

sc = copy.copy(a)
dc = copy.deepcopy(a)
```

```
$ python copy_hooks.py

__copy__()
__deepcopy__({})
```

7.10.4 Recursion in Deep Copy

To avoid problems with duplicating recursive data structures, `deepcopy()` uses a dictionary to track objects that have already been copied. This dictionary is passed to the `__deepcopy__()` method so it can be used there as well.

This example shows how an interconnected data structure such as a Digraph might assist with protecting against recursion by implementing a `__deepcopy__()` method. This particular example is just for illustration purposes, since the default implementation of `deepcopy()` already handles the recursion cases correctly.

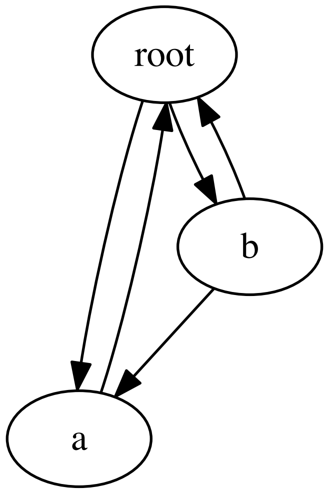
```
import copy
import pprint

class Graph:
    def __init__(self, name, connections):
        self.name = name
        self.connections = connections
    def addConnection(self, other):
        self.connections.append(other)
    def __repr__(self):
        return '<Graph(%s) id=%s>' % (self.name, id(self))
    def __deepcopy__(self, memo):
        print
        print repr(self)
        not_there = []
        existing = memo.get(self, not_there)
        if existing is not not_there:
            print '  ALREADY COPIED TO', repr(existing)
            return existing
        pprint.pprint(memo, indent=4, width=40)
        dup = Graph(copy.deepcopy(self.name, memo), [])
        print '  COPYING TO', repr(dup)
        memo[self] = dup
        for c in self.connections:
            dup.addConnection(copy.deepcopy(c, memo))
        return dup
```

```
root = Graph('root', [])
a = Graph('a', [root])
b = Graph('b', [a, root])
root.addConnection(a)
root.addConnection(b)

dup = copy.deepcopy(root)
```

First, some basic directed graph methods: A graph can be initialized with a name and a list of existing nodes to which it is connected. The addConnection() method is used to set up bi-directional connections. It is also used by the deepcopy operator.

The `__deepcopy__()` method prints messages to show how it is called, and manages the memo dictionary contents as needed. Instead of copying the connection list wholesale, it creates a new list and appends copies of the individual connections to it. That ensures that the memo dictionary is updated as each new node is duplicated, and avoids recursion issues or extra copies of nodes. As before, it returns the copied object when it is done.

Next we can set up a graph with a nodes *root*, *a*, and *b*. The graph looks like:



There are several cycles in the graph, but by handling the recursion with the memo dictionary we can avoid having the traversal cause a stack overflow error. When the *root* node is copied, we see:

```
$ python copy_recursion.py


<Graph(root) id=4299639696>
{   }
  COPYING TO <Graph(root) id=4299640056>

<Graph(a) id=4299639768>
{   <Graph(root) id=4299639696>: <Graph(root) id=4299640056>,
    4298517936: ['root'],
    4299576592: 'root'}
  COPYING TO <Graph(a) id=4299640128>
```

```
<Graph(root) id=4299639696>
  ALREADY COPIED TO <Graph(root) id=4299640056>

<Graph(b) id=4299639840>
{   <Graph(root) id=4299639696>: <Graph(root) id=4299640056>,
    <Graph(a) id=4299639768>: <Graph(a) id=4299640128>,
    4297844216: 'a',
    4298517936: [   'root',
                    'a',
                    <Graph(root) id=4299639696>,
                    <Graph(a) id=4299639768>],
    4299576592: 'root',
    4299639696: <Graph(root) id=4299640056>,
    4299639768: <Graph(a) id=4299640128>}
  COPYING TO <Graph(b) id=4299640632>
```

The second time the *root* node is encountered, while the *a* node is being copied, `__deepcopy__` detects the recursion and re-uses the existing value from the memo dictionary instead of creating a new object.

See also:

copy (http://docs.python.org/library/copy.html) The standard library documentation for this module.

7.11 pprint – Pretty-print data structures

Purpose Pretty-print data structures

Available In 1.4

`pprint` contains a "pretty printer" for producing aesthetically pleasing representations of your data structures. The formatter produces representations of data structures that can be parsed correctly by the interpreter, and are also easy for a human to read. The output is kept on a single line, if possible, and indented when split across multiple lines.

The examples below all depend on `pprint_data.py`, which contains:

```
data = [ (i, { 'a':'A',
               'b':'B',
               'c':'C',
               'd':'D',
               'e':'E',
               'f':'F',
               'g':'G',
               'h':'H',
               })
         for i in xrange(3)
         ]
```

7.11.1 Printing

The simplest way to use the module is through the `pprint()` function. It formats your object and writes it to the data stream passed as argument (or *sys.stdout* by default).

```
from pprint import pprint

from pprint_data import data
```

```
print 'PRINT:'
print data
print
print 'PPRINT:'
pprint(data)
```

```
$ python pprint_pprint.py

PRINT:
[(0, {'a': 'A', 'c': 'C', 'b': 'B', 'e': 'E', 'd': 'D', 'g': 'G', 'f': 'F', 'h': 'H'}), (1, {'a': 'A'

PPRINT:
[(0,
  {'a': 'A',
   'b': 'B',
   'c': 'C',
   'd': 'D',
   'e': 'E',
   'f': 'F',
   'g': 'G',
   'h': 'H'}),
 (1,
  {'a': 'A',
   'b': 'B',
   'c': 'C',
   'd': 'D',
   'e': 'E',
   'f': 'F',
   'g': 'G',
   'h': 'H'}),
 (2,
  {'a': 'A',
   'b': 'B',
   'c': 'C',
   'd': 'D',
   'e': 'E',
   'f': 'F',
   'g': 'G',
   'h': 'H'})]
```

7.11.2 Formatting

If you need to format a data structure, but do not want to write it directly to a stream (for logging purposes, for example) you can use `pformat()` to build a string representation that can then be passed to another function.

```
import logging
from pprint import pformat
from pprint_data import data

logging.basicConfig(level=logging.DEBUG,
                    format='%(levelname)-8s %(message)s',
                    )

logging.debug('Logging pformatted data')
logging.debug(pformat(data))
```

```
$ python pprint_pformat.py

DEBUG    Logging pformatted data
DEBUG    [(0,
  {'a': 'A',
   'b': 'B',
   'c': 'C',
   'd': 'D',
   'e': 'E',
   'f': 'F',
   'g': 'G',
   'h': 'H'}),
 (1,
  {'a': 'A',
   'b': 'B',
   'c': 'C',
   'd': 'D',
   'e': 'E',
   'f': 'F',
   'g': 'G',
   'h': 'H'}),
 (2,
  {'a': 'A',
   'b': 'B',
   'c': 'C',
   'd': 'D',
   'e': 'E',
   'f': 'F',
   'g': 'G',
   'h': 'H'})]
```

7.11.3 Arbitrary Classes

The `PrettyPrinter` class used by `pprint()` can also work with your own classes, if they define a `__repr__()` method.

```
from pprint import pprint

class node(object):
    def __init__(self, name, contents=[]):
        self.name = name
        self.contents = contents[:]
    def __repr__(self):
        return 'node(' + repr(self.name) + ', ' + repr(self.contents) + ')'

trees = [ node('node-1'),
          node('node-2', [ node('node-2-1')]),
          node('node-3', [ node('node-3-1')]),
          ]
pprint(trees)
```

```
$ python pprint_arbitrary_object.py

[node('node-1', []),
 node('node-2', [node('node-2-1', [])]),
 node('node-3', [node('node-3-1', [])])]
```

7.11.4 Recursion

Recursive data structures are represented with a reference to the original source of the data, with the form `<Recursion on typename with id=number>`. For example:

```
from pprint import pprint

local_data = [ 'a', 'b', 1, 2 ]
local_data.append(local_data)

print 'id(local_data) =>', id(local_data)
pprint(local_data)
```

```
$ python pprint_recursion.py

id(local_data) => 4299545560
['a', 'b', 1, 2, <Recursion on list with id=4299545560>]
```

7.11.5 Limiting Nested Output

For very deep data structures, you may not want the output to include all of the details. It might be impossible to format the data properly, the formatted text might be too large to manage, or you may need all of it. In that case, the depth argument can control how far down into the nested data structure the pretty printer goes.

```
from pprint import pprint

from pprint_data import data

pprint(data, depth=1)
```

```
$ python pprint_depth.py

[(...), (...), (...)]
```

7.11.6 Controlling Output Width

The default output width for the formatted text is 80 columns. To adjust that width, use the width argument to `pprint()`.

```
from pprint import pprint

from pprint_data import data

for d in data:
    for c in 'defgh':
        del d[1][c]

for width in [ 80, 20, 5 ]:
    print 'WIDTH =', width
    pprint(data, width=width)
    print
```

Notice that when the width is too low to accommodate the formatted data structure, the lines are not truncated or wrapped if that would introduce invalid syntax.

```
$ python pprint_width.py

WIDTH = 80
[(0, {'a': 'A', 'b': 'B', 'c': 'C'}),
 (1, {'a': 'A', 'b': 'B', 'c': 'C'}),
 (2, {'a': 'A', 'b': 'B', 'c': 'C'})]

WIDTH = 20
[(0,
  {'a': 'A',
   'b': 'B',
   'c': 'C'}),
 (1,
  {'a': 'A',
   'b': 'B',
   'c': 'C'}),
 (2,
  {'a': 'A',
   'b': 'B',
   'c': 'C'})]

WIDTH = 5
[(0,
  {'a': 'A',
   'b': 'B',
   'c': 'C'}),
 (1,
  {'a': 'A',
   'b': 'B',
   'c': 'C'}),
 (2,
  {'a': 'A',
   'b': 'B',
   'c': 'C'})]
```

See also:

pprint **(http://docs.python.org/lib/module-pprint.html)** Standard library documentation for this module.

CHAPTER

EIGHT

NUMERIC AND MATHEMATICAL MODULES

8.1 decimal – Fixed and floating point math

Purpose Decimal arithmetic using fixed and floating point numbers

Available In 2.4 and later

The decimal module implements fixed and floating point arithmetic using the model familiar to most people, rather than the IEEE floating point version implemented by most computer hardware. A Decimal instance can represent any number exactly, round up or down, and apply a limit to the number of significant digits.

8.1.1 Decimal

Decimal values are represented as instances of the Decimal class. The constructor takes as argument an integer, or a string. Floating point numbers must be converted to a string before being used to create a Decimal, letting the caller explicitly deal with the number of digits for values that cannot be expressed exactly using hardware floating point representations.

```
import decimal

fmt = '{0:<20} {1:<20}'
print fmt.format('Input', 'Output')
print fmt.format('-' * 20, '-' * 20)

# Integer
print fmt.format(5, decimal.Decimal(5))

# String
print fmt.format('3.14', decimal.Decimal('3.14'))

# Float
print fmt.format(repr(0.1), decimal.Decimal(str(0.1)))
```

Notice that the floating point value of 0.1 is not represented as an exact value, so the representation as a float is different from the Decimal value.

```
$ python decimal_create.py

Input                Output
-------------------- --------------------
5                    5
3.14                 3.14
0.1                  0.1
```

Less conveniently, Decimals can also be created from tuples containing a sign flag (`0` for positive, `1` for negative), a tuple of digits, and an integer exponent.

```
import decimal

# Tuple
t = (1, (1, 1), -2)
print 'Input  :', t
print 'Decimal:', decimal.Decimal(t)
```

```
$ python decimal_tuple.py

Input  : (1, (1, 1), -2)
Decimal: -0.11
```

8.1.2 Arithmetic

Decimal overloads the simple arithmetic operators so once you have a value you can manipulate it in much the same way as the built-in numeric types.

```
import decimal

a = decimal.Decimal('5.1')
b = decimal.Decimal('3.14')
c = 4
d = 3.14

print 'a     =', a
print 'b     =', b
print 'c     =', c
print 'd     =', d
print

print 'a + b =', a + b
print 'a - b =', a - b
print 'a * b =', a * b
print 'a / b =', a / b
print

print 'a + c =', a + c
print 'a - c =', a - c
print 'a * c =', a * c
print 'a / c =', a / c
print

print 'a + d =',
try:
    print a + d
except TypeError, e:
    print e
```

Decimal operators also accept integer arguments, but floating point values must be converted to Decimal instances.

```
$ python decimal_operators.py

a     = 5.1
b     = 3.14
c     = 4
```

```
d     = 3.14

a + b = 8.24
a - b = 1.96
a * b = 16.014
a / b = 1.624203821656050955414012739

a + c = 9.1
a - c = 1.1
a * c = 20.4
a / c = 1.275

a + d = unsupported operand type(s) for +: 'Decimal' and 'float'
```

8.1.3 Logarithms

Beyond basic arithmetic, Decimal includes methods to find the base 10 and natural logarithms.

```
import decimal

d = decimal.Decimal(100)
print 'd     :', d
print 'log10 :', d.log10()
print 'ln    :', d.ln()
```

```
$ python decimal_log.py

d     : 100
log10 : 2
ln    : 4.605170185988091368035982909
```

8.1.4 Special Values

In addition to the expected numerical values, `Decimal` can represent several special values, including positive and negative values for infinity, "not a number", and zero.

```
import decimal

for value in [ 'Infinity', 'NaN', '0' ]:
    print decimal.Decimal(value), decimal.Decimal('-' + value)
print

# Math with infinity
print 'Infinity + 1:', (decimal.Decimal('Infinity') + 1)
print '-Infinity + 1:', (decimal.Decimal('-Infinity') + 1)

# Print comparing NaN
print decimal.Decimal('NaN') == decimal.Decimal('Infinity')
print decimal.Decimal('NaN') != decimal.Decimal(1)
```

Adding to infinite values returns another infinite value. Comparing for equality with NaN always returns False and comparing for inequality always returns true. Comparing for sort order against NaN is undefined and results in an error.

```
$ python decimal_special.py

Infinity -Infinity
NaN -NaN
0 -0

Infinity + 1: Infinity
-Infinity + 1: -Infinity
False
True
```

8.1.5 Context

So far all of the examples have used the default behaviors of the decimal module. It is possible to override settings such as the precision maintained, how rounding is performed, error handling, etc. All of these settings are maintained via a *context*. Contexts can be applied for all Decimal instances in a thread or locally within a small code region.

Current Context

To retrieve the current global context, use `getcontext()`.

```
import decimal

print decimal.getcontext()
```

```
$ python decimal_getcontext.py

Context(prec=28, rounding=ROUND_HALF_EVEN, Emin=-999999999, Emax=999999999, capitals=1, flags=[], tra
```

Precision

The *prec* attribute of the context controls the precision maintained for new values created as a result of arithmetic. Literal values are maintained as described.

```
import decimal

d = decimal.Decimal('0.123456')

for i in range(4):
    decimal.getcontext().prec = i
    print i, ':', d, d * 1
```

```
$ python decimal_precision.py

0 : 0.123456 0
1 : 0.123456 0.1
2 : 0.123456 0.12
3 : 0.123456 0.123
```

Rounding

There are several options for rounding to keep values within the desired precision.

ROUND_CEILING Always round upwards towards infinity.

ROUND_DOWN Always round toward zero.

ROUND_FLOOR Always round down towards negative infinity.

ROUND_HALF_DOWN Rounds away from zero if the last significant digit is greater than or equal to 5, otherwise toward zero.

ROUND_HALF_EVEN Like ROUND_HALF_DOWN except that if the value is 5 then the preceding digit is examined. Even values cause the result to be rounded down and odd digits cause the result to be rounded up.

ROUND_HALF_UP Like ROUND_HALF_DOWN except if the last significant digit is 5 the value is rounded away from zero.

ROUND_UP Round away from zero.

ROUND_05UP Round away from zero if the last digit is `0` or `5`, otherwise towards zero.

```
import decimal

context = decimal.getcontext()

ROUNDING_MODES = [
    'ROUND_CEILING',
    'ROUND_DOWN',
    'ROUND_FLOOR',
    'ROUND_HALF_DOWN',
    'ROUND_HALF_EVEN',
    'ROUND_HALF_UP',
    'ROUND_UP',
    'ROUND_05UP',
    ]

header_fmt = '{0:20} {1:^10} {2:^10} {3:^10}'

print 'POSITIVES:'
print

print header_fmt.format(' ', '1/8 (1)', '1/8 (2)', '1/8 (3)')
print header_fmt.format(' ', '-' * 10, '-' * 10, '-' * 10)
for rounding_mode in ROUNDING_MODES:
    print '{0:20}'.format(rounding_mode),
    for precision in [ 1, 2, 3 ]:
        context.prec = precision
        context.rounding = getattr(decimal, rounding_mode)
        value = decimal.Decimal(1) / decimal.Decimal(8)
        print '{0:<10}'.format(value),
    print

print
print 'NEGATIVES:'

print header_fmt.format(' ', '-1/8 (1)', '-1/8 (2)', '-1/8 (3)')
print header_fmt.format(' ', '-' * 10, '-' * 10, '-' * 10)
for rounding_mode in ROUNDING_MODES:
    print '{0:20}'.format(rounding_mode),
    for precision in [ 1, 2, 3 ]:
        context.prec = precision
        context.rounding = getattr(decimal, rounding_mode)
        value = decimal.Decimal(-1) / decimal.Decimal(8)
        print '{0:<10}'.format(value),
    print
```

```
$ python decimal_rounding.py

POSITIVES:

                     1/8 (1)    1/8 (2)    1/8 (3)
                    ---------- ---------- ----------
ROUND_CEILING       0.2        0.13       0.125
ROUND_DOWN          0.1        0.12       0.125
ROUND_FLOOR         0.1        0.12       0.125
ROUND_HALF_DOWN     0.1        0.12       0.125
ROUND_HALF_EVEN     0.1        0.12       0.125
ROUND_HALF_UP       0.1        0.13       0.125
ROUND_UP            0.2        0.13       0.125
ROUND_05UP          0.1        0.12       0.125

NEGATIVES:
                     -1/8 (1)   -1/8 (2)   -1/8 (3)
                    ---------- ---------- ----------
ROUND_CEILING       -0.1       -0.12      -0.125
ROUND_DOWN          -0.1       -0.12      -0.125
ROUND_FLOOR         -0.2       -0.13      -0.125
ROUND_HALF_DOWN     -0.1       -0.12      -0.125
ROUND_HALF_EVEN     -0.1       -0.12      -0.125
ROUND_HALF_UP       -0.1       -0.13      -0.125
ROUND_UP            -0.2       -0.13      -0.125
ROUND_05UP          -0.1       -0.12      -0.125
```

Local Context

Using Python 2.5 or later you can also apply the context to a subset of your code using the `with` statement and a context manager.

```
import decimal

with decimal.localcontext() as c:
    c.prec = 2
    print 'Local precision:', c.prec
    print '3.14 / 3 =', (decimal.Decimal('3.14') / 3)

print
print 'Default precision:', decimal.getcontext().prec
print '3.14 / 3 =', (decimal.Decimal('3.14') / 3)
```

```
$ python decimal_context_manager.py

Local precision: 2
3.14 / 3 = 1.0

Default precision: 28
3.14 / 3 = 1.046666666666666666666666667
```

Per-Instance Context

Contexts can be used to construct Decimal instances, applying the precision and rounding arguments to the conversion from the input type. This lets your application select the precision of constant values separately from the precision of user data.

```
import decimal

# Set up a context with limited precision
c = decimal.getcontext().copy()
c.prec = 3

# Create our constant
pi = c.create_decimal('3.1415')

# The constant value is rounded off
print 'PI:', pi

# The result of using the constant uses the global context
print 'RESULT:', decimal.Decimal('2.01') * pi
```

```
$ python decimal_instance_context.py

PI: 3.14
RESULT: 6.3114
```

Threads

The "global" context is actually thread-local, so each thread can potentially be configured using different values.

```
import decimal
import threading
from Queue import Queue

class Multiplier(threading.Thread):
    def __init__(self, a, b, prec, q):
        self.a = a
        self.b = b
        self.prec = prec
        self.q = q
        threading.Thread.__init__(self)
    def run(self):
        c = decimal.getcontext().copy()
        c.prec = self.prec
        decimal.setcontext(c)
        self.q.put( (self.prec, a * b) )
        return

a = decimal.Decimal('3.14')
b = decimal.Decimal('1.234')
q = Queue()
threads = [ Multiplier(a, b, i, q) for i in range(1, 6) ]
for t in threads:
    t.start()

for t in threads:
    t.join()
```

```
for i in range(5):
    prec, value = q.get()
    print prec, '\t', value
```

```
$ python decimal_thread_context.py

1       4
2       3.9
3       3.87
4       3.875
5       3.8748
```

See also:

decimal (http://docs.python.org/library/decimal.html) The standard library documentation for this module.

Wikipedia: Floating Point (http://en.wikipedia.org/wiki/Floating_point) Article on floating point representations and arithmetic.

8.2 fractions – Rational Numbers

Purpose Implements a class for working with rational numbers.

Available In 2.6 and later

The Fraction class implements numerical operations for rational numbers based on the API defined by `Rational` in `numbers`.

8.2.1 Creating Fraction Instances

As with `decimal`, new values can be created in several ways. One easy way is to create them from separate numerator and denominator values:

```
import fractions

for n, d in [ (1, 2), (2, 4), (3, 6) ]:
    f = fractions.Fraction(n, d)
    print '%s/%s = %s' % (n, d, f)
```

The lowest common denominator is maintained as new values are computed.

```
$ python fractions_create_integers.py

1/2 = 1/2
2/4 = 1/2
3/6 = 1/2
```

Another way to create a Fraction is using a string representation of `<numerator> / <denominator>`:

```
import fractions

for s in [ '1/2', '2/4', '3/6' ]:
    f = fractions.Fraction(s)
    print '%s = %s' % (s, f)
```

```
$ python fractions_create_strings.py

1/2 = 1/2
2/4 = 1/2
3/6 = 1/2
```

Strings can also use the more usual decimal or floating point notation of `[<digits>].[<digits>]`.

```
import fractions

for s in [ '0.5', '1.5', '2.0' ]:
    f = fractions.Fraction(s)
    print '%s = %s' % (s, f)
```

```
$ python fractions_create_strings_floats.py

0.5 = 1/2
1.5 = 3/2
2.0 = 2
```

There are class methods for creating Fraction instances directly from other representations of rational values such as float or `decimal`.

```
import fractions

for v in [ 0.1, 0.5, 1.5, 2.0 ]:
    print '%s = %s' % (v, fractions.Fraction.from_float(v))
```

Notice that for floating point values that cannot be expressed exactly the rational representation may yield unexpected results.

```
$ python fractions_from_float.py

0.1 = 3602879701896397/36028797018963968
0.5 = 1/2
1.5 = 3/2
2.0 = 2
```

Using `decimal` representations of the values gives the expected results.

```
import decimal
import fractions

for v in [ decimal.Decimal('0.1'),
           decimal.Decimal('0.5'),
           decimal.Decimal('1.5'),
           decimal.Decimal('2.0'),
           ]:
    print '%s = %s' % (v, fractions.Fraction.from_decimal(v))
```

```
$ python fractions_from_decimal.py

0.1 = 1/10
0.5 = 1/2
1.5 = 3/2
2.0 = 2
```

8.2.2 Arithmetic

Once the fractions are instantiated, they can be used in mathematical expressions as you would expect.

```
import fractions

f1 = fractions.Fraction(1, 2)
f2 = fractions.Fraction(3, 4)

print '%s + %s = %s' % (f1, f2, f1 + f2)
print '%s - %s = %s' % (f1, f2, f1 - f2)
print '%s * %s = %s' % (f1, f2, f1 * f2)
print '%s / %s = %s' % (f1, f2, f1 / f2)
```

```
$ python fractions_arithmetic.py

1/2 + 3/4 = 5/4
1/2 - 3/4 = -1/4
1/2 * 3/4 = 3/8
1/2 / 3/4 = 2/3
```

8.2.3 Approximating Values

A useful feature of Fraction is the ability to convert a floating point number to an approximate rational value by limiting the size of the denominator.

```
import fractions
import math

print 'PI       =', math.pi

f_pi = fractions.Fraction(str(math.pi))
print 'No limit =', f_pi

for i in range(1, 100, 5):
    limited = f_pi.limit_denominator(i)
    print '{0:8} = {1}'.format(i, limited)
```

```
$ python fractions_limit_denominator.py

PI       = 3.14159265359
No limit = 314159265359/100000000000
       1 = 3
       6 = 19/6
      11 = 22/7
      16 = 22/7
      21 = 22/7
      26 = 22/7
      31 = 22/7
      36 = 22/7
      41 = 22/7
      46 = 22/7
      51 = 22/7
      56 = 22/7
      61 = 179/57
      66 = 201/64
      71 = 223/71
```

```
    76 = 223/71
    81 = 245/78
    86 = 267/85
    91 = 267/85
    96 = 289/92
```

See also:

fractions **(http://docs.python.org/library/fractions.html)** The standard library documentation for this module.

`decimal` The decimal module provides an API for fixed and floating point math.

`numbers` Numeric abstract base classes.

8.3 functools – Tools for Manipulating Functions

Purpose Functions that operate on other functions.

Available In 2.5 and later

The `functools` module provides tools for working with functions and other callable objects, to adapt or extend them for new purposes without completely rewriting them.

8.3.1 Decorators

The primary tool supplied by the `functools` module is the class `partial`, which can be used to "wrap" a callable object with default arguments. The resulting object is itself callable, and can be treated as though it is the original function. It takes all of the same arguments as the original, and can be invoked with extra positional or named arguments as well.

partial

This example shows two simple `partial` objects for the function `myfunc()`. Notice that `show_details()` prints the `func`, `args`, and `keywords` attributes of the partial object.

```
import functools

def myfunc(a, b=2):
    """Docstring for myfunc()."""
    print '\tcalled myfunc with:', (a, b)
    return

def show_details(name, f, is_partial=False):
    """Show details of a callable object."""
    print '%s:' % name
    print '\tobject:', f
    if not is_partial:
        print '\t__name__:', f.__name__
    print '\t__doc__', repr(f.__doc__)
    if is_partial:
        print '\tfunc:', f.func
        print '\targs:', f.args
        print '\tkeywords:', f.keywords
    return
```

```
show_details('myfunc', myfunc)
myfunc('a', 3)
print

p1 = functools.partial(myfunc, b=4)
show_details('partial with named default', p1, True)
p1('default a')
p1('override b', b=5)
print

p2 = functools.partial(myfunc, 'default a', b=99)
show_details('partial with defaults', p2, True)
p2()
p2(b='override b')
print

print 'Insufficient arguments:'
p1()
```

At the end of the example, the first `partial` created is invoked without passing a value for *a*, causing an exception.

```
$ python functools_partial.py

myfunc:
        object: <function myfunc at 0x100468c08>
        __name__: myfunc
        __doc__ 'Docstring for myfunc().'
        called myfunc with: ('a', 3)

partial with named default:
        object: <functools.partial object at 0x10046b050>
        __doc__ 'partial(func, *args, **keywords) - new function with partial
 application\n    of the given arguments and keywords.\n'
        func: <function myfunc at 0x100468c08>
        args: ()
        keywords: {'b': 4}
        called myfunc with: ('default a', 4)
        called myfunc with: ('override b', 5)

partial with defaults:
        object: <functools.partial object at 0x10046b0a8>
        __doc__ 'partial(func, *args, **keywords) - new function with partial
 application\n    of the given arguments and keywords.\n'
        func: <function myfunc at 0x100468c08>
        args: ('default a',)
        keywords: {'b': 99}
        called myfunc with: ('default a', 99)
        called myfunc with: ('default a', 'override b')

Insufficient arguments:
Traceback (most recent call last):
  File "functools_partial.py", line 49, in <module>
    p1()
TypeError: myfunc() takes at least 1 argument (1 given)
```

update_wrapper

The partial object does not have `__name__` or `__doc__` attributes by default, and without those attributes decorated functions are more difficult to debug. Using `update_wrapper()`, copies or adds attributes from the original function to the `partial` object.

```
import functools

def myfunc(a, b=2):
    """Docstring for myfunc()."""
    print '\tcalled myfunc with:', (a, b)
    return

def show_details(name, f):
    """Show details of a callable object."""
    print '%s:' % name
    print '\tobject:', f
    print '\t__name__:',
    try:
        print f.__name__
    except AttributeError:
        print '(no __name__)'
    print '\t__doc__', repr(f.__doc__)
    print
    return

show_details('myfunc', myfunc)

p1 = functools.partial(myfunc, b=4)
show_details('raw wrapper', p1)

print 'Updating wrapper:'
print '\tassign:', functools.WRAPPER_ASSIGNMENTS
print '\tupdate:', functools.WRAPPER_UPDATES
print

functools.update_wrapper(p1, myfunc)
show_details('updated wrapper', p1)
```

The attributes added to the wrapper are defined in `functools.WRAPPER_ASSIGNMENTS`, while `functools.WRAPPER_UPDATES` lists values to be modified.

```
$ python functools_update_wrapper.py

myfunc:
        object: <function myfunc at 0x100468c80>
        __name__: myfunc
        __doc__ 'Docstring for myfunc().'

raw wrapper:
        object: <functools.partial object at 0x10046c0a8>
        __name__: (no __name__)
        __doc__ 'partial(func, *args, **keywords) - new function with partial
 application\n    of the given arguments and keywords.\n'

Updating wrapper:
        assign: ('__module__', '__name__', '__doc__')
        update: ('__dict__',)
```

```
updated wrapper:
        object: <functools.partial object at 0x10046c0a8>
        __name__: myfunc
        __doc__ 'Docstring for myfunc().'
```

Other Callables

Partials work with any callable object, not just standalone functions.

```
import functools

class MyClass(object):
    """Demonstration class for functools"""

    def meth1(self, a, b=2):
        """Docstring for meth1()."""
        print '\tcalled meth1 with:', (self, a, b)
        return

    def meth2(self, c, d=5):
        """Docstring for meth2"""
        print '\tcalled meth2 with:', (self, c, d)
        return
    wrapped_meth2 = functools.partial(meth2, 'wrapped c')
    functools.update_wrapper(wrapped_meth2, meth2)

    def __call__(self, e, f=6):
        """Docstring for MyClass.__call__"""
        print '\tcalled object with:', (self, e, f)
        return

def show_details(name, f):
    """Show details of a callable object."""
    print '%s:' % name
    print '\tobject:', f
    print '\t__name__:',
    try:
        print f.__name__
    except AttributeError:
        print '(no __name__)'
    print '\t__doc__', repr(f.__doc__)
    return

o = MyClass()

show_details('meth1 straight', o.meth1)
o.meth1('no default for a', b=3)
print

p1 = functools.partial(o.meth1, b=4)
functools.update_wrapper(p1, o.meth1)
show_details('meth1 wrapper', p1)
p1('a goes here')
print

show_details('meth2', o.meth2)
o.meth2('no default for c', d=6)
```

```
print

show_details('wrapped meth2', o.wrapped_meth2)
o.wrapped_meth2('no default for c', d=6)
print

show_details('instance', o)
o('no default for e')
print

p2 = functools.partial(o, f=7)
show_details('instance wrapper', p2)
p2('e goes here')
```

This example creates partials from an instance, and methods of an instance.

```
$ python functools_method.py

meth1 straight:
        object: <bound method MyClass.meth1 of <__main__.MyClass object at
0x10046a3d0>>
        __name__: meth1
        __doc__ 'Docstring for meth1().'
        called meth1 with: (<__main__.MyClass object at 0x10046a3d0>, 'no d
efault for a', 3)

meth1 wrapper:
        object: <functools.partial object at 0x10046c158>
        __name__: meth1
        __doc__ 'Docstring for meth1().'
        called meth1 with: (<__main__.MyClass object at 0x10046a3d0>, 'a go
es here', 4)

meth2:
        object: <bound method MyClass.meth2 of <__main__.MyClass object at
0x10046a3d0>>
        __name__: meth2
        __doc__ 'Docstring for meth2'
        called meth2 with: (<__main__.MyClass object at 0x10046a3d0>, 'no d
efault for c', 6)

wrapped meth2:
        object: <functools.partial object at 0x10046c0a8>
        __name__: meth2
        __doc__ 'Docstring for meth2'
        called meth2 with: ('wrapped c', 'no default for c', 6)

instance:
        object: <__main__.MyClass object at 0x10046a3d0>
        __name__: (no __name__)
        __doc__ 'Demonstration class for functools'
        called object with: (<__main__.MyClass object at 0x10046a3d0>, 'no
default for e', 6)

instance wrapper:
        object: <functools.partial object at 0x10046c1b0>
        __name__: (no __name__)
        __doc__ 'partial(func, *args, **keywords) - new function with parti
```

```
al application\n    of the given arguments and keywords.\n'
        called object with: (<__main__.MyClass object at 0x10046a3d0>, 'e g
oes here', 7)
```

wraps

Updating the properties of a wrapped callable is especially useful when used in a decorator, since the transformed function ends up with properties of the original, "bare", function.

```
import functools

def show_details(name, f):
    """Show details of a callable object."""
    print '%s:' % name
    print '\tobject:', f
    print '\t__name__:',
    try:
        print f.__name__
    except AttributeError:
        print '(no __name__)'
    print '\t__doc__', repr(f.__doc__)
    print
    return

def simple_decorator(f):
    @functools.wraps(f)
    def decorated(a='decorated defaults', b=1):
        print '\tdecorated:', (a, b)
        print '\t',
        f(a, b=b)
        return
    return decorated

def myfunc(a, b=2):
    print '\tmyfunc:', (a,b)
    return

show_details('myfunc', myfunc)
myfunc('unwrapped, default b')
myfunc('unwrapped, passing b', 3)
print

wrapped_myfunc = simple_decorator(myfunc)
show_details('wrapped_myfunc', wrapped_myfunc)
wrapped_myfunc()
wrapped_myfunc('args to decorated', 4)
```

functools provides a decorator, `wraps()`, which applies `update_wrapper()` to the decorated function.

```
$ python functools_wraps.py

myfunc:
        object: <function myfunc at 0x10046c050>
        __name__: myfunc
        __doc__ None

        myfunc: ('unwrapped, default b', 2)
        myfunc: ('unwrapped, passing b', 3)

wrapped_myfunc:
        object: <function myfunc at 0x10046c0c8>
        __name__: myfunc
        __doc__ None

        decorated: ('decorated defaults', 1)
                myfunc: ('decorated defaults', 1)
        decorated: ('args to decorated', 4)
                myfunc: ('args to decorated', 4)
```

8.3.2 Comparison

Under Python 2, classes can define a `__cmp__()` method that returns `-1`, `0`, or `1` based on whether the object is less than, equal to, or greater than the item being compared. Python 2.1 introduces the *rich comparison* methods API, `__lt__()`, `__le__()`, `__eq__()`, `__ne__()`, `__gt__()`, and `__ge__()`, which perform a single comparison operation and return a boolean value. Python 3 deprecated `__cmp__()` in favor of these new methods, so `functools` provides tools to make it easier to write Python 2 classes that comply with the new comparison requirements in Python 3.

Rich Comparison

The rich comparison API is designed to allow classes with complex comparisons to implement each test in the most efficient way possible. However, for classes where comparison is relatively simple, there is no point in manually creating each of the rich comparison methods. The `total_ordering()` class decorator takes a class that provides some of the methods, and adds the rest of them.

```
import functools
import inspect
from pprint import pprint

@functools.total_ordering
class MyObject(object):
    def __init__(self, val):
        self.val = val
    def __eq__(self, other):
        print '  testing __eq__(%s, %s)' % (self.val, other.val)
        return self.val == other.val
    def __gt__(self, other):
        print '  testing __gt__(%s, %s)' % (self.val, other.val)
        return self.val > other.val

print 'Methods:\n'
pprint(inspect.getmembers(MyObject, inspect.ismethod))

a = MyObject(1)
b = MyObject(2)

print '\nComparisons:'
for expr in [ 'a < b', 'a <= b', 'a == b', 'a >= b', 'a > b' ]:
    print '\n%-6s:' % expr
    result = eval(expr)
    print '  result of %s: %s' % (expr, result)
```

The class must provide an implmentation of `__eq__()` and any one of the other rich comparison methods. The decorator adds implementations of the other methods that work by using the comparisons provided.

```
$ python functools_total_ordering.py

Methods:

[('__eq__', <unbound method MyObject.__eq__>),
 ('__ge__', <unbound method MyObject.__ge__>),
 ('__gt__', <unbound method MyObject.__gt__>),
 ('__init__', <unbound method MyObject.__init__>),
 ('__le__', <unbound method MyObject.__le__>),
 ('__lt__', <unbound method MyObject.__lt__>)]

Comparisons:

a < b :
  testing __gt__(1, 2)
  testing __eq__(1, 2)
  result of a < b: True

a <= b:
  testing __gt__(1, 2)
  result of a <= b: True

a == b:
  testing __eq__(1, 2)
  result of a == b: False

a >= b:
  testing __gt__(1, 2)
  testing __eq__(1, 2)
  result of a >= b: False

a > b :
  testing __gt__(1, 2)
  result of a > b: False
```

Collation Order

Since old-style comparison functions are deprecated in Python 3, the `cmp` argument to functions like `sort()` are also no longer supported. Python 2 programs that use comparison functions can use `cmp_to_key()` to convert them to a function that returns a *collation key*, which is used to determine the position in the final sequence.

```python
import functools

class MyObject(object):
    def __init__(self, val):
        self.val = val
    def __str__(self):
        return 'MyObject(%s)' % self.val

def compare_obj(a, b):
    """Old-style comparison function.
    """
    print 'comparing %s and %s' % (a, b)
    return cmp(a.val, b.val)
```

```
# Make a key function using cmp_to_key()
get_key = functools.cmp_to_key(compare_obj)

def get_key_wrapper(o):
    """Wrapper function for get_key to allow for print statements.
    """
    new_key = get_key(o)
    print 'key_wrapper(%s) -> %s' % (o, new_key)
    return new_key

objs = [ MyObject(x) for x in xrange(5, 0, -1) ]

for o in sorted(objs, key=get_key_wrapper):
    print o
```

Note: Normally `cmp_to_key()` would be used directly, but in this example an extra wrapper function is introduced to print out more information as the key function is being called.

The output shows that `sorted()` starts by calling `get_key_wrapper()` for each item in the sequence to produce a key. The keys returned by `cmp_to_key()` are instances of a class defined in `functools` that implements the rich comparison API based on the return value of the provided old-style comparison function. After all of the keys are created, the sequence is sorted by comparing the keys.

```
$ python functools_cmp_to_key.py

key_wrapper(MyObject(5)) -> <functools.K object at 0x100466558>
key_wrapper(MyObject(4)) -> <functools.K object at 0x100466590>
key_wrapper(MyObject(3)) -> <functools.K object at 0x1004665c8>
key_wrapper(MyObject(2)) -> <functools.K object at 0x100466600>
key_wrapper(MyObject(1)) -> <functools.K object at 0x100466638>
comparing MyObject(4) and MyObject(5)
comparing MyObject(3) and MyObject(4)
comparing MyObject(2) and MyObject(3)
comparing MyObject(1) and MyObject(2)
MyObject(1)
MyObject(2)
MyObject(3)
MyObject(4)
MyObject(5)
```

See also:

functools **(http://docs.python.org/library/functools.html)** The standard library documentation for this module.

Rich comparison methods **(http://docs.python.org/reference/datamodel.html#object.__lt__)** Description of the rich comparison methods from the Python Reference Guide.

8.4 itertools – Iterator functions for efficient looping

Purpose The itertools module includes a set of functions for working with iterable (sequence-like) data sets.

Available In 2.3

The functions provided are inspired by similar features of the "lazy functional programming language" Haskell and

SML. They are intended to be fast and use memory efficiently, but also to be hooked together to express more complicated iteration-based algorithms.

Iterator-based code may be preferred over code which uses lists for several reasons. Since data is not produced from the iterator until it is needed, all of the data is not stored in memory at the same time. Reducing memory usage can reduce swapping and other side-effects of large data sets, increasing performance.

8.4.1 Merging and Splitting Iterators

The `chain()` function takes several iterators as arguments and returns a single iterator that produces the contents of all of them as though they came from a single sequence.

```
from itertools import *

for i in chain([1, 2, 3], ['a', 'b', 'c']):
    print i
```

```
$ python itertools_chain.py

1
2
3
a
b
c
```

`izip()` returns an iterator that combines the elements of several iterators into tuples. It works like the built-in function `zip()`, except that it returns an iterator instead of a list.

```
from itertools import *

for i in izip([1, 2, 3], ['a', 'b', 'c']):
    print i
```

```
$ python itertools_izip.py

(1, 'a')
(2, 'b')
(3, 'c')
```

The `islice()` function returns an iterator which returns selected items from the input iterator, by index. It takes the same arguments as the slice operator for lists: start, stop, and step. The start and step arguments are optional.

```
from itertools import *

print 'Stop at 5:'
for i in islice(count(), 5):
    print i

print 'Start at 5, Stop at 10:'
for i in islice(count(), 5, 10):
    print i

print 'By tens to 100:'
for i in islice(count(), 0, 100, 10):
    print i
```

```
$ python itertools_islice.py

Stop at 5:
0
1
2
3
4
Start at 5, Stop at 10:
5
6
7
8
9
By tens to 100:
0
10
20
30
40
50
60
70
80
90
```

The `tee()` function returns several independent iterators (defaults to 2) based on a single original input. It has semantics similar to the Unix tee (http://unixhelp.ed.ac.uk/CGI/man-cgi?tee) utility, which repeats the values it reads from its input and writes them to a named file and standard output.

```
from itertools import *

r = islice(count(), 5)
i1, i2 = tee(r)

for i in i1:
    print 'i1:', i
for i in i2:
    print 'i2:', i
```

```
$ python itertools_tee.py

i1: 0
i1: 1
i1: 2
i1: 3
i1: 4
i2: 0
i2: 1
i2: 2
i2: 3
i2: 4
```

Since the new iterators created by `tee()` share the input, you should not use the original iterator any more. If you do consume values from the original input, the new iterators will not produce those values:

```
from itertools import *

r = islice(count(), 5)
```

```
i1, i2 = tee(r)

for i in r:
    print 'r:', i
    if i > 1:
        break

for i in i1:
    print 'i1:', i
for i in i2:
    print 'i2:', i
```

```
$ python itertools_tee_error.py

r: 0
r: 1
r: 2
i1: 3
i1: 4
i2: 3
i2: 4
```

8.4.2 Converting Inputs

The `imap()` function returns an iterator that calls a function on the values in the input iterators, and returns the results. It works like the built-in `map()`, except that it stops when any input iterator is exhausted (instead of inserting `None` values to completely consume all of the inputs).

In the first example, the lambda function multiplies the input values by 2. In a second example, the lambda function multiplies 2 arguments, taken from separate iterators, and returns a tuple with the original arguments and the computed value.

```
from itertools import *

print 'Doubles:'
for i in imap(lambda x:2*x, xrange(5)):
    print i

print 'Multiples:'
for i in imap(lambda x,y:(x, y, x*y), xrange(5), xrange(5,10)):
    print '%d * %d = %d' % i
```

```
$ python itertools_imap.py

Doubles:
0
2
4
6
8
Multiples:
0 * 5 = 0
1 * 6 = 6
2 * 7 = 14
3 * 8 = 24
4 * 9 = 36
```

The `starmap()` function is similar to `imap()`, but instead of constructing a tuple from multiple iterators it splits up the items in a single iterator as arguments to the mapping function using the `*` syntax. Where the mapping function to imap() is called f(i1, i2), the mapping function to starmap() is called `f(*i)`.

```
from itertools import *

values = [(0, 5), (1, 6), (2, 7), (3, 8), (4, 9)]
for i in starmap(lambda x,y:(x, y, x*y), values):
    print '%d * %d = %d' % i
```

```
$ python itertools_starmap.py

0 * 5 = 0
1 * 6 = 6
2 * 7 = 14
3 * 8 = 24
4 * 9 = 36
```

8.4.3 Producing New Values

The `count()` function returns an interator that produces consecutive integers, indefinitely. The first number can be passed as an argument, the default is zero. There is no upper bound argument (see the built-in `xrange()` for more control over the result set). In this example, the iteration stops because the list argument is consumed.

```
from itertools import *

for i in izip(count(1), ['a', 'b', 'c']):
    print i
```

```
$ python itertools_count.py

(1, 'a')
(2, 'b')
(3, 'c')
```

The `cycle()` function returns an iterator that repeats the contents of the arguments it is given indefinitely. Since it has to remember the entire contents of the input iterator, it may consume quite a bit of memory if the iterator is long. In this example, a counter variable is used to break out of the loop after a few cycles.

```
from itertools import *

i = 0
for item in cycle(['a', 'b', 'c']):
    i += 1
    if i == 10:
        break
    print (i, item)
```

```
$ python itertools_cycle.py

(1, 'a')
(2, 'b')
(3, 'c')
(4, 'a')
(5, 'b')
(6, 'c')
(7, 'a')
```

```
(8, 'b')
(9, 'c')
```

The `repeat()` function returns an iterator that produces the same value each time it is accessed. It keeps going forever, unless the optional times argument is provided to limit it.

```
from itertools import *

for i in repeat('over-and-over', 5):
    print i
```

```
$ python itertools_repeat.py

over-and-over
over-and-over
over-and-over
over-and-over
over-and-over
```

It is useful to combine `repeat()` with `izip()` or `imap()` when invariant values need to be included with the values from the other iterators.

```
from itertools import *

for i, s in izip(count(), repeat('over-and-over', 5)):
    print i, s
```

```
$ python itertools_repeat_izip.py

0 over-and-over
1 over-and-over
2 over-and-over
3 over-and-over
4 over-and-over
```

```
from itertools import *

for i in imap(lambda x,y:(x, y, x*y), repeat(2), xrange(5)):
    print '%d * %d = %d' % i
```

```
$ python itertools_repeat_imap.py

2 * 0 = 0
2 * 1 = 2
2 * 2 = 4
2 * 3 = 6
2 * 4 = 8
```

8.4.4 Filtering

The `dropwhile()` function returns an iterator that returns elements of the input iterator after a condition becomes false for the first time. It does not filter every item of the input; after the condition is false the first time, all of the remaining items in the input are returned.

```
from itertools import *

def should_drop(x):
    print 'Testing:', x
    return (x<1)

for i in dropwhile(should_drop, [ -1, 0, 1, 2, 3, 4, 1, -2 ]):
    print 'Yielding:', i
```

```
$ python itertools_dropwhile.py

Testing: -1
Testing: 0
Testing: 1
Yielding: 1
Yielding: 2
Yielding: 3
Yielding: 4
Yielding: 1
Yielding: -2
```

The opposite of `dropwhile()`, `takewhile()` returns an iterator that returns items from the input iterator as long as the test function returns true.

```
from itertools import *

def should_take(x):
    print 'Testing:', x
    return (x<2)

for i in takewhile(should_take, [ -1, 0, 1, 2, 3, 4, 1, -2 ]):
    print 'Yielding:', i
```

```
$ python itertools_takewhile.py

Testing: -1
Yielding: -1
Testing: 0
Yielding: 0
Testing: 1
Yielding: 1
Testing: 2
```

`ifilter()` returns an iterator that works like the built-in `filter()` does for lists, including only items for which the test function returns true. It is different from `dropwhile()` in that every item is tested before it is returned.

```
from itertools import *

def check_item(x):
    print 'Testing:', x
    return (x<1)

for i in ifilter(check_item, [ -1, 0, 1, 2, 3, 4, 1, -2 ]):
    print 'Yielding:', i
```

```
$ python itertools_ifilter.py

Testing: -1
Yielding: -1
Testing: 0
Yielding: 0
```

```
Testing: 1
Testing: 2
Testing: 3
Testing: 4
Testing: 1
Testing: -2
Yielding: -2
```

The opposite of `ifilter()`, `ifilterfalse()` returns an iterator that includes only items where the test function returns false.

```
from itertools import *

def check_item(x):
    print 'Testing:', x
    return (x<1)

for i in ifilterfalse(check_item, [ -1, 0, 1, 2, 3, 4, 1, -2 ]):
    print 'Yielding:', i
```

```
$ python itertools_ifilterfalse.py

Testing: -1
Testing: 0
Testing: 1
Yielding: 1
Testing: 2
Yielding: 2
Testing: 3
Yielding: 3
Testing: 4
Yielding: 4
Testing: 1
Yielding: 1
Testing: -2
```

8.4.5 Grouping Data

The `groupby()` function returns an iterator that produces sets of values grouped by a common key.

This example from the standard library documentation shows how to group keys in a dictionary which have the same value:

```
from itertools import *
from operator import itemgetter

d = dict(a=1, b=2, c=1, d=2, e=1, f=2, g=3)
di = sorted(d.iteritems(), key=itemgetter(1))
for k, g in groupby(di, key=itemgetter(1)):
    print k, map(itemgetter(0), g)
```

```
$ python itertools_groupby.py

1 ['a', 'c', 'e']
2 ['b', 'd', 'f']
3 ['g']
```

This more complicated example illustrates grouping related values based on some attribute. Notice that the input sequence needs to be sorted on the key in order for the groupings to work out as expected.

```
from itertools import *

class Point:
    def __init__(self, x, y):
        self.x = x
        self.y = y
    def __repr__(self):
        return 'Point(%s, %s)' % (self.x, self.y)
    def __cmp__(self, other):
        return cmp((self.x, self.y), (other.x, other.y))

# Create a dataset of Point instances
data = list(imap(Point,
                 cycle(islice(count(), 3)),
                 islice(count(), 10),
                 )
            )
print 'Data:', data
print

# Try to group the unsorted data based on X values
print 'Grouped, unsorted:'
for k, g in groupby(data, lambda o:o.x):
    print k, list(g)
print

# Sort the data
data.sort()
print 'Sorted:', data
print

# Group the sorted data based on X values
print 'Grouped, sorted:'
for k, g in groupby(data, lambda o:o.x):
    print k, list(g)
print
```

```
$ python itertools_groupby_seq.py

Data: [Point(0, 0), Point(1, 1), Point(2, 2), Point(0, 3), Point(1, 4), Point(2, 5), Point(0, 6), Po

Grouped, unsorted:
0 [Point(0, 0)]
1 [Point(1, 1)]
2 [Point(2, 2)]
0 [Point(0, 3)]
1 [Point(1, 4)]
2 [Point(2, 5)]
0 [Point(0, 6)]
1 [Point(1, 7)]
2 [Point(2, 8)]
0 [Point(0, 9)]

Sorted: [Point(0, 0), Point(0, 3), Point(0, 6), Point(0, 9), Point(1, 1), Point(1, 4), Point(1, 7), P

Grouped, sorted:
```

```
0 [Point(0, 0), Point(0, 3), Point(0, 6), Point(0, 9)]
1 [Point(1, 1), Point(1, 4), Point(1, 7)]
2 [Point(2, 2), Point(2, 5), Point(2, 8)]
```

See also:

itertools (http://docs.python.org/library/itertools.html) The standard library documentation for this module.

The Standard ML Basis Library (http://www.standardml.org/Basis/) The library for SML.

Definition of Haskell and the Standard Libraries (http://www.haskell.org/definition/) Standard library specification for the functional language Haskell.

8.5 math – Mathematical functions

Purpose Provides functions for specialized mathematical operations.

Available In 1.4

The math module implements many of the IEEE functions that would normally be found in the native platform C libraries for complex mathematical operations using floating point values, including logarithms and trigonometric operations.

8.5.1 Special Constants

Many math operations depend on special constants. math includes values for π (pi) and e.

```
import math

print 'π: %.30f' % math.pi
print 'e: %.30f' % math.e
```

Both values are limited in precision only by the platform's floating point C library.

```
$ python math_constants.py

π: 3.141592653589793115997963468544
e: 2.718281828459045090795598298428
```

8.5.2 Testing for Exceptional Values

Floating point calculations can result in two types of exceptional values. INF ("infinity") appears when the *double* used to hold a floating point value overflows from a value with a large absolute value.

```
import math

print '{:^3} {:6} {:6} {:6}'.format('e', 'x', 'x**2', 'isinf')
print '{:-^3} {:-^6} {:-^6} {:-^6}'.format('', '', '', '')

for e in range(0, 201, 20):
    x = 10.0 ** e
    y = x*x
    print '{:3d} {!s:6} {!s:6} {!s:6}'.format(e, x, y, math.isinf(y))
```

When the exponent in this example grows large enough, the square of *x* no longer fits inside a *double*, and the value is recorded as infinite.

```
$ python math_isinf.py

 e   x        x**2    isinf
---  ------   ------  ------
  0  1.0      1.0     False
 20  1e+20    1e+40   False
 40  1e+40    1e+80   False
 60  1e+60    1e+120  False
 80  1e+80    1e+160  False
100  1e+100   1e+200  False
120  1e+120   1e+240  False
140  1e+140   1e+280  False
160  1e+160   inf     True
180  1e+180   inf     True
200  1e+200   inf     True
```

Not all floating point overflows result in `INF` values, however. Calculating an exponent with floating point values, in particular, raises *OverflowError* instead of preserving the `INF` result.

```
x = 10.0 ** 200

print 'x    =', x
print 'x*x  =', x*x
try:
    print 'x**2 =', x**2
except OverflowError, err:
    print err
```

This discrepancy is caused by an implementation difference in the library used by C Python.

```
$ python math_overflow.py

x    = 1e+200
x*x  = inf
x**2 = (34, 'Result too large')
```

Division operations using infinite values are undefined. The result of dividing a number by infinity is `NaN` ("not a number").

```
import math

x = (10.0 ** 200) * (10.0 ** 200)
y = x/x

print 'x =', x
print 'isnan(x) =', math.isnan(x)
print 'y = x / x =', x/x
print 'y == nan =', y == float('nan')
print 'isnan(y) =', math.isnan(y)
```

`NaN` does not compare as equal to any value, even itself, so to check for `NaN` you must use `isnan()`.

```
$ python math_isnan.py

x = inf
isnan(x) = False
y = x / x = nan
y == nan = False
isnan(y) = True
```

8.5.3 Converting to Integers

The math module includes three functions for converting floating point values to whole numbers. Each takes a different approach, and will be useful in different circumstances.

The simplest is trunc(), which truncates the digits following the decimal, leaving only the significant digits making up the whole number portion of the value. floor() converts its input to the largest preceding integer, and ceil() (ceiling) produces the largest integer following sequentially after the input value.

```
import math

print '{:^5}  {:^5}  {:^5}  {:^5}  {:^5}'.format('i', 'int', 'trunk', 'floor', 'ceil')
print '{:-^5}  {:-^5}  {:-^5}  {:-^5}  {:-^5}'.format('', '', '', '', '')

fmt = '  '.join(['{:5.1f}'] * 5)

for i in [ -1.5, -0.8, -0.5, -0.2, 0, 0.2, 0.5, 0.8, 1 ]:
    print fmt.format(i, int(i), math.trunc(i), math.floor(i), math.ceil(i))
```

trunc() is equivalent to converting to int directly.

```
$ python math_integers.py

  i     int   trunk  floor  ceil 
-----  -----  -----  -----  -----
 -1.5   -1.0   -1.0   -2.0   -1.0
 -0.8    0.0    0.0   -1.0   -0.0
 -0.5    0.0    0.0   -1.0   -0.0
 -0.2    0.0    0.0   -1.0   -0.0
  0.0    0.0    0.0    0.0    0.0
  0.2    0.0    0.0    0.0    1.0
  0.5    0.0    0.0    0.0    1.0
  0.8    0.0    0.0    0.0    1.0
  1.0    1.0    1.0    1.0    1.0
```

8.5.4 Alternate Representations

modf() takes a single floating point number and returns a tuple containing the fractional and whole number parts of the input value.

```
import math

for i in range(6):
    print '{}/2 = {}'.format(i, math.modf(i/2.0))
```

Both numbers in the return value are floats.

```
$ python math_modf.py

0/2 = (0.0, 0.0)
1/2 = (0.5, 0.0)
2/2 = (0.0, 1.0)
3/2 = (0.5, 1.0)
4/2 = (0.0, 2.0)
5/2 = (0.5, 2.0)
```

frexp() returns the mantissa and exponent of a floating point number, and can be used to create a more portable representation of the value.

```
import math

print '{:^7}  {:^7}  {:^7}'.format('x', 'm', 'e')
print '{:-^7}  {:-^7}  {:-^7}'.format('', '', '')

for x in [ 0.1, 0.5, 4.0 ]:
    m, e = math.frexp(x)
    print '{:7.2f}  {:7.2f}  {:7d}'.format(x, m, e)
```

`frexp()` uses the formula `x = m * 2**e`, and returns the values *m* and *e*.

```
$ python math_frexp.py

   x         m         e
-------   -------   -------
   0.10      0.80       -3
   0.50      0.50        0
   4.00      0.50        3
```

`ldexp()` is the inverse of `frexp()`.

```
import math

print '{:^7}  {:^7}  {:^7}'.format('m', 'e', 'x')
print '{:-^7}  {:-^7}  {:-^7}'.format('', '', '')

for m, e in [ (0.8, -3),
              (0.5,  0),
              (0.5,  3),
              ]:
    x = math.ldexp(m, e)
    print '{:7.2f}  {:7d}  {:7.2f}'.format(m, e, x)
```

Using the same formula as `frexp()`, `ldexp()` takes the mantissa and exponent values as arguments and returns a floating point number.

```
$ python math_ldexp.py

   m         e         x
-------   -------   -------
   0.80       -3      0.10
   0.50        0      0.50
   0.50        3      4.00
```

8.5.5 Positive and Negative Signs

The absolute value of number is its value without a sign. Use `fabs()` to calculate the absolute value of a floating point number.

```
import math

print math.fabs(-1.1)
print math.fabs(-0.0)
print math.fabs(0.0)
print math.fabs(1.1)
```

In practical terms, the absolute value of a `float` is represented as a positive value.

```
$ python math_fabs.py

1.1
0.0
0.0
1.1
```

To determine the sign of a value, either to give a set of values the same sign or simply for comparison, use `copysign()` to set the sign of a known good value.

```
import math

print
print '{:^5}  {:^5}  {:^5}  {:^5}  {:^5}'.format('f', 's', '< 0', '> 0', '= 0')
print '{:-^5}  {:-^5}  {:-^5}  {:-^5}  {:-^5}'.format('', '', '', '', '')

for f in [ -1.0,
            0.0,
            1.0,
            float('-inf'),
            float('inf'),
            float('-nan'),
            float('nan'),
            ]:
    s = int(math.copysign(1, f))
    print '{:5.1f}  {:5d}  {!s:5}  {!s:5}  {!s:5}'.format(f, s, f < 0, f > 0, f==0)
```

An extra function like `copysign()` is needed because comparing NaN and -NaN directly with other values does not work.

```
$ python math_copysign.py


  f      s     < 0    > 0    = 0
-----  -----  -----  -----  -----
 -1.0     -1  True   False  False
  0.0      1  False  False  True
  1.0      1  False  True   False
 -inf     -1  True   False  False
  inf      1  False  True   False
  nan     -1  False  False  False
  nan      1  False  False  False
```

8.5.6 Commonly Used Calculations

Representing precise values in binary floating point memory is challenging. Some values cannot be represented exactly, and the more often a value is manipulated through repeated calculations, the more likely a representation error will be introduced. `math` includes a function for computing the sum of a series of floating point numbers using an efficient algorithm that minimize such errors.

```
import math

values = [ 0.1 ] * 10

print 'Input values:', values

print 'sum()       : {:.20f}'.format(sum(values))
```

```
s = 0.0
for i in values:
    s += i
print 'for-loop    : {:.20f}'.format(s)

print 'math.fsum() : {:.20f}'.format(math.fsum(values))
```

Given a sequence of ten values each equal to `0.1`, the expected value for the sum of the sequence is `1.0`. Since `0.1` cannot be represented exactly as a floating point value, however, errors are introduced into the sum unless it is calculated with `fsum()`.

```
$ python math_fsum.py

Input values: [0.1, 0.1, 0.1, 0.1, 0.1, 0.1, 0.1, 0.1, 0.1, 0.1]
sum()       : 0.99999999999999988898
for-loop    : 0.99999999999999988898
math.fsum() : 1.00000000000000000000
```

`factorial()` is commonly used to calculate the number of permutations and combinations of a series of objects. The factorial of a positive integer *n*, expressed `n!`, is defined recursively as `(n-1)! * n` and stops with `0! == 1`.

```
import math

for i in [ 0, 1.0, 2.0, 3.0, 4.0, 5.0, 6.1 ]:
    try:
        print '{:2.0f}  {:6.0f}'.format(i, math.factorial(i))
    except ValueError, err:
        print 'Error computing factorial(%s):' % i, err
```

`factorial()` only works with whole numbers, but does accept `float` arguments as long as they can be converted to an integer without losing value.

```
$ python math_factorial.py

 0       1
 1       1
 2       2
 3       6
 4      24
 5     120
Error computing factorial(6.1): factorial() only accepts integral values
```

`gamma()` is like `factorial()`, except it works with real numbers and the value is shifted down one (gamma is equal to `(n - 1)!`).

```
import math

for i in [ 0, 1.1, 2.2, 3.3, 4.4, 5.5, 6.6 ]:
    try:
        print '{:2.1f}  {:6.2f}'.format(i, math.gamma(i))
    except ValueError, err:
        print 'Error computing gamma(%s):' % i, err
```

Since zero causes the start value to be negative, it is not allowed.

```
$ python math_gamma.py

Error computing gamma(0): math domain error
```

```
1.1    0.95
2.2    1.10
3.3    2.68
4.4   10.14
5.5   52.34
6.6  344.70
```

`lgamma()` returns the natural logarithm of the absolute value of Gamma for the input value.

```
import math

for i in [ 0, 1.1, 2.2, 3.3, 4.4, 5.5, 6.6 ]:
    try:
        print '{:2.1f}  {:.20f}  {:.20f}'.format(i, math.lgamma(i), math.log(math.gamma(i)))
    except ValueError, err:
        print 'Error computing lgamma(%s):' % i, err
```

Using `lgamma()` retains more precision than calculating the logarithm separately using the results of `gamma()`.

```
$ python math_lgamma.py

Error computing lgamma(0): math domain error
1.1  -0.04987244125984036103  -0.04987244125983997245
2.2  0.09694746679063825923  0.09694746679063866168
3.3  0.98709857789473387513  0.98709857789473409717
4.4  2.31610349142485727469  2.31610349142485727469
5.5  3.95781396761871651080  3.95781396761871606671
6.6  5.84268005527463252236  5.84268005527463252236
```

The modulo operator (`%`) computes the remainder of a division expression (i.e., `5 % 2 = 1`). The operator built into the language works well with integers but, as with so many other floating point operations, intermediate calculations cause representational issues that result in a loss of data. `fmod()` provides a more accurate implementation for floating point values.

```
import math

print '{:^4}  {:^4}  {:^5}  {:^5}'.format('x', 'y', '%', 'fmod')
print '----  ----  -----  -----'

for x, y in [ (5, 2),
              (5, -2),
              (-5, 2),
              ]:
    print '{:4.1f}  {:4.1f}  {:5.2f}  {:5.2f}'.format(x, y, x % y, math.fmod(x, y))
```

A potentially more frequent source of confusion is the fact that the algorithm used by `fmod` for computing modulo is also different from that used by `%`, so the sign of the result is different. mixed-sign inputs.

```
$ python math_fmod.py

 x     y      %     fmod
----  ----  -----  -----
 5.0   2.0   1.00   1.00
 5.0  -2.0  -1.00   1.00
-5.0   2.0   1.00  -1.00
```

8.5.7 Exponents and Logarithms

Exponential growth curves appear in economics, physics, and other sciences. Python has a built-in exponentiation operator ("`**`"), but `pow()` can be useful when you need to pass a callable function as an argument.

```
import math

for x, y in [
    # Typical uses
    (2, 3),
    (2.1, 3.2),

    # Always 1
    (1.0, 5),
    (2.0, 0),

    # Not-a-number
    (2, float('nan')),

    # Roots
    (9.0, 0.5),
    (27.0, 1.0/3),
    ]:
    print '{:5.1f} ** {:5.3f} = {:6.3f}'.format(x, y, math.pow(x, y))
```

Raising `1` to any power always returns `1.0`, as does raising any value to a power of `0.0`. Most operations on the not-a-number value `nan` return `nan`. If the exponent is less than `1`, `pow()` computes a root.

```
$ python math_pow.py

  2.0 ** 3.000 =  8.000
  2.1 ** 3.200 = 10.742
  1.0 ** 5.000 =  1.000
  2.0 ** 0.000 =  1.000
  2.0 **   nan =    nan
  9.0 ** 0.500 =  3.000
 27.0 ** 0.333 =  3.000
```

Since square roots (exponent of `1/2`) are used so frequently, there is a separate function for computing them.

```
import math

print math.sqrt(9.0)
print math.sqrt(3)
try:
    print math.sqrt(-1)
except ValueError, err:
    print 'Cannot compute sqrt(-1):', err
```

Computing the square roots of negative numbers requires *complex numbers*, which are not handled by `math`. Any attempt to calculate a square root of a negative value results in a *ValueError*.

```
$ python math_sqrt.py

3.0
1.73205080757
Cannot compute sqrt(-1): math domain error
```

The logarithm function finds *y* where `x = b ** y`. By default, `log()` computes the natural logarithm (the base is *e*). If a second argument is provided, that value is used as the base.

```
import math

print math.log(8)
print math.log(8, 2)
print math.log(0.5, 2)
```

Logarithms where *x* is less than one yield negative results.

```
$ python math_log.py

2.07944154168
3.0
-1.0
```

There are two variations of `log()`. Given floating point representation and rounding errors the computed value produced by `log(x, b)` has limited accuracy, especially for some bases. `log10()` computes `log(x, 10)`, using a more accurate algorithm than `log()`.

```
import math

print '{:2}  {:^12}  {:^20}  {:^20}  {:8}'.format('i', 'x', 'accurate', 'inaccurate', 'mismatch')
print '{:-^2}  {:-^12}  {:-^20}  {:-^20}  {:-^8}'.format('', '', '', '', '')

for i in range(0, 10):
    x = math.pow(10, i)
    accurate = math.log10(x)
    inaccurate = math.log(x, 10)
    match = '' if int(inaccurate) == i else '*'
    print '{:2d}  {:12.1f}  {:20.18f}  {:20.18f}  {:^5}'.format(i, x, accurate, inaccurate, match)
```

The lines in the output with trailing `*` highlight the inaccurate values.

```
$ python math_log10.py

i        x              accurate             inaccurate       mismatch
--  ------------  --------------------  --------------------  --------
 0           1.0  0.000000000000000000  0.000000000000000000
 1          10.0  1.000000000000000000  1.000000000000000000
 2         100.0  2.000000000000000000  2.000000000000000000
 3        1000.0  3.000000000000000000  2.999999999999999556    *
 4       10000.0  4.000000000000000000  4.000000000000000000
 5      100000.0  5.000000000000000000  5.000000000000000000
 6     1000000.0  6.000000000000000000  5.999999999999999112    *
 7    10000000.0  7.000000000000000000  7.000000000000000000
 8   100000000.0  8.000000000000000000  8.000000000000000000
 9  1000000000.0  9.000000000000000000  8.999999999999998224    *
```

`log1p()` calculates the Newton-Mercator series (the natural logarithm of `1+x`).

```
import math

x = 0.0000000000000000000000001
print 'x       :', x
print '1 + x   :', 1+x
print 'log(1+x):', math.log(1+x)
print 'log1p(x):', math.log1p(x)
```

`log1p()` is more accurate for values of *x* very close to zero because it uses an algorithm that compensates for round-off errors from the initial addition.

```
$ python math_log1p.py

x       : 1e-25
1 + x   : 1.0
log(1+x): 0.0
log1p(x): 1e-25
```

`exp()` computes the exponential function (`e**x`).

```
import math

x = 2

fmt = '%.20f'
print fmt % (math.e ** 2)
print fmt % math.pow(math.e, 2)
print fmt % math.exp(2)
```

As with other special-case functions, it uses an algorithm that produces more accurate results than the general-purpose equivalent `math.pow(math.e, x)`.

```
$ python math_exp.py

7.38905609893064951876
7.38905609893064951876
7.38905609893065040694
```

`expm1()` is the inverse of `log1p()`, and calculates `e**x - 1`.

```
import math

x = 0.0000000000000000000000001

print x
print math.exp(x) - 1
print math.expm1(x)
```

As with `log1p()`, small values of *x* lose precision when the subtraction is performed separately.

```
$ python math_expm1.py

1e-25
0.0
1e-25
```

8.5.8 Angles

Although degrees are more commonly used in everyday discussions of angles, radians are the standard unit of angular measure in science and math. A radian is the angle created by two lines intersecting at the center of a circle, with their ends on the circumference of the circle spaced one radius apart.

The circumference is calculated as $2\pi r$, so there is a relationship between radians and π, a value that shows up frequently in trigonometric calculations. That relationship leads to radians being used in trigonometry and calculus, because they result in more compact formulas.

To convert from degrees to radians, use `radians()`.

```
import math

print '{:^7}  {:^7}  {:^7}'.format('Degrees', 'Radians', 'Expected')
print '{:-^7}  {:-^7}  {:-^7}'.format('', '', '')

for deg, expected in [ (  0,  0),
                       ( 30,  math.pi/6),
                       ( 45,  math.pi/4),
                       ( 60,  math.pi/3),
                       ( 90,  math.pi/2),
                       (180,  math.pi),
                       (270,  3/2.0 * math.pi),
                       (360,  2 * math.pi),
                       ]:
    print '{:7d}  {:7.2f}  {:7.2f}'.format(deg, math.radians(deg), expected)
```

The formula for the conversion is `rad = deg * π / 180`.

```
$ python math_radians.py

Degrees  Radians  Expected
-------  -------  -------
      0     0.00     0.00
     30     0.52     0.52
     45     0.79     0.79
     60     1.05     1.05
     90     1.57     1.57
    180     3.14     3.14
    270     4.71     4.71
    360     6.28     6.28
```

To convert from radians to degrees, use `degrees()`.

```
import math

print '{:^8}  {:^8}  {:^8}'.format('Radians', 'Degrees', 'Expected')
print '{:-^8}  {:-^8}  {:-^8}'.format('', '', '')
for rad, expected in [ (0,                  0),
                       (math.pi/6,         30),
                       (math.pi/4,         45),
                       (math.pi/3,         60),
                       (math.pi/2,         90),
                       (math.pi,          180),
                       (3 * math.pi / 2,  270),
                       (2 * math.pi,      360),
                       ]:
    print '{:8.2f}  {:8.2f}  {:8.2f}'.format(rad, math.degrees(rad), expected)
```

The formula is `deg = rad * 180 / π`.

```
$ python math_degrees.py

Radians   Degrees   Expected
--------  --------  --------
    0.00      0.00      0.00
    0.52     30.00     30.00
    0.79     45.00     45.00
    1.05     60.00     60.00
    1.57     90.00     90.00
    3.14    180.00    180.00
    4.71    270.00    270.00
    6.28    360.00    360.00
```

8.5.9 Trigonometry

Trigonometric functions relate angles in a triangle to the lengths of its sides. They show up in formulas with periodic properties such as harmonics, circular motion, or when dealing with angles.

Note: All of the trigonometric functions in the standard library take angles expressed as radians.

Given an angle in a right triangle, the *sine* is the ratio of the length of the side opposite the angle to the hypotenuse (`sin A = opposite/hypotenuse`). The *cosine* is the ratio of the length of the adjacent side to the hypotenuse (`cos A = adjacent/hypotenuse`). And the *tangent* is the ratio of the opposite side to the adjacent side (`tan A = opposite/adjacent`).

```
import math

print 'Degrees  Radians  Sine     Cosine    Tangent'
print '-------  -------  -------  --------  -------'

fmt = '  '.join(['%7.2f'] * 5)

for deg in range(0, 361, 30):
    rad = math.radians(deg)
    if deg in (90, 270):
        t = float('inf')
    else:
        t = math.tan(rad)
    print fmt % (deg, rad, math.sin(rad), math.cos(rad), t)
```

The tangent can also be defined as the ratio of the sine of the angle to its cosine, and since the cosine is 0 for $\pi/2$ and $3\pi/2$ radians, the tangent is infinite.

```
$ python math_trig.py

Degrees  Radians  Sine     Cosine    Tangent
-------  -------  -------  --------  -------
   0.00     0.00     0.00     1.00     0.00
  30.00     0.52     0.50     0.87     0.58
  60.00     1.05     0.87     0.50     1.73
  90.00     1.57     1.00     0.00      inf
 120.00     2.09     0.87    -0.50    -1.73
 150.00     2.62     0.50    -0.87    -0.58
 180.00     3.14     0.00    -1.00    -0.00
 210.00     3.67    -0.50    -0.87     0.58
 240.00     4.19    -0.87    -0.50     1.73
 270.00     4.71    -1.00    -0.00      inf
 300.00     5.24    -0.87     0.50    -1.73
 330.00     5.76    -0.50     0.87    -0.58
 360.00     6.28    -0.00     1.00    -0.00
```

Given a point (x, y), the length of the hypotenuse for the triangle between the points [(0, 0), (x, 0), (x, y)] is `(x**2 + y**2) ** 1/2`, and can be computed with `hypot()`.

```
import math

print '{:^7}  {:^7}  {:^10}'.format('X', 'Y', 'Hypotenuse')
print '{:-^7}  {:-^7}  {:-^10}'.format('', '', '')

for x, y in [ # simple points
              (1, 1),
              (-1, -1),
              (math.sqrt(2), math.sqrt(2)),
              (3, 4), # 3-4-5 triangle
              # on the circle
              (math.sqrt(2)/2, math.sqrt(2)/2), # pi/4 rads
              (0.5, math.sqrt(3)/2), # pi/3 rads
              ]:
    h = math.hypot(x, y)
    print '{:7.2f}  {:7.2f}  {:7.2f}'.format(x, y, h)
```

Points on the circle always have hypotenuse == `1`.

```
$ python math_hypot.py

   X        Y     Hypotenuse
-------  -------  ----------
   1.00     1.00     1.41
  -1.00    -1.00     1.41
   1.41     1.41     2.00
   3.00     4.00     5.00
   0.71     0.71     1.00
   0.50     0.87     1.00
```

The same function can be used to find the distance between two points.

```
import math

print '{:^8}  {:^8}  {:^8}  {:^8}  {:^8}'.format('X1', 'Y1', 'X2', 'Y2', 'Distance')
print '{:-^8}  {:-^8}  {:-^8}  {:-^8}  {:-^8}'.format('', '', '', '', '')


for (x1, y1), (x2, y2) in [ ((5, 5), (6, 6)),
                            ((-6, -6), (-5, -5)),
                            ((0, 0), (3, 4)), # 3-4-5 triangle
                            ((-1, -1), (2, 3)), # 3-4-5 triangle
                            ]:
    x = x1 - x2
    y = y1 - y2
    h = math.hypot(x, y)
    print '{:8.2f}  {:8.2f}  {:8.2f}  {:8.2f}  {:8.2f}'.format(x1, y1, x2, y2, h)
```

Use the difference in the *x* and *y* values to move one endpoint to the origin, and then pass the results to `hypot()`.

```
$ python math_distance_2_points.py

   X1        Y1        X2        Y2     Distance
--------  --------  --------  --------  --------
    5.00      5.00      6.00      6.00      1.41
   -6.00     -6.00     -5.00     -5.00      1.41
    0.00      0.00      3.00      4.00      5.00
   -1.00     -1.00      2.00      3.00      5.00
```

`math` also defines inverse trigonometric functions.

```
import math

for r in [ 0, 0.5, 1 ]:
    print 'arcsine(%.1f)    = %5.2f' % (r, math.asin(r))
    print 'arccosine(%.1f)  = %5.2f' % (r, math.acos(r))
    print 'arctangent(%.1f) = %5.2f' % (r, math.atan(r))
    print
```

`1.57` is roughly equal to $\pi/2$, or 90 degrees, the angle at which the sine is 1 and the cosine is 0.

```
$ python math_inverse_trig.py

arcsine(0.0)    =  0.00
arccosine(0.0)  =  1.57
arctangent(0.0) =  0.00

arcsine(0.5)    =  0.52
arccosine(0.5)  =  1.05
arctangent(0.5) =  0.46

arcsine(1.0)    =  1.57
arccosine(1.0)  =  0.00
arctangent(1.0) =  0.79
```

8.5.10 Hyperbolic Functions

Hyperbolic functions appear in linear differential equations and are used when working with electromagnetic fields, fluid dynamics, special relativity, and other advanced physics and mathematics.

```
import math

print '{:^6}  {:^6}  {:^6}  {:^6}'.format('X', 'sinh', 'cosh', 'tanh')
print '{:-^6}  {:-^6}  {:-^6}  {:-^6}'.format('', '', '', '')

fmt = '  '.join(['{:6.4f}'] * 4)

for i in range(0, 11, 2):
    x = i/10.0
    print fmt.format(x, math.sinh(x), math.cosh(x), math.tanh(x))
```

Whereas the cosine and sine functions enscribe a circle, the hyperbolic cosine and hyperbolic sine form half of a hyperbola.

```
$ python math_hyperbolic.py

  X      sinh    cosh    tanh
------  ------  ------  ------
0.0000  0.0000  1.0000  0.0000
0.2000  0.2013  1.0201  0.1974
0.4000  0.4108  1.0811  0.3799
0.6000  0.6367  1.1855  0.5370
0.8000  0.8881  1.3374  0.6640
1.0000  1.1752  1.5431  0.7616
```

Inverse hyperbolic functions `acosh()`, `asinh()`, and `atanh()` are also available.

8.5.11 Special Functions

The Gauss Error function is used in statistics.

```
import math

print '{:^5}  {:7}'.format('x', 'erf(x)')
print '{:-^5}  {:-^7}'.format('', '')

for x in [ -3, -2, -1, -0.5, -0.25, 0, 0.25, 0.5, 1, 2, 3 ]:
    print '{:5.2f}  {:7.4f}'.format(x, math.erf(x))
```

Notice that `erf(-x) == -erf(x)`.

```
$ python math_erf.py

  x    erf(x)
-----  -------
-3.00  -1.0000
-2.00  -0.9953
-1.00  -0.8427
-0.50  -0.5205
-0.25  -0.2763
 0.00   0.0000
 0.25   0.2763
 0.50   0.5205
 1.00   0.8427
 2.00   0.9953
 3.00   1.0000
```

The complimentary error function is `1 - erf(x)`.

```
import math

print '{:^5}  {:7}'.format('x', 'erfc(x)')
print '{:-^5}  {:-^7}'.format('', '')

for x in [ -3, -2, -1, -0.5, -0.25, 0, 0.25, 0.5, 1, 2, 3 ]:
    print '{:5.2f}  {:7.4f}'.format(x, math.erfc(x))
```

```
$ python math_erfc.py

  x    erfc(x)
-----  -------
-3.00   2.0000
-2.00   1.9953
-1.00   1.8427
-0.50   1.5205
-0.25   1.2763
 0.00   1.0000
 0.25   0.7237
 0.50   0.4795
 1.00   0.1573
 2.00   0.0047
 3.00   0.0000
```

See also:

math (http://docs.python.org/library/math.html) The standard library documentation for this module.

IEEE floating point arithmetic in Python (http://www.johndcook.com/blog/2009/07/21/ieee-arithmetic-python/)
Blog post by John Cook about how special values arise and are dealt with when doing math in Python.

SciPy (http://scipy.org/) Open source libraryes for scientific and mathematical calculations in Python.

8.6 operator – Functional interface to built-in operators

Purpose Functional interface to built-in operators.

Available In 1.4 and later

Functional programming using iterators occasionally requires creating small functions for simple expressions. Sometimes these can be expressed as lambda functions, but some operations do not need to be implemented with custom functions at all. The `operator` module defines functions that correspond to built-in operations for arithmetic and comparison, as well as sequence and dictionary operations.

8.6.1 Logical Operations

There are functions for determining the boolean equivalent for a value, negating that to create the opposite boolean value, and comparing objects to see if they are identical.

```
from operator import *

a = -1
b = 5

print 'a =', a
print 'b =', b
print

print 'not_(a)     :', not_(a)
print 'truth(a)    :', truth(a)
print 'is_(a, b)   :', is_(a,b)
print 'is_not(a, b):', is_not(a,b)
```

`not_()` includes the trailing underscore because **not** is a Python keyword. `truth()` applies the same logic used when testing an expression in an **if** statement. `is_()` implements the same check used by the **is** keyword, and `is_not()` does the same test and returns the opposite answer.

```
$ python operator_boolean.py

a = -1
b = 5

not_(a)     : False
truth(a)    : True
is_(a, b)   : False
is_not(a, b): True
```

8.6.2 Comparison Operators

All of the rich comparison operators are supported.

```
from operator import *

a = 1
b = 5.0
print

print 'a =', a
print 'b =', b
for func in (lt, le, eq, ne, ge, gt):
    print '%s(a, b):' % func.__name__, func(a, b)
```

The functions are equivalent to the expression syntax using <, <=, ==, >=, and >.

```
$ python operator_comparisons.py


a = 1
b = 5.0
lt(a, b): True
le(a, b): True
eq(a, b): False
ne(a, b): True
ge(a, b): False
gt(a, b): False
```

8.6.3 Arithmetic Operators

The arithmetic operators for manipulating numerical values are also supported.

```
from operator import *

a = -1
b = 5.0
c = 2
d = 6

print 'a =', a
print 'b =', b
print 'c =', c
print 'd =', d

print '\nPositive/Negative:'
print 'abs(a):', abs(a)
print 'neg(a):', neg(a)
print 'neg(b):', neg(b)
print 'pos(a):', pos(a)
print 'pos(b):', pos(b)

print '\nArithmetic:'
print 'add(a, b)     :', add(a, b)
print 'div(a, b)     :', div(a, b)
print 'div(d, c)     :', div(d, c)
print 'floordiv(a, b):', floordiv(a, b)
print 'floordiv(d, c):', floordiv(d, c)
print 'mod(a, b)     :', mod(a, b)
print 'mul(a, b)     :', mul(a, b)
print 'pow(c, d)     :', pow(c, d)
print 'sub(b, a)      :', sub(b, a)
print 'truediv(a, b) :', truediv(a, b)
print 'truediv(d, c) :', truediv(d, c)

print '\nBitwise:'
print 'and_(c, d)   :', and_(c, d)
print 'invert(c)    :', invert(c)
print 'lshift(c, d):', lshift(c, d)
print 'or_(c, d)    :', or_(c, d)
print 'rshift(d, c):', rshift(d, c)
print 'xor(c, d)    :', xor(c, d)
```

Note: There are two separate division operators: `floordiv()` (integer division as implemented in Python before version 3.0) and `truediv()` (floating point division).

```
$ python operator_math.py

a = -1
b = 5.0
c = 2
d = 6

Positive/Negative:
abs(a): 1
neg(a): 1
neg(b): -5.0
pos(a): -1
pos(b): 5.0

Arithmetic:
add(a, b)     : 4.0
div(a, b)     : -0.2
div(d, c)     : 3
floordiv(a, b): -1.0
floordiv(d, c): 3
mod(a, b)     : 4.0
mul(a, b)     : -5.0
pow(c, d)     : 64
sub(b, a)     : 6.0
truediv(a, b) : -0.2
truediv(d, c) : 3.0

Bitwise:
and_(c, d)  : 2
invert(c)   : -3
lshift(c, d): 128
or_(c, d)   : 6
rshift(d, c): 1
xor(c, d)   : 4
```

8.6.4 Sequence Operators

The operators for working with sequences can be divided into four groups for building up sequences, searching for items, accessing contents, and removing items from sequences.

```
from operator import *

a = [ 1, 2, 3 ]
b = [ 'a', 'b', 'c' ]

print 'a =', a
print 'b =', b

print '\nConstructive:'
print '  concat(a, b):', concat(a, b)
print '  repeat(a, 3):', repeat(a, 3)

print '\nSearching:'
print '  contains(a, 1)  :', contains(a, 1)
print '  contains(b, "d"):', contains(b, "d")
print '  countOf(a, 1)   :', countOf(a, 1)
print '  countOf(b, "d") :', countOf(b, "d")
print '  indexOf(a, 5)   :', indexOf(a, 1)

print '\nAccess Items:'
print '  getitem(b, 1)            :', getitem(b, 1)
print '  getslice(a, 1, 3)        :', getslice(a, 1, 3)
print '  setitem(b, 1, "d")       :', setitem(b, 1, "d"), ', after b =', b
print '  setslice(a, 1, 3, [4, 5]):', setslice(a, 1, 3, [4, 5]), ', after a =', a

print '\nDestructive:'
print '  delitem(b, 1)    :', delitem(b, 1), ', after b =', b
print '  delslice(a, 1, 3):', delslice(a, 1, 3), ', after a =', a
```

Some of these operations, such as `setitem()` and `delitem()`, modify the sequence in place and do not return a value.

```
$ python operator_sequences.py

a = [1, 2, 3]
b = ['a', 'b', 'c']

Constructive:
  concat(a, b): [1, 2, 3, 'a', 'b', 'c']
  repeat(a, 3): [1, 2, 3, 1, 2, 3, 1, 2, 3]

Searching:
  contains(a, 1)  : True
  contains(b, "d"): False
  countOf(a, 1)   : 1
  countOf(b, "d") : 0
  indexOf(a, 5)   : 0

Access Items:
  getitem(b, 1)            : b
  getslice(a, 1, 3)        : [2, 3]
  setitem(b, 1, "d")       : None , after b = ['a', 'd', 'c']
  setslice(a, 1, 3, [4, 5]): None , after a = [1, 4, 5]

Destructive:
  delitem(b, 1)    : None , after b = ['a', 'c']
  delslice(a, 1, 3): None , after a = [1]
```

8.6.5 In-place Operators

In addition to the standard operators, many types of objects support "in-place" modification through special operators such as +=. There are equivalent functions for in-place modifications, too:

```
from operator import *

a = -1
b = 5.0
c = [ 1, 2, 3 ]
d = [ 'a', 'b', 'c']
print 'a =', a
print 'b =', b
print 'c =', c
print 'd =', d
print

a = iadd(a, b)
print 'a = iadd(a, b) =>', a
print

c = iconcat(c, d)
print 'c = iconcat(c, d) =>', c
```

These examples only demonstrate a few of the functions. Refer to the stdlib documentation for complete details.

```
$ python operator_inplace.py

a = -1
b = 5.0
c = [1, 2, 3]
d = ['a', 'b', 'c']

a = iadd(a, b) => 4.0

c = iconcat(c, d) => [1, 2, 3, 'a', 'b', 'c']
```

8.6.6 Attribute and Item "Getters"

One of the most unusual features of the `operator` module is the concept of *getters*. These are callable objects constructed at runtime to retrieve attributes of objects or contents from sequences. Getters are especially useful when working with iterators or generator sequences, where they are intended to incur less overhead than a lambda or Python function.

```
from operator import *

class MyObj(object):
    """example class for attrgetter"""
    def __init__(self, arg):
        super(MyObj, self).__init__()
        self.arg = arg
    def __repr__(self):
        return 'MyObj(%s)' % self.arg

l = [ MyObj(i) for i in xrange(5) ]
print l
g = attrgetter('arg')
```

```
vals = [ g(i) for i in l ]
print vals
```

Attribute getters work like `lambda x, n='attrname': getattr(x, n)`:

```
$ python operator_attrgetter.py

[MyObj(0), MyObj(1), MyObj(2), MyObj(3), MyObj(4)]
[0, 1, 2, 3, 4]
```

While item getters work like `lambda x, y=5: x[y]`:

```
from operator import *

print 'Dictionaries:'
l = [ dict(val=i) for i in xrange(5) ]
print l
g = itemgetter('val')
vals = [ g(i) for i in l ]
print vals

print
print 'Tuples:'
l = [ (i, i*2) for i in xrange(5) ]
print l
g = itemgetter(1)
vals = [ g(i) for i in l ]
print vals
```

Item getters work with mappings as well as sequences.

```
$ python operator_itemgetter.py

Dictionaries:
[{'val': 0}, {'val': 1}, {'val': 2}, {'val': 3}, {'val': 4}]
[0, 1, 2, 3, 4]

Tuples:
[(0, 0), (1, 2), (2, 4), (3, 6), (4, 8)]
[0, 2, 4, 6, 8]
```

8.6.7 Combining Operators and Custom Classes

The functions in the `operator` module work via the standard Python interfaces for their operations, so they work with user-defined classes as well as the built-in types.

```
from operator import *

class MyObj(object):
    """Example for operator overloading"""
    def __init__(self, val):
        super(MyObj, self).__init__()
        self.val = val
        return
    def __str__(self):
        return 'MyObj(%s)' % self.val
    def __lt__(self, other):
        """compare for less-than"""
        print 'Testing %s < %s' % (self, other)
        return self.val < other.val
    def __add__(self, other):
        """add values"""
        print 'Adding %s + %s' % (self, other)
        return MyObj(self.val + other.val)

a = MyObj(1)
b = MyObj(2)

print 'Comparison:'
print lt(a, b)

print '\nArithmetic:'
print add(a, b)
```

Refer to the Python reference guide for a complete list of the special methods used by each operator.

```
$ python operator_classes.py

Comparison:
Testing MyObj(1) < MyObj(2)
True

Arithmetic:
Adding MyObj(1) + MyObj(2)
MyObj(3)
```

8.6.8 Type Checking

Besides the actual operators, there are functions for testing API compliance for mapping, number, and sequence types.

```
from operator import *

class NoType(object):
    """Supports none of the type APIs"""

class MultiType(object):
    """Supports multiple type APIs"""
    def __len__(self):
        return 0
    def __getitem__(self, name):
        return 'mapping'
    def __int__(self):
        return 0

o = NoType()
t = MultiType()

for func in (isMappingType, isNumberType, isSequenceType):
    print '%s(o):' % func.__name__, func(o)
    print '%s(t):' % func.__name__, func(t)
```

The tests are not perfect, since the interfaces are not strictly defined, but they do provide some idea of what is supported.

```
$ python operator_typechecking.py
```

```
isMappingType(o): False
isMappingType(t): True
isNumberType(o): False
isNumberType(t): True
isSequenceType(o): False
isSequenceType(t): True
```

abc includes *abstract base classes* that define the APIs for collection types.

See also:

operator (http://docs.python.org/lib/module-operator.html) Standard library documentation for this module.

functools Functional programming tools, including the `total_ordering()` decorator for adding rich comparison methods to a class.

itertools Iterator operations.

8.7 random – Pseudorandom number generators

Purpose Implements several types of pseudorandom number generators.

Available In 1.4 and later

The `random` module provides a fast pseudorandom number generator based on the *Mersenne Twister* algorithm. Originally developed to produce inputs for Monte Carlo simulations, Mersenne Twister generates numbers with nearly uniform distribution and a large period, making it suited for a wide range of applications.

8.7.1 Generating Random Numbers

The `random()` function returns the next random floating point value from the generated sequence. All of the return values fall within the range `0 <= n < 1.0`.

```
import random

for i in xrange(5):
    print '%04.3f' % random.random()
```

Running the program repeatedly produces different sequences of numbers.

```
$ python random_random.py

0.182
0.155
0.097
0.175
0.008

$ python random_random.py

0.851
0.607
0.700
0.922
0.496
```

To generate numbers in a specific numerical range, use `uniform()` instead.

```
import random

for i in xrange(5):
    print '%04.3f' % random.uniform(1, 100)
```

Pass minimum and maximum values, and `uniform()` adjusts the return values from `random()` using the formula `min + (max - min) * random()`.

```
$ python random_uniform.py

6.899
14.411
96.792
18.219
63.386
```

8.7.2 Seeding

`random()` produces different values each time it is called, and has a very large period before it repeats any numbers. This is useful for producing unique values or variations, but there are times when having the same dataset available to be processed in different ways is useful. One technique is to use a program to generate random values and save them to be processed by a separate step. That may not be practical for large amounts of data, though, so `random` includes the `seed()` function for initializing the pseudorandom generator so that it produces an expected set of values.

```
import random

random.seed(1)

for i in xrange(5):
    print '%04.3f' % random.random()
```

The seed value controls the first value produced by the formula used to produce pseudorandom numbers, and since the formula is deterministic it also sets the full sequence produced after the seed is changed. The argument to `seed()` can be any hashable object. The default is to use a platform-specific source of randomness, if one is available. Otherwise the current time is used.

```
$ python random_seed.py

0.134
0.847
0.764
0.255
0.495

$ python random_seed.py

0.134
0.847
0.764
0.255
0.495
```

8.7.3 Saving State

Another technique useful for controlling the number sequence is to save the internal state of the generator between test runs. Restoring the previous state before continuing reduces the likelyhood of repeating values or sequences of values from the earlier input. The `getstate()` function returns data that can be used to re-initialize the random number generator later with `setstate()`.

```
import random
import os
import cPickle as pickle

if os.path.exists('state.dat'):
    # Restore the previously saved sate
    print 'Found state.dat, initializing random module'
    with open('state.dat', 'rb') as f:
        state = pickle.load(f)
    random.setstate(state)
else:
    # Use a well-known start state
    print 'No state.dat, seeding'
    random.seed(1)

# Produce random values
for i in xrange(3):
    print '%04.3f' % random.random()

# Save state for next time
with open('state.dat', 'wb') as f:
    pickle.dump(random.getstate(), f)

# Produce more random values
print '\nAfter saving state:'
for i in xrange(3):
    print '%04.3f' % random.random()
```

The data returned by `getstate()` is an implementation detail, so this example saves the data to a file with `pickle` but otherwise treats it as a black box. If the file exists when the program starts, it loads the old state and continues. Each run produces a few numbers before and after saving the state, to show that restoring the state causes the generator to produce the same values again.

```
$ python random_state.py

No state.dat, seeding
0.134
0.847
0.764

After saving state:
0.255
0.495
0.449

$ python random_state.py

Found state.dat, initializing random module
0.255
0.495
0.449

After saving state:
0.652
0.789
0.094
```

8.7.4 Random Integers

random() generates floating point numbers. It is possible to convert the results to integers, but using randint() to generate integers directly is more convenient.

```
import random

print '[1, 100]:'

for i in xrange(3):
    print random.randint(1, 100)

print
print '[-5, 5]:'
for i in xrange(3):
    print random.randint(-5, 5)
```

The arguments to randint() are the ends of the inclusive range for the values. The numbers can be positive or negative, but the first value should be less than the second.

```
$ python random_randint.py

[1, 100]:
3
47
72

[-5, 5]:
4
1
-3
```

randrange() is a more general form of selecting values from a range.

```
import random

for i in xrange(3):
    print random.randrange(0, 101, 5)
```

randrange() supports a *step* argument, in addition to start and stop values, so it is fully equivalent to selecting a random value from range(start, stop, step). It is more efficient, because the range is not actually constructed.

```
$ python random_randrange.py

50
55
45
```

8.7.5 Picking Random Items

One common use for random number generators is to select a random item from a sequence of enumerated values, even if those values are not numbers. random includes the choice() function for making a random selection from a sequence. This example simulates flipping a coin 10,000 times to count how many times it comes up heads and how many times tails.

```
import random
import itertools

outcomes = { 'heads':0,
             'tails':0,
             }
sides = outcomes.keys()

for i in range(10000):
    outcomes[ random.choice(sides) ] += 1

print 'Heads:', outcomes['heads']
print 'Tails:', outcomes['tails']
```

There are only two outcomes allowed, so rather than use numbers and convert them the words "heads" and "tails" are used with `choice()`. The results are tabulated in a dictionary using the outcome names as keys.

```
$ python random_choice.py

Heads: 5069
Tails: 4931
```

8.7.6 Permutations

A simulation of a card game needs to mix up the deck of cards and then "deal" them to the players, without using the same card more than once. Using `choice()` could result in the same card being dealt twice, so instead the deck can be mixed up with `shuffle()` and then individual cards removed as they are dealt.

```
import random
import itertools

def new_deck():
    return list(itertools.product(
            itertools.chain(xrange(2, 11), ('J', 'Q', 'K', 'A')),
            ('H', 'D', 'C', 'S'),
            ))

def show_deck(deck):
    p_deck = deck[:]
    while p_deck:
        row = p_deck[:13]
        p_deck = p_deck[13:]
        for j in row:
            print '%2s%s' % j,
        print

# Get a new deck, with the cards in order
deck = new_deck()
print 'Initial deck:'
show_deck(deck)

# Shuffle the deck to randomize the order
random.shuffle(deck)
print '\nShuffled deck:'
show_deck(deck)

# Deal 4 hands of 5 cards each
```

```
hands = [ [], [], [], [] ]

for i in xrange(5):
    for h in hands:
        h.append(deck.pop())

# Show the hands
print '\nHands:'
for n, h in enumerate(hands):
    print '%d:' % (n+1),
    for c in h:
        print '%2s%s' % c,
    print

# Show the remaining deck
print '\nRemaining deck:'
show_deck(deck)
```

The cards are represented as tuples with the face value and a letter indicating the suit. The dealt "hands" are created by adding one card at a time to each of four lists, and removing it from the deck so it cannot be dealt again.

```
$ python random_shuffle.py

Initial deck:
 2H  2D  2C  2S  3H  3D  3C  3S  4H  4D  4C  4S  5H
 5D  5C  5S  6H  6D  6C  6S  7H  7D  7C  7S  8H  8D
 8C  8S  9H  9D  9C  9S 10H 10D 10C 10S  JH  JD  JC
 JS  QH  QD  QC  QS  KH  KD  KC  KS  AH  AD  AC  AS

Shuffled deck:
 4C  3H  AD  JH  7D  3D  5C  6D  5D  7S  5S  KH  8S
 QC  5H  7C  4D  4S  2H  JD  KD  AH 10S  KC  6C  6H
 8H 10H  QD  AC  2S  7H  JC  9S  AS  8C  QH  9D  4H
 8D  JS  2D  3S  9C 10D  3C  6S  2C  QS  KS 10C  9H

Hands:
1:  9H  2C  9C  8D  8C
2: 10C  6S  3S  4H  AS
3:  KS  3C  2D  9D  9S
4:  QS 10D  JS  QH  JC

Remaining deck:
 4C  3H  AD  JH  7D  3D  5C  6D  5D  7S  5S  KH  8S
 QC  5H  7C  4D  4S  2H  JD  KD  AH 10S  KC  6C  6H
 8H 10H  QD  AC  2S  7H
```

Many simulations need random samples from a population of input values. The `sample()` function generates samples without repeating values and without modifying the input sequence. This example prints a random sample of words from the system dictionary.

```
import random

with open('/usr/share/dict/words', 'rt') as f:
    words = f.readlines()
words = [ w.rstrip() for w in words ]

for w in random.sample(words, 5):
    print w
```

The algorithm for producing the result set takes into account the sizes of the input and the sample requested to produce the result as efficiently as possible.

```
$ python random_sample.py

pleasureman
consequency
docibility
youdendrift
Ituraean

$ python random_sample.py

jigamaree
readingdom
sporidium
pansylike
foraminiferan
```

8.7.7 Multiple Simultaneous Generators

In addition to module-level functions, `random` includes a `Random` class to manage the internal state for several random number generators. All of the functions described above are available as methods of the `Random` instances, and each instance can be initialized and used separately, without interfering with the values returned by other instances.

```
import random
import time

print 'Default initializiation:\n'

r1 = random.Random()
r2 = random.Random()

for i in xrange(3):
    print '%04.3f  %04.3f' % (r1.random(), r2.random())

print '\nSame seed:\n'

seed = time.time()
r1 = random.Random(seed)
r2 = random.Random(seed)

for i in xrange(3):
    print '%04.3f  %04.3f' % (r1.random(), r2.random())
```

On a system with good native random value seeding, the instances start out in unique states. However, if there is no good platform random value generator, the instances are likely to have been seeded with the current time, and therefore produce the same values.

```
$ python random_random_class.py

Default initializiation:

0.171  0.711
0.184  0.558
0.818  0.113
```

```
Same seed:

0.857  0.857
0.925  0.925
0.040  0.040
```

To ensure that the generators produce values from different parts of the random period, use `jumpahead()` to shift one of them away from its initial state.

```
import random
import time

r1 = random.Random()
r2 = random.Random()

# Force r2 to a different part of the random period than r1.
r2.setstate(r1.getstate())
r2.jumpahead(1024)

for i in xrange(3):
    print '%04.3f  %04.3f' % (r1.random(), r2.random())
```

The argument to `jumpahead()` should be a non-negative integer based the number of values needed from each generator. The internal state of the generator is scrambled based on the input value, but not simply by incrementing it by the number of steps given.

```
$ python random_jumpahead.py

0.405  0.159
0.592  0.765
0.501  0.764
```

8.7.8 SystemRandom

Some operating systems provide a random number generator that has access to more sources of entropy that can be introduced into the generator. `random` exposes this feature through the `SystemRandom` class, which has the same API as `Random` but uses `os.urandom()` to generate the values that form the basis of all of the other algorithms.

```
import random
import time

print 'Default initializiation:\n'

r1 = random.SystemRandom()
r2 = random.SystemRandom()

for i in xrange(3):
    print '%04.3f  %04.3f' % (r1.random(), r2.random())

print '\nSame seed:\n'

seed = time.time()
r1 = random.SystemRandom(seed)
r2 = random.SystemRandom(seed)

for i in xrange(3):
    print '%04.3f  %04.3f' % (r1.random(), r2.random())
```

Sequences produced by `SystemRandom` are not reproducable because the randomness is coming from the system, rather than software state (in fact, `seed()` and `setstate()` have no effect at all).

```
$ python random_system_random.py

Default initializiation:

0.374  0.932
0.002  0.022
0.692  1.000

Same seed:

0.182  0.939
0.154  0.430
0.649  0.970
```

8.7.9 Non-uniform Distributions

While the uniform distribution of the values produced by `random()` is useful for a lot of purposes, other distributions more accurately model specific situations. The `random` module includes functions to produce values in those distributions, too. They are listed here, but not covered in detail because their uses tend to be specialized and require more complex examples.

Normal

The *normal* distribution is commonly used for non-uniform continuous values such as grades, heights, weights, etc. The curve produced by the distribution has a distinctive shape which has lead to it being nicknamed a "bell curve." `random` includes two functions for generating values with a normal distribution, `normalvariate()` and the slightly faster `gauss()` (the normal distribution is also called the Gaussian distribution).

The related function, `lognormvariate()` produces pseudorandom values where the logarithm of the values is distributed normally. Log-normal distributions are useful for values that are the product of several random variables which do not interact.

Approximation

The *triangular* distribution is used as an approximate distribution for small sample sizes. The "curve" of a triangular distribution has low points at known minimum and maximum values, and a high point at and the mode, which is estimated based on a "most likely" outcome (reflected by the mode argument to `triangular()`).

Exponential

`expovariate()` produces an exponential distribution useful for simulating arrival or interval time values for in homogeneous Poisson processes such as the rate of radioactive decay or requests coming into a web server.

The Pareto, or power law, distribution matches many observable phenomena and was popularized by Chris Anderon's book, *The Long Tail*. The `paretovariate()` function is useful for simulating allocation of resources to individuals (wealth to people, demand for musicians, attention to blogs, etc.).

Angular

The von Mises, or circular normal, distribution (produced by `vonmisesvariate()`) is used for computing probabilities of cyclic values such as angles, calendar days, and times.

Sizes

`betavariate()` generates values with the Beta distribution, which is commonly used in Bayesian statistics and applications such as task duration modeling.

The Gamma distribution produced by `gammavariate()` is used for modeling the sizes of things such as waiting times, rainfall, and computational errors.

The Weibull distribution computed by `weibullvariate()` is used in failure analysis, industrial engineering, and weather forecasting. It describes the distribution of sizes of particles or other discrete objects.

See also:

random (http://docs.python.org/library/random.html) The standard library documentation for this module.

Mersenne Twister: A 623-dimensionally equidistributed uniform pseudorandom number generator Article by M. Matsumoto and T. Nishimura from *ACM Transactions on Modeling and Computer Simulation* Vol. 8, No. 1, January pp.3-30 1998.

Wikipedia: Mersenne Twister (http://en.wikipedia.org/wiki/Mersenne_twister) Article about the pseudorandom generator algorithm used by Python.

Wikipedia: Uniform distribution (http://en.wikipedia.org/wiki/Uniform_distribution_(continuous)) Article about continuous uniform distributions in statistics.

CHAPTER

NINE

INTERNET DATA HANDLING

9.1 base64 – Encode binary data into ASCII characters

Purpose The base64 module contains functions for translating binary data into a subset of ASCII suitable for transmission using plaintext protocols.

Available In 1.4 and later

The base64, base32, and base16 encodings convert 8 bit bytes to values with 6, 5, or 4 bits of useful data per byte, allowing non-ASCII bytes to be encoded as ASCII characters for transmission over protocols that require plain ASCII, such as SMTP. The *base* values correspond to the length of the alphabet used in each encoding. There are also URL-safe variations of the original encodings that use slightly different results.

9.1.1 Base 64 Encoding

A basic example of encoding some text looks like this:

```
import base64

# Load this source file and strip the header.
initial_data = open(__file__, 'rt').read().split('#end_pymotw_header')[1]

encoded_data = base64.b64encode(initial_data)

num_initial = len(initial_data)
padding = { 0:0, 1:2, 2:1 }[num_initial % 3]

print '%d bytes before encoding' % num_initial
print 'Expect %d padding bytes' % padding
print '%d bytes after encoding' % len(encoded_data)
print
#print encoded_data
for i in xrange((len(encoded_data)/40)+1):
    print encoded_data[i*40:(i+1)*40]
```

The output shows the 558 bytes of the original source expand to 744 bytes after being encoded.

Note: There are no carriage returns in the output produced by the library, so I have broken the encoded data up artificially to make it fit better on the page.

```
$ python base64_b64encode.py

113 bytes before encoding
```

```
Expect 1 padding bytes
152 bytes after encoding

CgppbXBvcnQgYmFzZTY0CgojIExvYWQgdGhpcyBz
b3VyY2UgZmlsZSBhbmQgc3RyaXAgdGhlIGhlYWRl
ci4KaW5pdGlhbF9kYXRhID0gb3BlbihfX2ZpbGVf
XywgJ3J0JykucmVhZCgpLnNwbGl0KCc=
```

9.1.2 Base 64 Decoding

The encoded string can be converted back to the original form by taking 4 bytes and converting them to the original 3, using a reverse lookup. The `b64decode()` function does that for you.

```
import base64

original_string = 'This is the data, in the clear.'
print 'Original:', original_string

encoded_string = base64.b64encode(original_string)
print 'Encoded :', encoded_string

decoded_string = base64.b64decode(encoded_string)
print 'Decoded :', decoded_string
```

The encoding process looks at each sequence of 24 bits in the input (3 bytes) and encodes those same 24 bits spread over 4 bytes in the output. The last two characters, the ==, are padding because the number of bits in the original string was not evenly divisible by 24 in this example.

```
$ python base64_b64decode.py

Original: This is the data, in the clear.
Encoded : VGhpcyBpcyB0aGUgZGF0YSwgaW4gdGhlIGNsZWFyLg==
Decoded : This is the data, in the clear.
```

9.1.3 URL-safe Variations

Because the default base64 alphabet may use + and /, and those two characters are used in URLs, it became necessary to specify an alternate encoding with substitutes for those characters. The + is replaced with a -, and / is replaced with underscore (_). Otherwise, the alphabet is the same.

```
import base64

for original in [ chr(251) + chr(239), chr(255) * 2 ]:
    print 'Original         :', repr(original)
    print 'Standard encoding:', base64.standard_b64encode(original)
    print 'URL-safe encoding:', base64.urlsafe_b64encode(original)
    print
```

```
$ python base64_urlsafe.py

Original         : '\xfb\xef'
Standard encoding: ++8=
URL-safe encoding: --8=

Original         : '\xff\xff'
```

```
Standard encoding: //8=
URL-safe encoding: __8=
```

9.1.4 Other Encodings

Besides base 64, the module provides functions for working with base 32 and base 16 (hex) encoded data.

```
import base64

original_string = 'This is the data, in the clear.'
print 'Original:', original_string

encoded_string = base64.b32encode(original_string)
print 'Encoded :', encoded_string

decoded_string = base64.b32decode(encoded_string)
print 'Decoded :', decoded_string
```

```
$ python base64_base32.py

Original: This is the data, in the clear.
Encoded : KRUGS4ZANFZSA5DIMUQGIYLUMEWCA2LOEB2GQZJAMNWGKYLSFY======
Decoded : This is the data, in the clear.
```

The base 16 functions work with the hexadecimal alphabet.

```
import base64

original_string = 'This is the data, in the clear.'
print 'Original:', original_string

encoded_string = base64.b16encode(original_string)
print 'Encoded :', encoded_string

decoded_string = base64.b16decode(encoded_string)
print 'Decoded :', decoded_string
```

```
$ python base64_base16.py

Original: This is the data, in the clear.
Encoded : 546869732069732074686520646174612C20696E2074686520636C6561722E
Decoded : This is the data, in the clear.
```

See also:

base64 **(http://docs.python.org/library/base64.html)** The standard library documentation for this module.

RFC 3548 **(http://tools.ietf.org/html/rfc3548.html)** The Base16, Base32, and Base64 Data Encodings

9.2 json – JavaScript Object Notation Serializer

Purpose Encode Python objects as JSON strings, and decode JSON strings into Python objects.

Available In 2.6

The json module provides an API similar to pickle for converting in-memory Python objects to a serialized representation known as JavaScript Object Notation (http://json.org/) (JSON). Unlike pickle, JSON has the benefit of having implementations in many languages (especially JavaScript), making it suitable for inter-application communication. JSON is probably most widely used for communicating between the web server and client in an AJAX application, but is not limited to that problem domain.

9.2.1 Encoding and Decoding Simple Data Types

The encoder understands Python's native types by default (string, unicode, int, float, list, tuple, dict).

```
import json

data = [ { 'a':'A', 'b':(2, 4), 'c':3.0 } ]
print 'DATA:', repr(data)

data_string = json.dumps(data)
print 'JSON:', data_string
```

Values are encoded in a manner very similar to Python's `repr()` output.

```
$ python json_simple_types.py

DATA: [{'a': 'A', 'c': 3.0, 'b': (2, 4)}]
JSON: [{"a": "A", "c": 3.0, "b": [2, 4]}]
```

Encoding, then re-decoding may not give exactly the same type of object.

```
import json

data = [ { 'a':'A', 'b':(2, 4), 'c':3.0 } ]
data_string = json.dumps(data)
print 'ENCODED:', data_string

decoded = json.loads(data_string)
print 'DECODED:', decoded

print 'ORIGINAL:', type(data[0]['b'])
print 'DECODED :', type(decoded[0]['b'])
```

In particular, strings are converted to unicode and tuples become lists.

```
$ python json_simple_types_decode.py

ENCODED: [{"a": "A", "c": 3.0, "b": [2, 4]}]
DECODED: [{u'a': u'A', u'c': 3.0, u'b': [2, 4]}]
ORIGINAL: <type 'tuple'>
DECODED : <type 'list'>
```

9.2.2 Human-consumable vs. Compact Output

Another benefit of JSON over pickle is that the results are human-readable. The `dumps()` function accepts several arguments to make the output even nicer. For example, `sort_keys` tells the encoder to output the keys of a dictionary in sorted, instead of random, order.

```
import json
```

```
data = [ { 'a':'A', 'b':(2, 4), 'c':3.0 } ]
print 'DATA:', repr(data)

unsorted = json.dumps(data)
print 'JSON:', json.dumps(data)
print 'SORT:', json.dumps(data, sort_keys=True)

first = json.dumps(data, sort_keys=True)
second = json.dumps(data, sort_keys=True)

print 'UNSORTED MATCH:', unsorted == first
print 'SORTED MATCH  :', first == second
```

Sorting makes it easier to scan the results by eye, and also makes it possible to compare JSON output in tests.

```
$ python json_sort_keys.py

DATA: [{'a': 'A', 'c': 3.0, 'b': (2, 4)}]
JSON: [{"a": "A", "c": 3.0, "b": [2, 4]}]
SORT: [{"a": "A", "b": [2, 4], "c": 3.0}]
UNSORTED MATCH: False
SORTED MATCH  : True
```

For highly-nested data structures, you will want to specify a value for `indent`, so the output is formatted nicely as well.

```
import json

data = [ { 'a':'A', 'b':(2, 4), 'c':3.0 } ]
print 'DATA:', repr(data)

print 'NORMAL:', json.dumps(data, sort_keys=True)
print 'INDENT:', json.dumps(data, sort_keys=True, indent=2)
```

When indent is a non-negative integer, the output more closely resembles that of `pprint`, with leading spaces for each level of the data structure matching the indent level.

```
$ python json_indent.py

DATA: [{'a': 'A', 'c': 3.0, 'b': (2, 4)}]
NORMAL: [{"a": "A", "b": [2, 4], "c": 3.0}]
INDENT: [
  {
    "a": "A",
    "b": [
      2,
      4
    ],
    "c": 3.0
  }
]
```

Verbose output like this increases the number of bytes needed to transmit the same amount of data, however, so it isn't the sort of thing you necessarily want to use in a production environment. In fact, you may want to adjust the settings for separating data in the encoded output to make it even more compact than the default.

```
import json

data = [ { 'a':'A', 'b':(2, 4), 'c':3.0 } ]
```

```
print 'DATA:', repr(data)
print 'repr(data)             :', len(repr(data))
print 'dumps(data)            :', len(json.dumps(data))
print 'dumps(data, indent=2)  :', len(json.dumps(data, indent=2))
print 'dumps(data, separators):', len(json.dumps(data, separators=(',',':')))
```

The `separators` argument to `dumps()` should be a tuple containing the strings to separate items in a list and keys from values in a dictionary. The default is `(', ', ': ')`. By removing the whitespace, we can produce a more compact output.

```
$ python json_compact_encoding.py

DATA: [{'a': 'A', 'c': 3.0, 'b': (2, 4)}]
repr(data)             : 35
dumps(data)            : 35
dumps(data, indent=2)  : 76
dumps(data, separators): 29
```

9.2.3 Encoding Dictionaries

The JSON format expects the keys to a dictionary to be strings. If you have other types as keys in your dictionary, trying to encode the object will produce a *ValueError*. One way to work around that limitation is to skip over non-string keys using the `skipkeys` argument:

```
import json

data = [ { 'a':'A', 'b':(2, 4), 'c':3.0, ('d',):'D tuple' } ]

print 'First attempt'
try:
    print json.dumps(data)
except (TypeError, ValueError) as err:
    print 'ERROR:', err

print
print 'Second attempt'
print json.dumps(data, skipkeys=True)
```

Rather than raising an exception, the non-string key is simply ignored.

```
$ python json_skipkeys.py

First attempt
ERROR: keys must be a string

Second attempt
[{"a": "A", "c": 3.0, "b": [2, 4]}]
```

9.2.4 Working with Your Own Types

All of the examples so far have used Pythons built-in types because those are supported by `json` natively. It isn't uncommon, of course, to have your own types that you want to be able to encode as well. There are two ways to do that.

First, we'll need a class to encode:

```
class MyObj(object):
    def __init__(self, s):
        self.s = s
    def __repr__(self):
        return '<MyObj(%s)>' % self.s
```

The simple way of encoding a `MyObj` instance is to define a function to convert an unknown type to a known type. You don't have to do the encoding yourself, just convert one object to another.

```
import json
import json_myobj

obj = json_myobj.MyObj('instance value goes here')

print 'First attempt'
try:
    print json.dumps(obj)
except TypeError, err:
    print 'ERROR:', err

def convert_to_builtin_type(obj):
    print 'default(', repr(obj), ')'
    # Convert objects to a dictionary of their representation
    d = { '__class__':obj.__class__.__name__,
          '__module__':obj.__module__,
          }
    d.update(obj.__dict__)
    return d

print
print 'With default'
print json.dumps(obj, default=convert_to_builtin_type)
```

In `convert_to_builtin_type()`, instances of classes not recognized by `json` are converted to dictionaries with enough information to re-create the object if a program has access to the Python modules necessary.

```
$ python json_dump_default.py

First attempt
ERROR: <MyObj(instance value goes here)> is not JSON serializable

With default
default( <MyObj(instance value goes here)> )
{"s": "instance value goes here", "__module__": "json_myobj", "__class__": "MyObj"}
```

To decode the results and create a `MyObj` instance, we need to tie in to the decoder so we can import the class from the module and create the instance. For that, we use the `object_hook` argument to `loads()`.

The `object_hook` is called for each dictionary decoded from the incoming data stream, giving us a chance to convert the dictionary to another type of object. The hook function should return the object it wants the calling application to receive instead of the dictionary.

```
import json

def dict_to_object(d):
    if '__class__' in d:
        class_name = d.pop('__class__')
        module_name = d.pop('__module__')
        module = __import__(module_name)
        print 'MODULE:', module
        class_ = getattr(module, class_name)
        print 'CLASS:', class_
        args = dict( (key.encode('ascii'), value) for key, value in d.items())
        print 'INSTANCE ARGS:', args
        inst = class_(**args)
    else:
        inst = d
    return inst

encoded_object = '[{"s": "instance value goes here", "__module__": "json_myobj", "__class__": "MyObj"

myobj_instance = json.loads(encoded_object, object_hook=dict_to_object)
print myobj_instance
```

Since json converts string values to unicode objects, we need to re-encode them as ASCII strings before using them as keyword arguments to the class constructor.

```
$ python json_load_object_hook.py

MODULE: <module 'json_myobj' from '/Users/dhellmann/Documents/PyMOTW/src/PyMOTW/json/json_myobj.pyc'>
CLASS: <class 'json_myobj.MyObj'>
INSTANCE ARGS: {'s': u'instance value goes here'}
[<MyObj(instance value goes here)>]
```

Similar hooks are available for the built-in types integers (`parse_int`), floating point numbers (`parse_float`), and constants (`parse_constant`).

9.2.5 Encoder and Decoder Classes

Besides the convenience functions we have already examined, the json module provides classes for encoding and decoding. When using the classes directly, you have access to extra APIs and can create subclasses to customize their behavior.

The JSONEncoder provides an iterable interface for producing "chunks" of encoded data, making it easier for you to write to files or network sockets without having to represent an entire data structure in memory.

```
import json

encoder = json.JSONEncoder()
data = [ { 'a':'A', 'b':(2, 4), 'c':3.0 } ]

for part in encoder.iterencode(data):
    print 'PART:', part
```

As you can see, the output is generated in logical units, rather than being based on any size value.

```
$ python json_encoder_iterable.py

PART: [
PART: {
PART: "a"
PART: :
PART: "A"
PART: ,
PART: "c"
PART: :
PART: 3.0
PART: ,
PART: "b"
PART: :
PART: [2
PART: , 4
PART: ]
PART: }
PART: ]
```

The `encode()` method is basically equivalent to `''.join(encoder.iterencode())`, with some extra error checking up front.

To encode arbitrary objects, we can override the `default()` method with an implementation similar to what we used above in `convert_to_builtin_type()`.

```
import json
import json_myobj

class MyEncoder(json.JSONEncoder):

    def default(self, obj):
        print 'default(', repr(obj), ')'
        # Convert objects to a dictionary of their representation
        d = { '__class__':obj.__class__.__name__,
              '__module__':obj.__module__,
              }
        d.update(obj.__dict__)
        return d

obj = json_myobj.MyObj('internal data')
print obj
print MyEncoder().encode(obj)
```

The output is the same as the previous implementation.

```
$ python json_encoder_default.py

<MyObj(internal data)>
default( <MyObj(internal data)> )
{"s": "internal data", "__module__": "json_myobj", "__class__": "MyObj"}
```

Decoding text, then converting the dictionary into an object takes a little more work to set up than our previous implementation, but not much.

```
import json

class MyDecoder(json.JSONDecoder):

    def __init__(self):
        json.JSONDecoder.__init__(self, object_hook=self.dict_to_object)

    def dict_to_object(self, d):
        if '__class__' in d:
            class_name = d.pop('__class__')
            module_name = d.pop('__module__')
            module = __import__(module_name)
            print 'MODULE:', module
            class_ = getattr(module, class_name)
            print 'CLASS:', class_
            args = dict( (key.encode('ascii'), value) for key, value in d.items())
            print 'INSTANCE ARGS:', args
            inst = class_(**args)
        else:
            inst = d
        return inst

encoded_object = '[{"s": "instance value goes here", "__module__": "json_myobj", "__class__": "MyObj"

myobj_instance = MyDecoder().decode(encoded_object)
print myobj_instance
```

And the output is the same as the earlier example.

```
$ python json_decoder_object_hook.py

MODULE: <module 'json_myobj' from '/Users/dhellmann/Documents/PyMOTW/src/PyMOTW/json/json_myobj.pyc'>
CLASS: <class 'json_myobj.MyObj'>
INSTANCE ARGS: {'s': u'instance value goes here'}
[<MyObj(instance value goes here)>]
```

9.2.6 Working with Streams and Files

In all of the examples so far, we have assumed that we could (and should) hold the encoded version of the entire data structure in memory at one time. With large data structures it may be preferable to write the encoding directly to a file-like object. The convenience functions `load()` and `dump()` accept references to a file-like object to use for reading or writing.

```
import json
import tempfile

data = [ { 'a':'A', 'b':(2, 4), 'c':3.0 } ]

f = tempfile.NamedTemporaryFile(mode='w+')
json.dump(data, f)
f.flush()

print open(f.name, 'r').read()
```

A socket would work in much the same way as the normal file handle used here.

```
$ python json_dump_file.py

[{"a": "A", "c": 3.0, "b": [2, 4]}]
```

Although it isn't optimized to read only part of the data at a time, the `load()` function still offers the benefit of encapsulating the logic of generating objects from stream input.

```
import json
import tempfile

f = tempfile.NamedTemporaryFile(mode='w+')
f.write('[{"a": "A", "c": 3.0, "b": [2, 4]}]')
f.flush()
f.seek(0)

print json.load(f)
```

```
$ python json_load_file.py

[{u'a': u'A', u'c': 3.0, u'b': [2, 4]}]
```

9.2.7 Mixed Data Streams

The JSONDecoder includes the `raw_decode()` method for decoding a data structure followed by more data, such as JSON data with trailing text. The return value is the object created by decoding the input data, and an index into that data indicating where decoding left off.

```
import json

decoder = json.JSONDecoder()
def get_decoded_and_remainder(input_data):
    obj, end = decoder.raw_decode(input_data)
    remaining = input_data[end:]
    return (obj, end, remaining)

encoded_object = '[{"a": "A", "c": 3.0, "b": [2, 4]}]'
extra_text = 'This text is not JSON.'

print 'JSON first:'
obj, end, remaining = get_decoded_and_remainder(' '.join([encoded_object, extra_text]))
print 'Object              :', obj
print 'End of parsed input :', end
print 'Remaining text      :', repr(remaining)

print
print 'JSON embedded:'
try:
    obj, end, remaining = get_decoded_and_remainder(
        ' '.join([extra_text, encoded_object, extra_text])
        )
except ValueError, err:
    print 'ERROR:', err
```

Unfortunately, this only works if the object appears at the beginning of the input.

```
$ python json_mixed_data.py

JSON first:
Object              : [{u'a': u'A', u'c': 3.0, u'b': [2, 4]}]
End of parsed input : 35
Remaining text      : ' This text is not JSON.'

JSON embedded:
ERROR: No JSON object could be decoded
```

See also:

json (http://docs.python.org/library/json.html) The standard library documentation for this module.

JavaScript Object Notation (http://json.org/) JSON home, with documentation and implementations in other languages.

http://code.google.com/p/simplejson/ simplejson, from Bob Ippolito, et al, is the externally maintained development version of the json library included with Python 2.6 and Python 3.0. It maintains backwards compatibility with Python 2.4 and Python 2.5.

jsonpickle (http://code.google.com/p/jsonpickle/) jsonpickle allows for any Python object to be serialized into JSON.

Data Persistence and Exchange Other examples of storing data from Python programs.

9.3 mailbox – Access and manipulate email archives

Purpose Work with email messages in various local file formats.

Available In 1.4 and later

The `mailbox` module defines a common API for accessing email messages stored in local disk formats, including:

- Maildir
- mbox
- MH
- Babyl
- MMDF

There are base classes for `Mailbox` and `Message`, and each mailbox format includes a corresponding pair of subclasses to implement the details for that format.

9.3.1 mbox

The mbox format is the simplest to illustrate in documentation, since it is entirely plain text. Each mailbox is stored as a single file, with all of the messages concatenated together. Each time a line starting with "From " (`From` followed by a single space) is encountered it is treated as the beginning of a new message. Any time those characters appear at the beginning of a line in the message body, they are escaped by prefixing the line with ">".

Creating an mbox mailbox

Instantiate the `email.mbox` class by passing the filename to the constructor. If the file does not exist, it is created when you add messages to it using `add()`.

```
import mailbox
import email.utils

from_addr = email.utils.formataddr(('Author', 'author@example.com'))
to_addr = email.utils.formataddr(('Recipient', 'recipient@example.com'))

mbox = mailbox.mbox('example.mbox')
mbox.lock()
try:
    msg = mailbox.mboxMessage()
    msg.set_unixfrom('author Sat Feb  7 01:05:34 2009')
    msg['From'] = from_addr
    msg['To'] = to_addr
    msg['Subject'] = 'Sample message 1'
    msg.set_payload('This is the body.\nFrom (should be escaped).\nThere are 3 lines.\n')
    mbox.add(msg)
    mbox.flush()

    msg = mailbox.mboxMessage()
    msg.set_unixfrom('author')
    msg['From'] = from_addr
    msg['To'] = to_addr
    msg['Subject'] = 'Sample message 2'
    msg.set_payload('This is the second body.\n')
    mbox.add(msg)
    mbox.flush()
finally:
    mbox.unlock()

print open('example.mbox', 'r').read()
```

The result of this script is a new mailbox file with 2 email messages.

```
$ python mailbox_mbox_create.py

From MAILER-DAEMON Thu Feb 21 11:35:54 2013
From: Author <author@example.com>
To: Recipient <recipient@example.com>
Subject: Sample message 1

This is the body.
>From (should be escaped).
There are 3 lines.

From MAILER-DAEMON Thu Feb 21 11:35:54 2013
From: Author <author@example.com>
To: Recipient <recipient@example.com>
Subject: Sample message 2

This is the second body.
```

Reading an mbox Mailbox

To read an existing mailbox, open it and treat the mbox object like a dictionary. They keys are arbitrary values defined by the mailbox instance and are not necessary meaningful other than as internal identifiers for message objects.

```
import mailbox

mbox = mailbox.mbox('example.mbox')
for message in mbox:
    print message['subject']
```

You can iterate over the open mailbox but notice that, unlike with dictionaries, the default iterator for a mailbox works on the *values* instead of the *keys*.

```
$ python mailbox_mbox_read.py

Sample message 1
Sample message 2
```

Removing Messages from an mbox Mailbox

To remove an existing message from an mbox file, use its key with `remove()` or use `del`.

```
import mailbox

mbox = mailbox.mbox('example.mbox')
to_remove = []
for key, msg in mbox.iteritems():
    if '2' in msg['subject']:
        print 'Removing:', key
        to_remove.append(key)
mbox.lock()
try:
    for key in to_remove:
        mbox.remove(key)
finally:
    mbox.flush()
    mbox.close()

print open('example.mbox', 'r').read()
```

Notice the use of `lock()` and `unlock()` to prevent issues from simultaneous access to the file, and `flush()` to force the changes to be written to disk.

```
$ python mailbox_mbox_remove.py

Removing: 1
From MAILER-DAEMON Thu Feb 21 11:35:54 2013
From: Author <author@example.com>
To: Recipient <recipient@example.com>
Subject: Sample message 1

This is the body.
>From (should be escaped).
There are 3 lines.
```

9.3.2 Maildir

The Maildir format was created to eliminate the problem of concurrent modification to an mbox file. Instead of using a single file, the mailbox is organized as directory where each message is contained in its own file. This also allows mailboxes to be nested, and so the API for a Maildir mailbox is extended with methods to work with sub-folders.

Creating a Maildir Mailbox

The only real difference between using a Maildir and mbox is that to instantiate the `email.Maildir` object we need to pass the directory containing the mailbox to the constructor. As before, if it does not exist, the mailbox is created when you add messages to it using `add()`.

```
import mailbox
import email.utils
import os

from_addr = email.utils.formataddr(('Author', 'author@example.com'))
to_addr = email.utils.formataddr(('Recipient', 'recipient@example.com'))

mbox = mailbox.Maildir('Example')
mbox.lock()
try:
    msg = mailbox.mboxMessage()
    msg.set_unixfrom('author Sat Feb  7 01:05:34 2009')
    msg['From'] = from_addr
    msg['To'] = to_addr
    msg['Subject'] = 'Sample message 1'
    msg.set_payload('This is the body.\nFrom (will not be escaped).\nThere are 3 lines.\n')
    mbox.add(msg)
    mbox.flush()

    msg = mailbox.mboxMessage()
    msg.set_unixfrom('author Sat Feb  7 01:05:34 2009')
    msg['From'] = from_addr
    msg['To'] = to_addr
    msg['Subject'] = 'Sample message 2'
    msg.set_payload('This is the second body.\n')
    mbox.add(msg)
    mbox.flush()
finally:
    mbox.unlock()

for dirname, subdirs, files in os.walk('Example'):
    print dirname
    print '\tDirectories:', subdirs
    for name in files:
        fullname = os.path.join(dirname, name)
        print
        print '***', fullname
        print open(fullname).read()
        print '*' * 20
```

Since we have added messages to the mailbox, they go to the "new" subdirectory. Once they are "read" a client could move them to the "cur" subdirectory.

Warning: Although it is safe to write to the same maildir from multiple processes, `add()` is not thread-safe, so make sure you use a semaphore or other locking device to prevent simultaneous modifications to the mailbox from multiple threads of the same process.

```
$ python mailbox_maildir_create.py

Example
        Directories: ['cur', 'new', 'tmp']
Example/cur
        Directories: []
Example/new
        Directories: []

*** Example/new/1361446554.M933748P13757Q1.hubert.local
From: Author <author@example.com>
To: Recipient <recipient@example.com>
Subject: Sample message 1

This is the body.
From (will not be escaped).
There are 3 lines.

********************

*** Example/new/1361446554.M963206P13757Q2.hubert.local
```

```
From: Author <author@example.com>
To: Recipient <recipient@example.com>
Subject: Sample message 2

This is the second body.

********************
Example/tmp
        Directories: []
```

Reading a Maildir Mailbox

Reading from an existing Maildir mailbox works just like with mbox.

```
import mailbox

mbox = mailbox.Maildir('Example')
for message in mbox:
    print message['subject']
```

Notice that the messages are not guaranteed to be read in any particular order.

```
$ python mailbox_maildir_read.py

Sample message 2
Sample message 1
```

Removing Messages from a Maildir Mailbox

To remove an existing message from a Maildir mailbox, use its key with `remove()` or use `del`.

```
import mailbox
import os

mbox = mailbox.Maildir('Example')
to_remove = []
for key, msg in mbox.iteritems():
    if '2' in msg['subject']:
        print 'Removing:', key
        to_remove.append(key)
mbox.lock()
try:
    for key in to_remove:
        mbox.remove(key)
finally:
    mbox.flush()
    mbox.close()

for dirname, subdirs, files in os.walk('Example'):
    print dirname
    print '\tDirectories:', subdirs
    for name in files:
        fullname = os.path.join(dirname, name)
        print
        print '***', fullname
        print open(fullname).read()
        print '*' * 20
```

```
$ python mailbox_maildir_remove.py

Removing: 1361446554.M963206P13757Q2.hubert.local
Example
        Directories: ['cur', 'new', 'tmp']
Example/cur
        Directories: []
Example/new
        Directories: []

*** Example/new/1361446554.M933748P13757Q1.hubert.local
From: Author <author@example.com>
To: Recipient <recipient@example.com>
Subject: Sample message 1

This is the body.
From (will not be escaped).
There are 3 lines.

********************
Example/tmp
        Directories: []
```

Maildir folders

Subdirectories or *folders* of a Maildir mailbox can be managed directly through the methods of the Maildir class. Callers can list, retrieve, create, and remove sub-folders for a given mailbox.

```
import mailbox
import os

def show_maildir(name):
    os.system('find %s -print' % name)

mbox = mailbox.Maildir('Example')
print 'Before:', mbox.list_folders()
show_maildir('Example')

print
print '#' * 30
print

mbox.add_folder('subfolder')
print 'subfolder created:', mbox.list_folders()
show_maildir('Example')

subfolder = mbox.get_folder('subfolder')
print 'subfolder contents:', subfolder.list_folders()

print
print '#' * 30
print

subfolder.add_folder('second_level')
```

```
print 'second_level created:', subfolder.list_folders()
show_maildir('Example')

print
print '#' * 30
print

subfolder.remove_folder('second_level')
print 'second_level removed:', subfolder.list_folders()
show_maildir('Example')
```

The directory name for the folder is constructed by prefixing the folder name with `.`.

```
$ python mailbox_maildir_folders.py

Example
Example/cur
Example/new
Example/new/1361446554.M933748P13757Q1.hubert.local
Example/tmp
Example
Example/.subfolder
Example/.subfolder/cur
Example/.subfolder/maildirfolder
Example/.subfolder/new
Example/.subfolder/tmp
Example/cur
Example/new
Example/new/1361446554.M933748P13757Q1.hubert.local
Example/tmp
Example
Example/.subfolder
Example/.subfolder/.second_level
Example/.subfolder/.second_level/cur
Example/.subfolder/.second_level/maildirfolder
Example/.subfolder/.second_level/new
Example/.subfolder/.second_level/tmp
Example/.subfolder/cur
Example/.subfolder/maildirfolder
Example/.subfolder/new
Example/.subfolder/tmp
Example/cur
Example/new
Example/new/1361446554.M933748P13757Q1.hubert.local
Example/tmp
Example
Example/.subfolder
Example/.subfolder/cur
Example/.subfolder/maildirfolder
Example/.subfolder/new
Example/.subfolder/tmp
Example/cur
Example/new
Example/new/1361446554.M933748P13757Q1.hubert.local
Example/tmp
Before: []

##############################
```

```
subfolder created: ['subfolder']
subfolder contents: []

##############################

second_level created: ['second_level']

##############################

second_level removed: []
```

9.3.3 Other Formats

MH is another multi-file mailbox format used by some mail handlers. Babyl and MMDF are single-file formats with different message separators than mbox. None seem to be as popular as mbox or Maildir. The single-file formats support the same API as mbox, and MH includes the folder-related methods found in the Maildir class.

See also:

mailbox (http://docs.python.org/library/mailbox.html) The standard library documentation for this module.

mbox manpage from qmail http://www.qmail.org/man/man5/mbox.html

maildir manpage from qmail http://www.qmail.org/man/man5/maildir.html

`email` The email module.

`mhlib` The mhlib module.

9.4 mhlib – Work with MH mailboxes

Purpose Manipulate the contents of MH mailboxes.

Available In 1.4 and later

Note: This module is superseded by `mailbox`.

See also:

mhlib (http://docs.python.org/lib/module-mhlib.html) Standard library documentation for this module.

`email` The email module.

`mailbox` The mailbox module.

CHAPTER

TEN

FILE FORMATS

10.1 csv – Comma-separated value files

Purpose Read and write comma separated value files.

Available In 2.3 and later

The csv module is useful for working with data exported from spreadsheets and databases into text files formatted with fields and records, commonly referred to as *comma-separated value* (CSV) format because commas are often used to separate the fields in a record.

Note: The Python 2.5 version of csv does not support Unicode data. There are also "issues with ASCII NUL characters". Using UTF-8 or printable ASCII is recommended.

10.1.1 Reading

Use reader() to create a an object for reading data from a CSV file. The reader can be used as an iterator to process the rows of the file in order. For example:

```
import csv
import sys

f = open(sys.argv[1], 'rt')
try:
    reader = csv.reader(f)
    for row in reader:
        print row
finally:
    f.close()
```

The first argument to reader() is the source of text lines. In this case, it is a file, but any iterable is accepted (StringIO instances, lists, etc.). Other optional arguments can be given to control how the input data is parsed.

This example file was exported from NeoOffice (http://www.neooffice.org/).

```
"Title 1","Title 2","Title 3"
1,"a",08/18/07
2,"b",08/19/07
3,"c",08/20/07
4,"d",08/21/07
5,"e",08/22/07
6,"f",08/23/07
7,"g",08/24/07
```

```
8,"h",08/25/07
9,"i",08/26/07
```

As it is read, each row of the input data is parsed and converted to a list of strings.

```
$ python csv_reader.py testdata.csv

['Title 1', 'Title 2', 'Title 3']
['1', 'a', '08/18/07']
['2', 'b', '08/19/07']
['3', 'c', '08/20/07']
['4', 'd', '08/21/07']
['5', 'e', '08/22/07']
['6', 'f', '08/23/07']
['7', 'g', '08/24/07']
['8', 'h', '08/25/07']
['9', 'i', '08/26/07']
```

The parser handles line breaks embedded within strings in a row, which is why a "row" is not always the same as a "line" of input from the file.

```
"Title 1","Title 2","Title 3"
1,"first line
second line",08/18/07
```

Values with line breaks in the input retain the internal line breaks when returned by the parser.

```
$ python csv_reader.py testlinebreak.csv

['Title 1', 'Title 2', 'Title 3']
['1', 'first line\nsecond line', '08/18/07']
```

10.1.2 Writing

Writing CSV files is just as easy as reading them. Use `writer()` to create an object for writing, then iterate over the rows, using `writerow()` to print them.

```
import csv
import sys

f = open(sys.argv[1], 'wt')
try:
    writer = csv.writer(f)
    writer.writerow( ('Title 1', 'Title 2', 'Title 3') )
    for i in range(10):
        writer.writerow( (i+1, chr(ord('a') + i), '08/%02d/07' % (i+1)) )
finally:
    f.close()

print open(sys.argv[1], 'rt').read()
```

The output does not look exactly like the exported data used in the reader example:

```
$ python csv_writer.py testout.csv

Title 1,Title 2,Title 3
1,a,08/01/07
2,b,08/02/07
```

```
3,c,08/03/07
4,d,08/04/07
5,e,08/05/07
6,f,08/06/07
7,g,08/07/07
8,h,08/08/07
9,i,08/09/07
10,j,08/10/07
```

The default quoting behavior is different for the writer, so the string column is not quoted. That is easy to change by adding a quoting argument to quote non-numeric values:

```
writer = csv.writer(f, quoting=csv.QUOTE_NONNUMERIC)
```

And now the strings are quoted:

```
$ python csv_writer_quoted.py testout_quoted.csv

"Title 1","Title 2","Title 3"
1,"a","08/01/07"
2,"b","08/02/07"
3,"c","08/03/07"
4,"d","08/04/07"
5,"e","08/05/07"
6,"f","08/06/07"
7,"g","08/07/07"
8,"h","08/08/07"
9,"i","08/09/07"
10,"j","08/10/07"
```

Quoting

There are four different quoting options, defined as constants in the csv module.

QUOTE_ALL Quote everything, regardless of type.

QUOTE_MINIMAL Quote fields with special characters (anything that would confuse a parser configured with the same dialect and options). This is the default

QUOTE_NONNUMERIC Quote all fields that are not integers or floats. When used with the reader, input fields that are not quoted are converted to floats.

QUOTE_NONE Do not quote anything on output. When used with the reader, quote characters are included in the field values (normally, they are treated as delimiters and stripped).

10.1.3 Dialects

There is no well-defined standard for comma-separated value files, so the parser needs to be flexible. This flexibility means there are many parameters to control how `csv` parses or writes data. Rather than passing each of these parameters to the reader and writer separately, they are grouped together conveniently into a *dialect* object.

Dialect classes can be registered by name, so that callers of the csv module do not need to know the parameter settings in advance. The complete list of registered dialects can be retrieved with `list_dialects()`.

```
import csv

print csv.list_dialects()
```

The standard library includes two dialects: `excel`, and `excel-tabs`. The `excel` dialect is for working with data in the default export format for Microsoft Excel, and also works with OpenOffice or NeoOffice.

```
$ python csv_list_dialects.py

['excel-tab', 'excel']
```

Creating a Dialect

Suppose instead of using commas to delimit fields, the input file uses `|`, like this:

```
"Title 1"|"Title 2"|"Title 3"
1|"first line
second line"|08/18/07
```

A new dialect can be registered using the appropriate delimiter:

```
import csv

csv.register_dialect('pipes', delimiter='|')

with open('testdata.pipes', 'r') as f:
    reader = csv.reader(f, dialect='pipes')
    for row in reader:
        print row
```

and the file can be read just as with the comma-delimited file:

```
$ python csv_dialect.py

['Title 1', 'Title 2', 'Title 3']
['1', 'first line\nsecond line', '08/18/07']
```

Dialect Parameters

A dialect specifies all of the tokens used when parsing or writing a data file. Every aspect of the file format can be specified, from the way columns are delimited to the character used to escape a token.

Attribute	Default	Meaning
delimiter	,	Field separator (one character)
doublequote	True	Flag controlling whether quotechar instances are doubled
escapechar	None	Character used to indicate an escape sequence
lineterminator	\r\n	String used by writer to terminate a line
quotechar	"	String to surround fields containing special values (one character)
quoting	QUOTE_MINIMAL	Controls quoting behavior described above
skipinitialspace	False	Ignore whitespace after the field delimiter

```
import csv
import sys

csv.register_dialect('escaped', escapechar='\\', doublequote=False, quoting=csv.QUOTE_NONE)
csv.register_dialect('singlequote', quotechar="'", quoting=csv.QUOTE_ALL)

quoting_modes = dict( (getattr(csv,n), n) for n in dir(csv) if n.startswith('QUOTE_') )

for name in sorted(csv.list_dialects()):
    print '\nDialect: "%s"\n' % name
    dialect = csv.get_dialect(name)

    print '  delimiter   = %-6r    skipinitialspace = %r' % (dialect.delimiter,
                                                             dialect.skipinitialspace)
    print '  doublequote = %-6r    quoting          = %s' % (dialect.doublequote,
                                                             quoting_modes[dialect.quoting])
    print '  quotechar   = %-6r    lineterminator   = %r' % (dialect.quotechar,
                                                             dialect.lineterminator)
    print '  escapechar  = %-6r' % dialect.escapechar
    print

    writer = csv.writer(sys.stdout, dialect=dialect)
    for i in xrange(3):
        writer.writerow(
            ('col1', i, '10/%02d/2010' % i,
             'Contains special chars: " \' %s to be parsed' % dialect.delimiter)
            )
    print
```

This program shows how the same data appears in several different dialects.

```
$ python csv_dialect_variations.py


Dialect: "escaped"

  delimiter   = ','       skipinitialspace = 0
  doublequote = 0         quoting          = QUOTE_NONE
  quotechar   = '"'       lineterminator   = '\r\n'
  escapechar  = '\\'

col1,0,10/00/2010,Contains special chars: \" ' \, to be parsed
col1,1,10/01/2010,Contains special chars: \" ' \, to be parsed
col1,2,10/02/2010,Contains special chars: \" ' \, to be parsed


Dialect: "excel"

  delimiter   = ','       skipinitialspace = 0
  doublequote = 1         quoting          = QUOTE_MINIMAL
  quotechar   = '"'       lineterminator   = '\r\n'
  escapechar  = None

col1,0,10/00/2010,"Contains special chars: "" ' , to be parsed"
col1,1,10/01/2010,"Contains special chars: "" ' , to be parsed"
col1,2,10/02/2010,"Contains special chars: "" ' , to be parsed"


Dialect: "excel-tab"

  delimiter   = '\t'      skipinitialspace = 0
  doublequote = 1         quoting          = QUOTE_MINIMAL
  quotechar   = '"'       lineterminator   = '\r\n'
  escapechar  = None

col1    0       10/00/2010      "Contains special chars: "" '    to be parsed"
col1    1       10/01/2010      "Contains special chars: "" '    to be parsed"
```

```
col1    2       10/02/2010      "Contains special chars: "" '    to be parsed"


Dialect: "singlequote"

  delimiter   = ','       skipinitialspace = 0
  doublequote = 1         quoting          = QUOTE_ALL
  quotechar   = "'"       lineterminator   = '\r\n'
  escapechar  = None

'col1','0','10/00/2010','Contains special chars: " '' , to be parsed'
'col1','1','10/01/2010','Contains special chars: " '' , to be parsed'
'col1','2','10/02/2010','Contains special chars: " '' , to be parsed'
```

Automatically Detecting Dialects

The best way to configure a dialect for parsing an input file is to know the right settings in advance. For data where the dialect parameters are unknown, the `Sniffer` class can be used to make an educated guess. The `sniff()` method takes a sample of the input data and an optional argument giving the possible delimiter characters.

```
import csv
from StringIO import StringIO
import textwrap

csv.register_dialect('escaped', escapechar='\\', doublequote=False, quoting=csv.QUOTE_NONE)
csv.register_dialect('singlequote', quotechar="'", quoting=csv.QUOTE_ALL)

# Generate sample data for all known dialects

samples = []

for name in sorted(csv.list_dialects()):
    buffer = StringIO()
    dialect = csv.get_dialect(name)
    writer = csv.writer(buffer, dialect=dialect)
    for i in xrange(3):
        writer.writerow(
            ('col1', i, '10/%02d/2010' % i,
             'Contains special chars: " \' %s to be parsed' % dialect.delimiter)
            )
    samples.append( (name, dialect, buffer.getvalue()) )

# Guess the dialect for a given sample, then use the results to parse
# the data.

sniffer = csv.Sniffer()

for name, expected, sample in samples:
    print '\nDialect: "%s"\n' % name

    dialect = sniffer.sniff(sample, delimiters=',\t')

    reader = csv.reader(StringIO(sample), dialect=dialect)
    for row in reader:
        print row
```

`sniff()` returns a `Dialect` instance with the settings to be used for parsing the data. The results are not always perfect, as demonstrated by the "escaped" dialect in the example.

```
$ python csv_dialect_sniffer.py


Dialect: "escaped"

['col1', '0', '10/00/2010', 'Contains special chars: \\" \' \\', ' to be parsed']
['col1', '1', '10/01/2010', 'Contains special chars: \\" \' \\', ' to be parsed']
['col1', '2', '10/02/2010', 'Contains special chars: \\" \' \\', ' to be parsed']

Dialect: "excel"

['col1', '0', '10/00/2010', 'Contains special chars: " \' , to be parsed']
['col1', '1', '10/01/2010', 'Contains special chars: " \' , to be parsed']
['col1', '2', '10/02/2010', 'Contains special chars: " \' , to be parsed']

Dialect: "excel-tab"

['col1', '0', '10/00/2010', 'Contains special chars: " \' \t to be parsed']
['col1', '1', '10/01/2010', 'Contains special chars: " \' \t to be parsed']
['col1', '2', '10/02/2010', 'Contains special chars: " \' \t to be parsed']

Dialect: "singlequote"

['col1', '0', '10/00/2010', 'Contains special chars: " \' , to be parsed']
['col1', '1', '10/01/2010', 'Contains special chars: " \' , to be parsed']
['col1', '2', '10/02/2010', 'Contains special chars: " \' , to be parsed']
```

10.1.4 Using Field Names

In addition to working with sequences of data, the `csv` module includes classes for working with rows as dictionaries so that the fields can be named. The `DictReader` and `DictWriter` classes translate rows to dictionaries instead of lists. Keys for the dictionary can be passed in, or inferred from the first row in the input (when the row contains headers).

```
import csv
import sys

f = open(sys.argv[1], 'rt')
try:
    reader = csv.DictReader(f)
    for row in reader:
        print row
finally:
    f.close()
```

The dictionary-based reader and writer are implemented as wrappers around the sequence-based classes, and use the same methods and arguments. The only difference in the reader API is that rows are returned as dictionaries instead of lists or tuples.

```
$ python csv_dictreader.py testdata.csv

{'Title 1': '1', 'Title 3': '08/18/07', 'Title 2': 'a'}
{'Title 1': '2', 'Title 3': '08/19/07', 'Title 2': 'b'}
{'Title 1': '3', 'Title 3': '08/20/07', 'Title 2': 'c'}
{'Title 1': '4', 'Title 3': '08/21/07', 'Title 2': 'd'}
```

```
{'Title 1': '5', 'Title 3': '08/22/07', 'Title 2': 'e'}
{'Title 1': '6', 'Title 3': '08/23/07', 'Title 2': 'f'}
{'Title 1': '7', 'Title 3': '08/24/07', 'Title 2': 'g'}
{'Title 1': '8', 'Title 3': '08/25/07', 'Title 2': 'h'}
{'Title 1': '9', 'Title 3': '08/26/07', 'Title 2': 'i'}
```

The `DictWriter` must be given a list of field names so it knows how to order the columns in the output.

```
import csv
import sys

f = open(sys.argv[1], 'wt')
try:
    fieldnames = ('Title 1', 'Title 2', 'Title 3')
    writer = csv.DictWriter(f, fieldnames=fieldnames)
    headers = dict( (n,n) for n in fieldnames )
    writer.writerow(headers)
    for i in range(10):
        writer.writerow({ 'Title 1':i+1,
                          'Title 2':chr(ord('a') + i),
                          'Title 3':'08/%02d/07' % (i+1),
                          })
finally:
    f.close()

print open(sys.argv[1], 'rt').read()
```

```
$ python csv_dictwriter.py testout.csv

Title 1,Title 2,Title 3
1,a,08/01/07
2,b,08/02/07
3,c,08/03/07
4,d,08/04/07
5,e,08/05/07
6,f,08/06/07
7,g,08/07/07
8,h,08/08/07
9,i,08/09/07
10,j,08/10/07
```

See also:

csv **(http://docs.python.org/library/csv.html)** The standard library documentation for this module.

PEP 305 **(http://www.python.org/dev/peps/pep-0305)** CSV File API

10.2 ConfigParser – Work with configuration files

Purpose Read/write configuration files similar to Windows INI files

Available In 1.5

Use the `ConfigParser` module to manage user-editable configuration files for an application. The configuration files are organized into sections, and each section can contain name-value pairs for configuration data. Value interpolation using Python formatting strings is also supported, to build values that depend on one another (this is especially handy for URLs and message strings).

10.2.1 Configuration File Format

The file format used by ConfigParser is similar to the format used by older versions of Microsoft Windows. It consists of one or more named *sections*, each of which can contain individual *options* with names and values.

Config file sections are identified by looking for lines starting with [and ending with]. The value between the square brackets is the section name, and can contain any characters except square brackets.

Options are listed one per line within a section. The line starts with the name of the option, which is separated from the value by a colon (:) or equal sign (=). Whitespace around the separator is ignored when the file is parsed.

A sample configuration file with section "bug_tracker" and three options would look like:

```
[bug_tracker]
url = http://localhost:8080/bugs/
username = dhellmann
password = SECRET
```

10.2.2 Reading Configuration Files

The most common use for a configuration file is to have a user or system administrator edit the file with a regular text editor to set application behavior defaults, and then have the application read the file, parse it, and act based on its contents. Use the read() method of SafeConfigParser to read the configuration file.

```
from ConfigParser import SafeConfigParser

parser = SafeConfigParser()
parser.read('simple.ini')

print parser.get('bug_tracker', 'url')
```

This program reads the simple.ini file from the previous section and prints the value of the url option from the bug_tracker section.

```
$ python ConfigParser_read.py

http://localhost:8080/bugs/
```

The read() method also accepts a list of filenames. Each name in turn is scanned, and if the file exists it is opened and read.

```
from ConfigParser import SafeConfigParser
import glob

parser = SafeConfigParser()

candidates = ['does_not_exist.ini', 'also-does-not-exist.ini',
              'simple.ini', 'multisection.ini',
              ]

found = parser.read(candidates)

missing = set(candidates) - set(found)

print 'Found config files:', sorted(found)
print 'Missing files     :', sorted(missing)
```

read() returns a list containing the names of the files successfully loaded, so the program can discover which configuration files are missing and decide whether to ignore them.

```
$ python ConfigParser_read_many.py

Found config files: ['multisection.ini', 'simple.ini']
Missing files     : ['also-does-not-exist.ini', 'does_not_exist.ini']
```

Unicode Configuration Data

Configuration files containing Unicode data should be opened using the `codecs` module to set the proper encoding value.

Changing the password value of the original input to contain Unicode characters and saving the results in UTF-8 encoding gives:

```
[bug_tracker]
url = http://localhost:8080/bugs/
username = dhellmann
password = ßéç®é†
```

The `codecs` file handle can be passed to `readfp()`, which uses the `readline()` method of its argument to get lines from the file and parse them.

```
from ConfigParser import SafeConfigParser
import codecs

parser = SafeConfigParser()

# Open the file with the correct encoding
with codecs.open('unicode.ini', 'r', encoding='utf-8') as f:
    parser.readfp(f)

password = parser.get('bug_tracker', 'password')

print 'Password:', password.encode('utf-8')
print 'Type    :', type(password)
print 'repr()  :', repr(password)
```

The value returned by `get()` is a `unicode` object, so in order to print it safely it must be re-encoded as UTF-8.

```
$ python ConfigParser_unicode.py

Password: ßéç®é†
Type    : <type 'unicode'>
repr()  : u'\xdf\xe9\xe7\xae\xe9\u2020'
```

10.2.3 Accessing Configuration Settings

`SafeConfigParser` includes methods for examining the structure of the parsed configuration, including listing the sections and options, and getting their values. This configuration file includes two sections for separate web services:

```
[bug_tracker]
url = http://localhost:8080/bugs/
username = dhellmann
password = SECRET

[wiki]
url = http://localhost:8080/wiki/
```

```
username = dhellmann
password = SECRET
```

And this sample program exercies some of the methods for looking at the configuration data, including `sections()`, `options()`, and `items()`.

```
from ConfigParser import SafeConfigParser

parser = SafeConfigParser()
parser.read('multisection.ini')

for section_name in parser.sections():
    print 'Section:', section_name
    print '  Options:', parser.options(section_name)
    for name, value in parser.items(section_name):
        print '  %s = %s' % (name, value)
    print
```

Both `sections()` and `options()` return lists of strings, while `items()` returns a list of tuples containing the name-value pairs.

```
$ python ConfigParser_structure.py

Section: bug_tracker
  Options: ['url', 'username', 'password']
  url = http://localhost:8080/bugs/
  username = dhellmann
  password = SECRET

Section: wiki
  Options: ['url', 'username', 'password']
  url = http://localhost:8080/wiki/
  username = dhellmann
  password = SECRET
```

Testing whether values are present

To test if a section exists, use `has_section()`, passing the section name.

```
from ConfigParser import SafeConfigParser

parser = SafeConfigParser()
parser.read('multisection.ini')

for candidate in [ 'wiki', 'bug_tracker', 'dvcs' ]:
    print '%-12s: %s' % (candidate, parser.has_section(candidate))
```

Testing if a section exists before calling `get()` avoids exceptions for missing data.

```
$ python ConfigParser_has_section.py

wiki        : True
bug_tracker : True
dvcs        : False
```

Use `has_option()` to test if an option exists within a section.

```
from ConfigParser import SafeConfigParser

parser = SafeConfigParser()
parser.read('multisection.ini')

for section in [ 'wiki', 'none' ]:
    print '%s section exists: %s' % (section, parser.has_section(section))
    for candidate in [ 'username', 'password', 'url', 'description' ]:
        print '%s.%-12s  : %s' % (section, candidate, parser.has_option(section, candidate))
    print
```

If the section does not exist, `has_option()` returns `False`.

```
$ python ConfigParser_has_option.py

wiki section exists: True
wiki.username      : True
wiki.password      : True
wiki.url           : True
wiki.description   : False

none section exists: False
none.username      : False
none.password      : False
none.url           : False
none.description   : False
```

Value Types

All section and option names are treated as strings, but option values can be strings, integers, floating point numbers, or booleans. There are a range of possible boolean values that are converted true or false. This example file includes one of each:

```
[ints]
positive = 1
negative = -5

[floats]
positive = 0.2
negative = -3.14

[booleans]
number_true = 1
number_false = 0
yn_true = yes
yn_false = no
tf_true = true
tf_false = false
onoff_true = on
onoff_false = false
```

`SafeConfigParser` does not make any attempt to understand the option type. The application is expected to use the correct method to fetch the value as the desired type. `get()` always returns a string. Use `getint()` for integers, `getfloat()` for floating point numbers, and `getboolean()` for boolean values.

```
from ConfigParser import SafeConfigParser
```

```
parser = SafeConfigParser()
parser.read('types.ini')

print 'Integers:'
for name in parser.options('ints'):
    string_value = parser.get('ints', name)
    value = parser.getint('ints', name)
    print '  %-12s : %-7r -> %d' % (name, string_value, value)

print '\nFloats:'
for name in parser.options('floats'):
    string_value = parser.get('floats', name)
    value = parser.getfloat('floats', name)
    print '  %-12s : %-7r -> %0.2f' % (name, string_value, value)

print '\nBooleans:'
for name in parser.options('booleans'):
    string_value = parser.get('booleans', name)
    value = parser.getboolean('booleans', name)
    print '  %-12s : %-7r -> %s' % (name, string_value, value)
```

Running this program with the example input produces:

```
$ python ConfigParser_value_types.py

Integers:
  positive     : '1'     -> 1
  negative     : '-5'    -> -5

Floats:
  positive     : '0.2'   -> 0.20
  negative     : '-3.14' -> -3.14

Booleans:
  number_true  : '1'     -> True
  number_false : '0'     -> False
  yn_true      : 'yes'   -> True
  yn_false     : 'no'    -> False
  tf_true      : 'true'  -> True
  tf_false     : 'false' -> False
  onoff_true   : 'on'    -> True
  onoff_false  : 'false' -> False
```

Options as Flags

Usually the parser requires an explicit value for each option, but with the `SafeConfigParser` parameter *allow_no_value* set to `True` an option can appear by itself on a line in the input file, and be used as a flag.

```
import ConfigParser

# Requre values
try:
    parser = ConfigParser.SafeConfigParser()
    parser.read('allow_no_value.ini')
except ConfigParser.ParsingError, err:
    print 'Could not parse:', err
```

```
# Allow stand-alone option names
print '\nTrying again with allow_no_value=True'
parser = ConfigParser.SafeConfigParser(allow_no_value=True)
parser.read('allow_no_value.ini')
for flag in [ 'turn_feature_on', 'turn_other_feature_on' ]:
    print
    print flag
    exists = parser.has_option('flags', flag)
    print '  has_option:', exists
    if exists:
        print '         get:', parser.get('flags', flag)
```

When an option has no explicit value, `has_option()` reports that the option exists and `get()` returns `None`.

```
$ python ConfigParser_allow_no_value.py

Could not parse: File contains parsing errors: allow_no_value.ini
        [line  2]: 'turn_feature_on\n'

Trying again with allow_no_value=True

turn_feature_on
  has_option: True
         get: None

turn_other_feature_on
  has_option: False
```

10.2.4 Modifying Settings

While `SafeConfigParser` is primarily intended to be configured by reading settings from files, settings can also be populated by calling `add_section()` to create a new section, and `set()` to add or change an option.

```
import ConfigParser

parser = ConfigParser.SafeConfigParser()

parser.add_section('bug_tracker')
parser.set('bug_tracker', 'url', 'http://localhost:8080/bugs')
parser.set('bug_tracker', 'username', 'dhellmann')
parser.set('bug_tracker', 'password', 'secret')

for section in parser.sections():
    print section
    for name, value in parser.items(section):
        print '  %s = %r' % (name, value)
```

All options must be set as strings, even if they will be retrieved as integer, float, or boolean values.

```
$ python ConfigParser_populate.py

bug_tracker
  url = 'http://localhost:8080/bugs'
  username = 'dhellmann'
  password = 'secret'
```

Sections and options can be removed from a `SafeConfigParser` with `remove_section()` and `remove_option()`.

```
from ConfigParser import SafeConfigParser

parser = SafeConfigParser()
parser.read('multisection.ini')

print 'Read values:\n'
for section in parser.sections():
    print section
    for name, value in parser.items(section):
        print '  %s = %r' % (name, value)

parser.remove_option('bug_tracker', 'password')
parser.remove_section('wiki')

print '\nModified values:\n'
for section in parser.sections():
    print section
    for name, value in parser.items(section):
        print '  %s = %r' % (name, value)
```

Removing a section deletes any options it contains.

```
$ python ConfigParser_remove.py

Read values:

bug_tracker
  url = 'http://localhost:8080/bugs/'
  username = 'dhellmann'
  password = 'SECRET'
wiki
  url = 'http://localhost:8080/wiki/'
  username = 'dhellmann'
  password = 'SECRET'

Modified values:

bug_tracker
  url = 'http://localhost:8080/bugs/'
  username = 'dhellmann'
```

10.2.5 Saving Configuration Files

Once a `SafeConfigParser` is populated with desired data, it can be saved to a file by calling the `write()` method. This makes it possible to provide a user interface for editing the configuration settings, without having to write any code to manage the file.

```
import ConfigParser
import sys

parser = ConfigParser.SafeConfigParser()

parser.add_section('bug_tracker')
parser.set('bug_tracker', 'url', 'http://localhost:8080/bugs')
parser.set('bug_tracker', 'username', 'dhellmann')
parser.set('bug_tracker', 'password', 'secret')
parser.write(sys.stdout)
```

The `write()` method takes a file-like object as argument. It writes the data out in the INI format so it can be parsed again by `SafeConfigParser`.

```
$ python ConfigParser_write.py

[bug_tracker]
url = http://localhost:8080/bugs
username = dhellmann
password = secret
```

10.2.6 Option Search Path

`SafeConfigParser` uses a multi-step search process when looking for an option.

Before starting the option search, the section name is tested. If the section does not exist, and the name is not the special value `DEFAULT`, then `NoSectionError` is raised.

1. If the option name appears in the *vars* dictionary passed to `get()`, the value from *vars* is returned.
2. If the option name appears in the specified section, the value from that section is returned.
3. If the option name appears in the `DEFAULT` section, that value is returned.
4. If the option name appears in the *defaults* dictionary passed to the constructor, that value is returned.

If the name is not found in any of those locations, `NoOptionError` is raised.

The search path behavior can be demonstrated using this configuration file:

```
[DEFAULT]
file-only = value from DEFAULT section
init-and-file = value from DEFAULT section
from-section = value from DEFAULT section
from-vars = value from DEFAULT section

[sect]
section-only = value from section in file
from-section = value from section in file
from-vars = value from section in file
```

and this test program:

```
import ConfigParser

# Define the names of the options
option_names =  [
    'from-default',
    'from-section', 'section-only',
    'file-only', 'init-only', 'init-and-file',
    'from-vars',
    ]

# Initialize the parser with some defaults
parser = ConfigParser.SafeConfigParser(
    defaults={'from-default':'value from defaults passed to init',
              'init-only':'value from defaults passed to init',
              'init-and-file':'value from defaults passed to init',
              'from-section':'value from defaults passed to init',
              'from-vars':'value from defaults passed to init',
              })

print 'Defaults before loading file:'
defaults = parser.defaults()
for name in option_names:
    if name in defaults:
        print '  %-15s = %r' % (name, defaults[name])

# Load the configuration file
parser.read('with-defaults.ini')

print '\nDefaults after loading file:'
defaults = parser.defaults()
for name in option_names:
    if name in defaults:
        print '  %-15s = %r' % (name, defaults[name])

# Define some local overrides
vars = {'from-vars':'value from vars'}

# Show the values of all of the options
print '\nOption lookup:'
for name in option_names:
    value = parser.get('sect', name, vars=vars)
    print '  %-15s = %r' % (name, value)

# Show error messages for options that do not exist
print '\nError cases:'
try:
    print 'No such option :', parser.get('sect', 'no-option')
except ConfigParser.NoOptionError, err:
    print str(err)

try:
    print 'No such section:', parser.get('no-sect', 'no-option')
except ConfigParser.NoSectionError, err:
    print str(err)
```

The output shows the origin for the value of each option, and illustrates the way defaults from different sources override existing values.

```
$ python ConfigParser_defaults.py

Defaults before loading file:
  from-default    = 'value from defaults passed to init'
  from-section    = 'value from defaults passed to init'
  init-only       = 'value from defaults passed to init'
  init-and-file   = 'value from defaults passed to init'
  from-vars       = 'value from defaults passed to init'

Defaults after loading file:
  from-default    = 'value from defaults passed to init'
  from-section    = 'value from DEFAULT section'
  file-only       = 'value from DEFAULT section'
  init-only       = 'value from defaults passed to init'
  init-and-file   = 'value from DEFAULT section'
  from-vars       = 'value from DEFAULT section'

Option lookup:
  from-default    = 'value from defaults passed to init'
  from-section    = 'value from section in file'
  section-only    = 'value from section in file'
  file-only       = 'value from DEFAULT section'
  init-only       = 'value from defaults passed to init'
  init-and-file   = 'value from DEFAULT section'
  from-vars       = 'value from vars'

Error cases:
No such option : No option 'no-option' in section: 'sect'
No such section: No section: 'no-sect'
```

10.2.7 Combining Values with Interpolation

SafeConfigParser provides a feature called *interpolation* that can be used to combine values together. Values containing standard Python format strings trigger the interpolation feature when they are retrieved with get(). Options named within the value being fetched are replaced with their values in turn, until no more substitution is necessary.

The URL examples from earlier in this section can be rewritten to use interpolation to make it easier to change only part of the value. For example, this configuration file separates the protocol, hostname, and port from the URL as separate options.

```
[bug_tracker]
protocol = http
server = localhost
port = 8080
url = %(protocol)s://%(server)s:%(port)s/bugs/
username = dhellmann
password = SECRET
```

Interpolation is performed by default each time get() is called. Pass a true value in the raw argument to retrieve the original value, without interpolation.

```python
from ConfigParser import SafeConfigParser

parser = SafeConfigParser()
parser.read('interpolation.ini')

print 'Original value       :', parser.get('bug_tracker', 'url')

parser.set('bug_tracker', 'port', '9090')
print 'Altered port value   :', parser.get('bug_tracker', 'url')

print 'Without interpolation:', parser.get('bug_tracker', 'url', raw=True)
```

Because the value is computed by get(), changing one of the settings being used by the url value changes the return value.

```
$ python ConfigParser_interpolation.py

Original value       : http://localhost:8080/bugs/
Altered port value   : http://localhost:9090/bugs/
Without interpolation: %(protocol)s://%(server)s:%(port)s/bugs/
```

Using Defaults

Values for interpolation do not need to appear in the same section as the original option. Defaults can be mixed with override values. Using this config file:

```
[DEFAULT]
url = %(protocol)s://%(server)s:%(port)s/bugs/
protocol = http
server = bugs.example.com
port = 80

[bug_tracker]
server = localhost
port = 8080
username = dhellmann
password = SECRET
```

The `url` value comes from the `DEFAULT` section, and the substitution starts by looking in `bug_tracker` and falling back to `DEFAULT` for pieces not found.

```
from ConfigParser import SafeConfigParser

parser = SafeConfigParser()
parser.read('interpolation_defaults.ini')

print 'URL:', parser.get('bug_tracker', 'url')
```

The `hostname` and `port` values come from the `bug_tracker` section, but the `protocol` comes from `DEFAULT`.

```
$ python ConfigParser_interpolation_defaults.py

URL: http://localhost:8080/bugs/
```

Substitution Errors

Substitution stops after `MAX_INTERPOLATION_DEPTH` steps to avoid problems due to recursive references.

```
import ConfigParser

parser = ConfigParser.SafeConfigParser()

parser.add_section('sect')
parser.set('sect', 'opt', '%(opt)s')

try:
    print parser.get('sect', 'opt')
except ConfigParser.InterpolationDepthError, err:
    print 'ERROR:', err
```

An `InterpolationDepthError` exception is raised if there are too many substitution steps.

```
$ python ConfigParser_interpolation_recursion.py

ERROR: Value interpolation too deeply recursive:
        section: [sect]
        option : opt
        rawval : %(opt)s
```

Missing values result in an `InterpolationMissingOptionError` exception.

```
import ConfigParser

parser = ConfigParser.SafeConfigParser()

parser.add_section('bug_tracker')
parser.set('bug_tracker', 'url', 'http://%(server)s:%(port)s/bugs')

try:
    print parser.get('bug_tracker', 'url')
except ConfigParser.InterpolationMissingOptionError, err:
    print 'ERROR:', err
```

Since no `server` value is defined, the `url` cannot be constructed.

```
$ python ConfigParser_interpolation_error.py

ERROR: Bad value substitution:
        section: [bug_tracker]
        option : url
        key    : server
        rawval : :%(port)s/bugs
```

See also:

ConfigParser (http://docs.python.org/library/configparser.html) The standard library documentation for this module.

`codecs` The codecs module is for reading and writing Unicode files.

10.3 robotparser – Internet spider access control

Purpose Parse robots.txt file used to control Internet spiders

Available In 2.1.3 and later

`robotparser` implements a parser for the `robots.txt` file format, including a simple function for checking if a given user agent can access a resource. It is intended for use in well-behaved spiders or other crawler applications that need to either be throttled or otherwise restricted.

Note: The `robotparser` module has been renamed `urllib.robotparser` in Python 3.0. Existing code using `robotparser` can be updated using 2to3.

10.3.1 robots.txt

The `robots.txt` file format is a simple text-based access control system for computer programs that automatically access web resources ("spiders", "crawlers", etc.). The file is made up of records that specify the user agent identifier for the program followed by a list of URLs (or URL prefixes) the agent may not access.

This is the `robots.txt` file for `http://www.doughellmann.com/`:

```
User-agent: *
Disallow: /admin/
Disallow: /downloads/
Disallow: /media/
```

```
Disallow: /static/
Disallow: /codehosting/
```

It prevents access to some of the expensive parts of my site that would overload the server if a search engine tried to index them. For a more complete set of examples, refer to The Web Robots Page (http://www.robotstxt.org/orig.html).

10.3.2 Simple Example

Using the data above, a simple crawler can test whether it is allowed to download a page using the `RobotFileParser`'s `can_fetch()` method.

```
import robotparser
import urlparse

AGENT_NAME = 'PyMOTW'
URL_BASE = 'http://www.doughellmann.com/'
parser = robotparser.RobotFileParser()
parser.set_url(urlparse.urljoin(URL_BASE, 'robots.txt'))
parser.read()

PATHS = [
    '/',
    '/PyMOTW/',
    '/admin/',
    '/downloads/PyMOTW-1.92.tar.gz',
    ]

for path in PATHS:
    print '%6s : %s' % (parser.can_fetch(AGENT_NAME, path), path)
    url = urlparse.urljoin(URL_BASE, path)
    print '%6s : %s' % (parser.can_fetch(AGENT_NAME, url), url)
    print
```

The URL argument to `can_fetch()` can be a path relative to the root of the site, or full URL.

```
$ python robotparser_simple.py

  True : /
  True : http://www.doughellmann.com/

  True : /PyMOTW/
  True : http://www.doughellmann.com/PyMOTW/

  True : /admin/
  True : http://www.doughellmann.com/admin/

 False : /downloads/PyMOTW-1.92.tar.gz
 False : http://www.doughellmann.com/downloads/PyMOTW-1.92.tar.gz
```

10.3.3 Long-lived Spiders

An application that takes a long time to process the resources it downloads or that is throttled to pause between downloads may want to check for new `robots.txt` files periodically based on the age of the content it has downloaded already. The age is not managed automatically, but there are convenience methods to make tracking it easier.

```
import robotparser
import time
import urlparse

AGENT_NAME = 'PyMOTW'
parser = robotparser.RobotFileParser()
# Using the local copy
parser.set_url('robots.txt')
parser.read()
parser.modified()

PATHS = [
    '/',
    '/PyMOTW/',
    '/admin/',
    '/downloads/PyMOTW-1.92.tar.gz',
    ]

for n, path in enumerate(PATHS):
    print
    age = int(time.time() - parser.mtime())
    print 'age:', age,
    if age > 1:
        print 're-reading robots.txt'
        parser.read()
        parser.modified()
    else:
        print
    print '%6s : %s' % (parser.can_fetch(AGENT_NAME, path), path)
    # Simulate a delay in processing
    time.sleep(1)
```

This extreme example downloads a new `robots.txt` file if the one it has is more than 1 second old.

```
$ python robotparser_longlived.py


age: 0
  True : /

age: 1
  True : /PyMOTW/

age: 2 re-reading robots.txt
 False : /admin/

age: 1
 False : /downloads/PyMOTW-1.92.tar.gz
```

A "nicer" version of the long-lived application might request the modification time for the file before downloading the entire thing. On the other hand, `robots.txt` files are usually fairly small, so it isn't that much more expensive to just grab the entire document again.

See also:

robotparser **(http://docs.python.org/library/robotparser.html)** The standard library documentation for this module.

The Web Robots Page **(http://www.robotstxt.org/orig.html)** Description of robots.txt format.

CHAPTER

ELEVEN

CRYPTOGRAPHIC SERVICES

11.1 hashlib – Cryptographic hashes and message digests

Purpose Cryptographic hashes and message digests

Available In 2.5

The hashlib module deprecates the separate md5 and sha modules and makes their API consistent. To work with a specific hash algorithm, use the appropriate constructor function to create a hash object. Then you can use the same API to interact with the hash no matter what algorithm is being used.

Since hashlib is "backed" by OpenSSL, all of of the algorithms provided by that library are available, including:

- md5
- sha1
- sha224
- sha256
- sha384
- sha512

11.1.1 Sample Data

All of the examples below use the same sample data:

```
import hashlib

lorem = '''Lorem ipsum dolor sit amet, consectetur adipisicing elit, sed do
eiusmod tempor incididunt ut labore et dolore magna aliqua. Ut enim ad minim
veniam, quis nostrud exercitation ullamco laboris nisi ut aliquip ex ea commodo
consequat. Duis aute irure dolor in reprehenderit in voluptate velit esse cillum
dolore eu fugiat nulla pariatur. Excepteur sint occaecat cupidatat non proident,
sunt in culpa qui officia deserunt mollit anim id est laborum.'''
```

11.1.2 MD5 Example

To calculate the MD5 digest for a block of data (here an ASCII string), create the hash object, add the data, and compute the digest.

```
import hashlib

from hashlib_data import lorem

h = hashlib.md5()
h.update(lorem)
print h.hexdigest()
```

This example uses the `hexdigest()` method instead of `digest()` because the output is formatted to be printed. If a binary digest value is acceptable, you can use `digest()`.

```
$ python hashlib_md5.py

c3abe541f361b1bfbbcfecbf53aad1fb
```

11.1.3 SHA1 Example

A SHA1 digest for the same data would be calculated in much the same way.

```
import hashlib

from hashlib_data import lorem

h = hashlib.sha1()
h.update(lorem)
print h.hexdigest()
```

The digest value is different in this example because we changed the algorithm from MD5 to SHA1

```
$ python hashlib_sha1.py

ac2a96a4237886637d5352d606d7a7b6d7ad2f29
```

11.1.4 new()

Sometimes it is more convenient to refer to the algorithm by name in a string rather than by using the constructor function directly. It is useful, for example, to be able to store the hash type in a configuration file. In those cases, use `new()` to create a hash calculator.

```
import hashlib
import sys


try:
    hash_name = sys.argv[1]
except IndexError:
    print 'Specify the hash name as the first argument.'
else:
    try:
        data = sys.argv[2]
    except IndexError:
        from hashlib_data import lorem as data

    h = hashlib.new(hash_name)
    h.update(data)
    print h.hexdigest()
```

When run with a variety of arguments:

```
$ python hashlib_new.py sha1

ac2a96a4237886637d5352d606d7a7b6d7ad2f29

$ python hashlib_new.py sha256

88b7404fc192fcdb9bb1dba1ad118aa1ccd580e9faa110d12b4d63988cf20332

$ python hashlib_new.py sha512

f58c6935ef9d5a94d296207ee4a7d9bba411539d8677482b7e9d60e4b7137f68d25f9747cab62fe752ec5ed1e5b2fa4cdbc8c

$ python hashlib_new.py md5

c3abe541f361b1bfbbcfecbf53aad1fb
```

11.1.5 Calling update() more than once

The `update()` method of the hash calculators can be called repeatedly. Each time, the digest is updated based on the additional text fed in. This can be much more efficient than reading an entire file into memory, for example.

```python
import hashlib

from hashlib_data import lorem

h = hashlib.md5()
h.update(lorem)
all_at_once = h.hexdigest()

def chunkize(size, text):
    "Return parts of the text in size-based increments."
    start = 0
    while start < len(text):
        chunk = text[start:start+size]
        yield chunk
        start += size
    return

h = hashlib.md5()
for chunk in chunkize(64, lorem):
    h.update(chunk)
line_by_line = h.hexdigest()

print 'All at once :', all_at_once
print 'Line by line:', line_by_line
print 'Same        :', (all_at_once == line_by_line)
```

This example is a little contrived because it works with such a small amount of text, but it illustrates how you could incrementally update a digest as data is read or otherwise produced.

```
$ python hashlib_update.py

All at once : c3abe541f361b1bfbbcfecbf53aad1fb
Line by line: c3abe541f361b1bfbbcfecbf53aad1fb
Same        : True
```

See also:

hashlib (http://docs.python.org/library/hashlib.html) The standard library documentation for this module.

Voidspace: IronPython and hashlib (http://www.voidspace.org.uk/python/weblog/arch_d7_2006_10_07.shtml#e497)
A wrapper for `hashlib` that works with IronPython.

`hmac` The `hmac` module.

11.2 hmac – Cryptographic signature and verification of messages.

Purpose The hmac module implements keyed-hashing for message authentication, as described in **RFC 2104** (http://tools.ietf.org/html/rfc2104.html).

Available In 2.2

The HMAC algorithm can be used to verify the integrity of information passed between applications or stored in a potentially vulnerable location. The basic idea is to generate a cryptographic hash of the actual data combined with a shared secret key. The resulting hash can then be used to check the transmitted or stored message to determine a level of trust, without transmitting the secret key.

Disclaimer: I'm not a security expert. For the full details on HMAC, check out **RFC 2104** (http://tools.ietf.org/html/rfc2104.html).

11.2.1 Example

Creating the hash is not complex. Here's a simple example which uses the default MD5 hash algorithm:

```
import hmac

digest_maker = hmac.new('secret-shared-key-goes-here')

f = open('lorem.txt', 'rb')
try:
    while True:
        block = f.read(1024)
        if not block:
            break
        digest_maker.update(block)
finally:
    f.close()

digest = digest_maker.hexdigest()
print digest
```

When run, the code reads its source file and computes an HMAC signature for it:

```
$ python hmac_simple.py

4bcb287e284f8c21e87e14ba2dc40b16
```

Note: If I haven't changed the file by the time I release the example source for this week, the copy you download should produce the same hash.

11.2.2 SHA vs. MD5

Although the default cryptographic algorithm for `hmac` is MD5, that is not the most secure method to use. MD5 hashes have some weaknesses, such as collisions (where two different messages produce the same hash). The SHA-1 algorithm is considered to be stronger, and should be used instead.

```
import hmac
import hashlib

digest_maker = hmac.new('secret-shared-key-goes-here', '', hashlib.sha1)

f = open('hmac_sha.py', 'rb')
try:
    while True:
        block = f.read(1024)
        if not block:
            break
        digest_maker.update(block)
finally:
    f.close()

digest = digest_maker.hexdigest()
print digest
```

`hmac.new()` takes 3 arguments. The first is the secret key, which should be shared between the two endpoints which are communicating so both ends can use the same value. The second value is an initial message. If the message content that needs to be authenticated is small, such as a timestamp or HTTP POST, the entire body of the message can be passed to `new()` instead of using the update() method. The last argument is the digest module to be used. The default is `hashlib.md5`. The previous example substitutes `hashlib.sha1`.

```
$ python hmac_sha.py

69b26d1731a0a5f0fc7a92fc6c540823ec210759
```

11.2.3 Binary Digests

The first few examples used the `hexdigest()` method to produce printable digests. The hexdigest is is a different representation of the value calculated by the `digest()` method, which is a binary value that may include unprintable or non-ASCII characters, including NULs. Some web services (Google checkout, Amazon S3) use the `base64` encoded version of the binary digest instead of the hexdigest.

```
import base64
import hmac
import hashlib

f = open('lorem.txt', 'rb')
try:
    body = f.read()
finally:
    f.close()

digest = hmac.new('secret-shared-key-goes-here', body, hashlib.sha1).digest()
print base64.encodestring(digest)
```

The base64 encoded string ends in a newline, which frequently needs to be stripped off when embedding the string in HTTP headers or other formatting-sensitive contexts.

```
$ python hmac_base64.py

olW2DoXHGJEKGU0aE9fOwSVE/o4=
```

11.2.4 Applications

HMAC authentication should be used for any public network service, and any time data is stored where security is important. For example, when sending data through a pipe or socket, that data should be signed and then the signature should be tested before the data is used. The extended example below is available in the `hmac_pickle.py` file as part of the PyMOTW source package.

First, let's establish a function to calculate a digest for a string, and a simple class to be instantiated and passed through a communication channel.

```
import hashlib
import hmac
try:
    import cPickle as pickle
except:
    import pickle
import pprint
from StringIO import StringIO


def make_digest(message):
    "Return a digest for the message."
    return hmac.new('secret-shared-key-goes-here', message, hashlib.sha1).hexdigest()


class SimpleObject(object):
    "A very simple class to demonstrate checking digests before unpickling."
    def __init__(self, name):
        self.name = name
    def __str__(self):
        return self.name
```

Next, create a `StringIO` buffer to represent the socket or pipe. We will using a naive, but easy to parse, format for the data stream. The digest and length of the data are written, followed by a new line. The serialized representation of the object, generated by `pickle`, follows. In a real system, we would not want to depend on a length value, since if the digest is wrong the length is probably wrong as well. Some sort of terminator sequence not likely to appear in the real data would be more appropriate.

For this example, we will write two objects to the stream. The first is written using the correct digest value.

```
# Simulate a writable socket or pipe with StringIO
out_s = StringIO()

# Write a valid object to the stream:
#  digest\nlength\npickle
o = SimpleObject('digest matches')
pickled_data = pickle.dumps(o)
digest = make_digest(pickled_data)
header = '%s %s' % (digest, len(pickled_data))
print '\nWRITING:', header
out_s.write(header + '\n')
out_s.write(pickled_data)
```

The second object is written to the stream with an invalid digest, produced by calculating the digest for some other data instead of the pickle.

```
# Write an invalid object to the stream
o = SimpleObject('digest does not match')
pickled_data = pickle.dumps(o)
digest = make_digest('not the pickled data at all')
header = '%s %s' % (digest, len(pickled_data))
print '\nWRITING:', header
out_s.write(header + '\n')
out_s.write(pickled_data)

out_s.flush()
```

Now that the data is in the `StringIO` buffer, we can read it back out again. The first step is to read the line of data with the digest and data length. Then the remaining data is read (using the length value). We could use `pickle.load()` to read directly from the stream, but that assumes a trusted data stream and we do not yet trust the data enough to unpickle it. Reading the pickle as a string collect the data from the stream, without actually unpickling the object.

```
# Simulate a readable socket or pipe with StringIO
in_s = StringIO(out_s.getvalue())

# Read the data
while True:
    first_line = in_s.readline()
    if not first_line:
        break
    incoming_digest, incoming_length = first_line.split(' ')
    incoming_length = int(incoming_length)
    print '\nREAD:', incoming_digest, incoming_length
    incoming_pickled_data = in_s.read(incoming_length)
```

Once we have the pickled data, we can recalculate the digest value and compare it against what we read. If the digests match, we know it is safe to trust the data and unpickle it.

```
actual_digest = make_digest(incoming_pickled_data)
print 'ACTUAL:', actual_digest

if incoming_digest != actual_digest:
    print 'WARNING: Data corruption'
else:
    obj = pickle.loads(incoming_pickled_data)
    print 'OK:', obj
```

The output shows that the first object is verified and the second is deemed "corrupted", as expected:

```
$ python hmac_pickle.py


WRITING: 387632cfa3d18cd19bdfe72b61ac395dfcdc87c9 124

WRITING: b01b209e28d7e053408ebe23b90fe5c33bc6a0ec 131

READ: 387632cfa3d18cd19bdfe72b61ac395dfcdc87c9 124
ACTUAL: 387632cfa3d18cd19bdfe72b61ac395dfcdc87c9
OK: digest matches

READ: b01b209e28d7e053408ebe23b90fe5c33bc6a0ec 131
ACTUAL: dec53ca1ad3f4b657dd81d514f17f735628b6828
```

```
WARNING: Data corruption
```

See also:

hmac (http://docs.python.org/library/hmac.html) The standard library documentation for this module.

RFC 2104 (http://tools.ietf.org/html/rfc2104.html) HMAC: Keyed-Hashing for Message Authentication

`hashlib` The `hashlib` module.

`pickle` Serialization library.

WikiPedia: MD5 (http://en.wikipedia.org/wiki/MD5) Description of the MD5 hashing algorithm.

Authenticating to Amazon S3 Web Service (http://docs.amazonwebservices.com/AmazonS3/2006-03-01/index.html?S3_Authenti
Instructions for authenticating to S3 using HMAC-SHA1 signed credentials.

CHAPTER

TWELVE

FILE AND DIRECTORY ACCESS

12.1 os.path – Platform-independent manipulation of file names.

Purpose Parse, build, test, and otherwise work on file names and paths.

Available In 1.4 and later

Writing code to work with files on multiple platforms is easy using the functions included in the `os.path` module. Even programs not intended to be ported between platforms should use `os.path` for reliable filename parsing.

12.1.1 Parsing Paths

The first set of functions in os.path can be used to parse strings representing filenames into their component parts. It is important to realize that these functions do not depend on the paths actually existing; they operate solely on the strings.

Path parsing depends on a few variable defined in `os`:

- `os.sep` - The separator between portions of the path (e.g., "`/`" or "`\`").
- `os.extsep` - The separator between a filename and the file "extension" (e.g., "`.`").
- `os.pardir` - The path component that means traverse the directory tree up one level (e.g., "`..`").
- `os.curdir` - The path component that refers to the current directory (e.g., "`.`").

`split()` breaks the path into 2 separate parts and returns the tuple. The second element is the last component of the path, and the first element is everything that comes before it.

```
import os.path

for path in [ '/one/two/three',
              '/one/two/three/',
              '/',
              '.',
              '']:
    print '"%s" : "%s"' % (path, os.path.split(path))
```

```
$ python ospath_split.py

"/one/two/three" : "('/one/two', 'three')"
"/one/two/three/" : "('/one/two/three', '')"
"/" : "('/', '')"
"." : "('', '.')"
"" : "('', '')"
```

`basename()` returns a value equivalent to the second part of the `split()` value.

```
import os.path

for path in [ '/one/two/three',
              '/one/two/three/',
              '/',
              '.',
              '']:
    print '"%s" : "%s"' % (path, os.path.basename(path))
```

```
$ python ospath_basename.py

"/one/two/three" : "three"
"/one/two/three/" : ""
"/" : ""
"." : "."
"" : ""
```

`dirname()` returns the first part of the split path:

```
import os.path

for path in [ '/one/two/three',
              '/one/two/three/',
              '/',
              '.',
              '']:
    print '"%s" : "%s"' % (path, os.path.dirname(path))
```

```
$ python ospath_dirname.py

"/one/two/three" : "/one/two"
"/one/two/three/" : "/one/two/three"
"/" : "/"
"." : ""
"" : ""
```

`splitext()` works like `split()` but divides the path on the extension separator, rather than the directory separator.

```
import os.path

for path in [ 'filename.txt', 'filename', '/path/to/filename.txt', '/', '' ]:
    print '"%s" :' % path, os.path.splitext(path)
```

```
$ python ospath_splitext.py

"filename.txt" : ('filename', '.txt')
"filename" : ('filename', '')
"/path/to/filename.txt" : ('/path/to/filename', '.txt')
"/" : ('/', '')
"" : ('', '')
```

`commonprefix()` takes a list of paths as an argument and returns a single string that represents a common prefix present in all of the paths. The value may represent a path that does not actually exist, and the path separator is not included in the consideration, so the prefix might not stop on a separator boundary.

```
import os.path

paths = ['/one/two/three/four',
         '/one/two/threefold',
         '/one/two/three/',
         ]
print paths
print os.path.commonprefix(paths)
```

In this example the common prefix string is `/one/two/three`, even though one path does not include a directory named `three`.

```
$ python ospath_commonprefix.py

['/one/two/three/four', '/one/two/threefold', '/one/two/three/']
/one/two/three
```

12.1.2 Building Paths

Besides taking existing paths apart, you will frequently need to build paths from other strings.

To combine several path components into a single value, use `join()`:

```
import os.path

for parts in [ ('one', 'two', 'three'),
               ('/', 'one', 'two', 'three'),
               ('/one', '/two', '/three'),
               ]:
    print parts, ':', os.path.join(*parts)
```

```
$ python ospath_join.py

('one', 'two', 'three') : one/two/three
('/', 'one', 'two', 'three') : /one/two/three
('/one', '/two', '/three') : /three
```

It's also easy to work with paths that include "variable" components that can be expanded automatically. For example, `expanduser()` converts the tilde (~) character to a user's home directory.

```
import os.path

for user in [ '', 'dhellmann', 'postgres' ]:
    lookup = '~' + user
    print lookup, ':', os.path.expanduser(lookup)
```

```
$ python ospath_expanduser.py

~ : /Users/dhellmann
~dhellmann : /Users/dhellmann
~postgres : /Library/PostgreSQL/9.0
```

`expandvars()` is more general, and expands any shell environment variables present in the path.

```
import os.path
import os

os.environ['MYVAR'] = 'VALUE'

print os.path.expandvars('/path/to/$MYVAR')
```

```
$ python ospath_expandvars.py

/path/to/VALUE
```

12.1.3 Normalizing Paths

Paths assembled from separate strings using `join()` or with embedded variables might end up with extra separators or relative path components. Use `normpath()` to clean them up:

```
import os.path

for path in [ 'one//two//three',
              'one/./two/./three',
              'one/../one/two/three',
              ]:
    print path, ':', os.path.normpath(path)
```

```
$ python ospath_normpath.py

one//two//three : one/two/three
one/./two/./three : one/two/three
one/../one/two/three : one/two/three
```

To convert a relative path to a complete absolute filename, use `abspath()`.

```
import os.path

for path in [ '.', '..', './one/two/three', '../one/two/three']:
    print '"%s" : "%s"' % (path, os.path.abspath(path))
```

```
$ python ospath_abspath.py

"." : "/Users/dhellmann/Documents/PyMOTW/src/PyMOTW/ospath"
".." : "/Users/dhellmann/Documents/PyMOTW/src/PyMOTW"
"./one/two/three" : "/Users/dhellmann/Documents/PyMOTW/src/PyMOTW/ospath/one/two/three"
"../one/two/three" : "/Users/dhellmann/Documents/PyMOTW/src/PyMOTW/one/two/three"
```

12.1.4 File Times

Besides working with paths, os.path also includes some functions for retrieving file properties, which can be more convenient than calling `os.stat()`:

```
import os.path
import time

print 'File         :', __file__
print 'Access time  :', time.ctime(os.path.getatime(__file__))
print 'Modified time:', time.ctime(os.path.getmtime(__file__))
print 'Change time  :', time.ctime(os.path.getctime(__file__))
print 'Size         :', os.path.getsize(__file__)
```

```
$ python ospath_properties.py

File          : ospath_properties.py
Access time   : Thu Feb 21 06:36:29 2013
```

```
Modified time: Sat Feb 19 19:18:23 2011
Change time  : Sat Jul 16 12:28:42 2011
Size         : 495
```

12.1.5 Testing Files

When your program encounters a path name, it often needs to know whether the path refers to a file or directory. If you are working on a platform that supports it, you may need to know if the path refers to a symbolic link or mount point. You will also want to test whether the path exists or not. `os.path` provides functions to test all of these conditions.

```
import os.path

for file in [ __file__, os.path.dirname(__file__), '/', './broken_link']:
    print 'File        :', file
    print 'Absolute    :', os.path.isabs(file)
    print 'Is File?    :', os.path.isfile(file)
    print 'Is Dir?     :', os.path.isdir(file)
    print 'Is Link?    :', os.path.islink(file)
    print 'Mountpoint? :', os.path.ismount(file)
    print 'Exists?     :', os.path.exists(file)
    print 'Link Exists?:', os.path.lexists(file)
    print
```

```
$ ln -s /does/not/exist broken_link
$ python ospath_tests.py

File        : ospath_tests.py
Absolute    : False
Is File?    : True
Is Dir?     : False
Is Link?    : False
Mountpoint? : False
Exists?     : True
Link Exists?: True

File        :
Absolute    : False
Is File?    : False
Is Dir?     : False
Is Link?    : False
Mountpoint? : False
Exists?     : False
Link Exists?: False

File        : /
Absolute    : True
Is File?    : False
Is Dir?     : True
Is Link?    : False
Mountpoint? : True
Exists?     : True
Link Exists?: True

File        : ./broken_link
Absolute    : False
Is File?    : False
Is Dir?     : False
Is Link?    : True
Mountpoint? : False
Exists?     : False
Link Exists?: True
```

12.1.6 Traversing a Directory Tree

`os.path.walk()` traverses all of the directories in a tree and calls a function you provide passing the directory name and the names of the contents of that directory. This example produces a recursive directory listing, ignoring `.svn` directories.

```
import os
import os.path
import pprint

def visit(arg, dirname, names):
    print dirname, arg
    for name in names:
        subname = os.path.join(dirname, name)
        if os.path.isdir(subname):
            print '  %s/' % name
        else:
            print '  %s' % name
    print

os.mkdir('example')
os.mkdir('example/one')
f = open('example/one/file.txt', 'wt')
f.write('contents')
f.close()
f = open('example/two.txt', 'wt')
f.write('contents')
f.close()
os.path.walk('example', visit, '(User data)')
```

```
$ python ospath_walk.py

example (User data)
  one/
  two.txt

example/one (User data)
  file.txt
```

See also:

os.path (http://docs.python.org/lib/module-os.path.html) Standard library documentation for this module.

`os` The os module is a parent of os.path.

File Access Other tools for working with files.

12.2 fileinput – Process lines from input streams

Purpose Create command-line filter programs to process lines from input streams.

Available In 1.5.2 and later

The fileinput module is a framework for creating command line programs for processing text files in a filter-ish manner.

12.2.1 Converting M3U files to RSS

For example, the m3utorss (http://www.doughellmann.com/projects/m3utorss) app I recently wrote for my friend Patrick (http://events.mediumloud.com/) to convert some of his demo recordings into a podcastable format.

The inputs to the program are one or more m3u file listing the mp3 files to be distributed. The output is a single blob of XML that looks like an RSS feed (output is written to stdout, for simplicity). To process the input, I need to iterate over the list of filenames and:

- Open each file.
- Read each line of the file.
- Figure out if the line refers to an mp3 file.
- If it does, extract the information from the mp3 file needed for the RSS feed.
- Print the output.

I could have written all of that file handling out by hand. It isn't that complicated, and with some testing I'm sure I could even get the error handling right. But with the fileinput module, I don't need to worry about that. I just write something like:

```
for line in fileinput.input(sys.argv[1:]):
    mp3filename = line.strip()
    if not mp3filename or mp3filename.startswith('#'):
        continue
    item = SubElement(rss, 'item')
    title = SubElement(item, 'title')
    title.text = mp3filename
    encl = SubElement(item, 'enclosure', {'type':'audio/mpeg', 'url':mp3filename})
```

The `fileinput.input()` function takes as argument a list of filenames to examine. If the list is empty, the module reads data from standard input. The function returns an iterator which returns individual lines from the text files being processed. So, all I have to do is loop over each line, skipping blanks and comments, to find the references to mp3 files.

Here's the complete program:

```
import fileinput
import sys
import time
from xml.etree.ElementTree import Element, SubElement, tostring
from xml.dom import minidom

# Establish the RSS and channel nodes
rss = Element('rss', {'xmlns:dc':"http://purl.org/dc/elements/1.1/",
                      'version':'2.0',
                      })
channel = SubElement(rss, 'channel')
title = SubElement(channel, 'title')
title.text = 'Sample podcast feed'
desc = SubElement(channel, 'description')
desc.text = 'Generated for PyMOTW'
pubdate = SubElement(channel, 'pubDate')
pubdate.text = time.asctime()
```

```
gen = SubElement(channel, 'generator')
gen.text = 'http://www.doughellmann.com/PyMOTW/'

for line in fileinput.input(sys.argv[1:]):
    mp3filename = line.strip()
    if not mp3filename or mp3filename.startswith('#'):
        continue
    item = SubElement(rss, 'item')
    title = SubElement(item, 'title')
    title.text = mp3filename
    encl = SubElement(item, 'enclosure', {'type':'audio/mpeg', 'url':mp3filename})

rough_string = tostring(rss)
reparsed = minidom.parseString(rough_string)
print reparsed.toprettyxml(indent="  ")
```

and its output:

```
$ python fileinput_example.py sample_data.m3u

<?xml version="1.0" ?>
<rss version="2.0" xmlns:dc="http://purl.org/dc/elements/1.1/">
  <channel>
    <title>
      Sample podcast feed
    </title>
    <description>
      Generated for PyMOTW
    </description>
    <pubDate>
      Thu Feb 21 06:35:49 2013
    </pubDate>
    <generator>
      http://www.doughellmann.com/PyMOTW/
    </generator>
  </channel>
  <item>
    <title>
      episode-one.mp3
    </title>
    <enclosure type="audio/mpeg" url="episode-one.mp3"/>
  </item>
  <item>
    <title>
      episode-two.mp3
    </title>
    <enclosure type="audio/mpeg" url="episode-two.mp3"/>
  </item>
</rss>
```

12.2.2 Progress Meta-data

In the previous example, I did not care what file or line number we are processing in the input. For other tools (grep-like searching, for example) you might. The fileinput module includes functions for accessing that information (`filename()`, `filelineno()`, `lineno()`, etc.).

```
import fileinput
import re
import sys

pattern = re.compile(sys.argv[1])

for line in fileinput.input(sys.argv[2:]):
    if pattern.search(line):
        if fileinput.isstdin():
            fmt = '{lineno}:{line}'
        else:
            fmt = '{filename:<20}:{lineno}:{line}'
        print fmt.format(filename=fileinput.filename(),
                         lineno=fileinput.filelineno(),
                         line=line.rstrip())
```

We can use this basic pattern matching loop to find the occurances of "fileinput" in the source for the examples.

```
$ python fileinput_grep.py fileinput *.py

fileinput_change_subnet.py:10:import fileinput
fileinput_change_subnet.py:17:for line in fileinput.input(files, inplace=True):
fileinput_change_subnet_noisy.py:10:import fileinput
fileinput_change_subnet_noisy.py:18:for line in fileinput.input(files, inplace=True):
fileinput_change_subnet_noisy.py:19:    if fileinput.isfirstline():
fileinput_change_subnet_noisy.py:20:        sys.stderr.write('Started processing %s\n' % fileinput.fi
fileinput_example.py:6:"""Example for fileinput module.
fileinput_example.py:10:import fileinput
fileinput_example.py:30:for line in fileinput.input(sys.argv[1:]):
fileinput_grep.py   :10:import fileinput
fileinput_grep.py   :16:for line in fileinput.input(sys.argv[2:]):
fileinput_grep.py   :18:        if fileinput.isstdin():
fileinput_grep.py   :22:        print fmt.format(filename=fileinput.filename(),
fileinput_grep.py   :23:                         lineno=fileinput.filelineno(),
```

We can also pass input to it through stdin.

```
$ cat *.py | python fileinput_grep.py fileinput

10:import fileinput
17:for line in fileinput.input(files, inplace=True):
29:import fileinput
37:for line in fileinput.input(files, inplace=True):
38:    if fileinput.isfirstline():
39:        sys.stderr.write('Started processing %s\n' % fileinput.filename())
51:"""Example for fileinput module.
55:import fileinput
75:for line in fileinput.input(sys.argv[1:]):
96:import fileinput
102:for line in fileinput.input(sys.argv[2:]):
104:        if fileinput.isstdin():
108:        print fmt.format(filename=fileinput.filename(),
109:                         lineno=fileinput.filelineno(),
```

12.2.3 In-place Filtering

Another common file processing operation is to modify the contents. For example, a Unix hosts file might need to be updated if a subnet range changes.

```
##
# Host Database
#
# localhost is used to configure the loopback interface
# when the system is booting.  Do not change this entry.
##
127.0.0.1       localhost
255.255.255.255 broadcasthost
::1             localhost
fe80::1%lo0     localhost
172.16.177.128  hubert hubert.hellfly.net
172.16.177.132  cubert cubert.hellfly.net
172.16.177.136  zoidberg zoidberg.hellfly.net
```

The safe way to make the change automatically is to create a new file based on the input and then replace the original with the edited copy. fileinput supports this automatically using the *inplace* option.

```
import fileinput
import sys

from_base = sys.argv[1]
to_base = sys.argv[2]
files = sys.argv[3:]

for line in fileinput.input(files, inplace=True):
    line = line.rstrip().replace(from_base, to_base)
    print line
```

```
$ python fileinput_change_subnet.py 172.16.177 172.16.178 etc_hosts.txt
```

Although the script uses `print`, no output is produced to stdout because fileinput maps stdout to the file being overwritten.

```
##
# Host Database
#
# localhost is used to configure the loopback interface
# when the system is booting.  Do not change this entry.
##
127.0.0.1       localhost
255.255.255.255 broadcasthost
::1             localhost
fe80::1%lo0     localhost
172.16.178.128  hubert hubert.hellfly.net
172.16.178.132  cubert cubert.hellfly.net
172.16.178.136  zoidberg zoidberg.hellfly.net
```

Before processing begins, a backup file is created using the original name plus `.bak`. The backup file is removed when the input is closed.

```
import fileinput
import glob
import sys
```

```
from_base = sys.argv[1]
to_base = sys.argv[2]
files = sys.argv[3:]

for line in fileinput.input(files, inplace=True):
    if fileinput.isfirstline():
        sys.stderr.write('Started processing %s\n' % fileinput.filename())
        sys.stderr.write('Directory contains: %s\n' % glob.glob('etc_hosts.txt*'))
    line = line.rstrip().replace(from_base, to_base)
    print line

sys.stderr.write('Finished processing\n')
sys.stderr.write('Directory contains: %s\n' % glob.glob('etc_hosts.txt*'))
```

```
$ python fileinput_change_subnet_noisy.py 172.16.177 172.16.178 etc_host\
s.txt

Started processing etc_hosts.txt
Directory contains: ['etc_hosts.txt', 'etc_hosts.txt.bak']
Finished processing
Directory contains: ['etc_hosts.txt']
```

See also:

fileinput (http://docs.python.org/library/fileinput.html) The standard library documentation for this module.

Patrick Bryant (http://events.mediumloud.com/) Atlanta-based singer/song-writer.

m3utorss (http://www.doughellmann.com/projects/m3utorss) Script to convert m3u files listing MP3s to an RSS file suitable for use as a podcast feed.

Creating XML Documents More details of using ElementTree to produce XML.

File Access Other modules for working with files.

Text Processing Tools Other modules for working with text.

12.3 filecmp – Compare files

Purpose Compare files and directories on the filesystem.

Available In 2.1 and later

12.3.1 Example Data

The examples in the discussion below use a set of test files created by `filecmp_mkexamples.py`.

```
import os

def mkfile(filename, body=None):
    with open(filename, 'w') as f:
        f.write(body or filename)
    return

def make_example_dir(top):
    if not os.path.exists(top):
        os.mkdir(top)
    curdir = os.getcwd()
    os.chdir(top)

    os.mkdir('dir1')
    os.mkdir('dir2')

    mkfile('dir1/file_only_in_dir1')
    mkfile('dir2/file_only_in_dir2')

    os.mkdir('dir1/dir_only_in_dir1')
    os.mkdir('dir2/dir_only_in_dir2')

    os.mkdir('dir1/common_dir')
    os.mkdir('dir2/common_dir')

    mkfile('dir1/common_file', 'this file is the same')
    mkfile('dir2/common_file', 'this file is the same')

    mkfile('dir1/not_the_same')
    mkfile('dir2/not_the_same')

    mkfile('dir1/file_in_dir1', 'This is a file in dir1')
    os.mkdir('dir2/file_in_dir1')

    os.chdir(curdir)
    return

if __name__ == '__main__':
    os.chdir(os.path.dirname(__file__) or os.getcwd())
    make_example_dir('example')
    make_example_dir('example/dir1/common_dir')
    make_example_dir('example/dir2/common_dir')
```

```
$ ls -Rlast example
total 0
0 drwxr-xr-x  4 dhellmann  dhellmann  136 Apr 20 17:04 .
0 drwxr-xr-x  9 dhellmann  dhellmann  306 Apr 20 17:04 ..
0 drwxr-xr-x  8 dhellmann  dhellmann  272 Apr 20 17:04 dir1
0 drwxr-xr-x  8 dhellmann  dhellmann  272 Apr 20 17:04 dir2

example/dir1:
total 32
0 drwxr-xr-x  8 dhellmann  dhellmann  272 Apr 20 17:04 .
0 drwxr-xr-x  4 dhellmann  dhellmann  136 Apr 20 17:04 ..
0 drwxr-xr-x  2 dhellmann  dhellmann   68 Apr 20 17:04 common_dir
8 -rw-r--r--  1 dhellmann  dhellmann   21 Apr 20 17:04 common_file
0 drwxr-xr-x  2 dhellmann  dhellmann   68 Apr 20 17:04 dir_only_in_dir1
8 -rw-r--r--  1 dhellmann  dhellmann   22 Apr 20 17:04 file_in_dir1
8 -rw-r--r--  1 dhellmann  dhellmann   22 Apr 20 17:04 file_only_in_dir1
8 -rw-r--r--  1 dhellmann  dhellmann   17 Apr 20 17:04 not_the_same

example/dir2:
total 24
0 drwxr-xr-x  8 dhellmann  dhellmann  272 Apr 20 17:04 .
0 drwxr-xr-x  4 dhellmann  dhellmann  136 Apr 20 17:04 ..
0 drwxr-xr-x  2 dhellmann  dhellmann   68 Apr 20 17:04 common_dir
8 -rw-r--r--  1 dhellmann  dhellmann   21 Apr 20 17:04 common_file
0 drwxr-xr-x  2 dhellmann  dhellmann   68 Apr 20 17:04 dir_only_in_dir2
```

```
0 drwxr-xr-x  2 dhellmann  dhellmann   68 Apr 20 17:04 file_in_dir1
8 -rw-r--r--  1 dhellmann  dhellmann   22 Apr 20 17:04 file_only_in_dir2
8 -rw-r--r--  1 dhellmann  dhellmann   17 Apr 20 17:04 not_the_same
```

The same directory structure is repeated one time under the "common_dir" directories to give interesting recursive comparison options.

12.3.2 Comparing Files

The filecmp module includes functions and a class for comparing files and directories on the filesystem. If you need to compare two files, use the cmp() function.

```
import filecmp

print 'common_file:',
print filecmp.cmp('example/dir1/common_file',
                  'example/dir2/common_file'),
print filecmp.cmp('example/dir1/common_file',
                  'example/dir2/common_file',
                  shallow=False)

print 'not_the_same:',
print filecmp.cmp('example/dir1/not_the_same',
                  'example/dir2/not_the_same'),
print filecmp.cmp('example/dir1/not_the_same',
                  'example/dir2/not_the_same',
                  shallow=False)

print 'identical:',
print filecmp.cmp('example/dir1/file_only_in_dir1',
                  'example/dir1/file_only_in_dir1'),
print filecmp.cmp('example/dir1/file_only_in_dir1',
                  'example/dir1/file_only_in_dir1',
                  shallow=False)
```

By default, cmp() looks only at the information available from os.stat(). The shallow argument tells cmp() whether to look at the contents of the file, as well. The default is to perform a shallow comparison, without looking inside the files. Notice that files of the same size created at the same time seem to be the same if their contents are not compared.

```
$ python filecmp_cmp.py

common_file: True True
not_the_same: True False
identical: True True
```

To compare a set of files in two directories without recursing, use filecmp.cmpfiles(). The arguments are the names of the directories and a list of files to be checked in the two locations. The list of common files should contain only filenames (directories always result in a mismatch) and the files must be present in both locations. The code below shows a simple way to build the common list. If you have a shorter formula, post it in the comments. The comparison also takes the shallow flag, just as with cmp().

```
import filecmp
import os

# Determine the items that exist in both directories
d1_contents = set(os.listdir('example/dir1'))
d2_contents = set(os.listdir('example/dir2'))
```

```
common = list(d1_contents & d2_contents)
common_files = [ f
                for f in common
                if os.path.isfile(os.path.join('example/dir1', f))
                ]
print 'Common files:', common_files

# Compare the directories
match, mismatch, errors = filecmp.cmpfiles('example/dir1',
                                           'example/dir2',
                                           common_files)
print 'Match:', match
print 'Mismatch:', mismatch
print 'Errors:', errors
```

cmpfiles() returns three lists of filenames for files that match, files that do not match, and files that could not be compared (due to permission problems or for any other reason).

```
$ python filecmp_cmpfiles.py

Common files: ['not_the_same', 'file_in_dir1', 'common_file']
Match: ['not_the_same', 'common_file']
Mismatch: ['file_in_dir1']
Errors: []
```

12.3.3 Using dircmp

The functions described above are suitable for relatively simple comparisons, but for recursive comparison of large directory trees or for more complete analysis, the dircmp class is more useful. In its simplest use case, you can print a report comparing two directories with the report() method:

```
import filecmp

filecmp.dircmp('example/dir1', 'example/dir2').report()
```

The output is a plain-text report showing the results of just the contents of the directories given, without recursing. In this case, the file "not_the_same" is thought to be the same because the contents are not being compared. There is no way to have dircmp compare the contents of files like cmp() can.

```
$ python filecmp_dircmp_report.py

diff example/dir1 example/dir2
Only in example/dir1 : ['dir_only_in_dir1', 'file_only_in_dir1']
Only in example/dir2 : ['dir_only_in_dir2', 'file_only_in_dir2']
Identical files : ['common_file', 'not_the_same']
Common subdirectories : ['common_dir']
Common funny cases : ['file_in_dir1']
```

For more detail, and a recursive comparison, use report_full_closure():

```
import filecmp

filecmp.dircmp('example/dir1', 'example/dir2').report_full_closure()
```

The output includes comparisons of all parallel subdirectories.

```
$ python filecmp_dircmp_report_full_closure.py

diff example/dir1 example/dir2
Only in example/dir1 : ['dir_only_in_dir1', 'file_only_in_dir1']
Only in example/dir2 : ['dir_only_in_dir2', 'file_only_in_dir2']
Identical files : ['common_file', 'not_the_same']
Common subdirectories : ['common_dir']
Common funny cases : ['file_in_dir1']

diff example/dir1/common_dir example/dir2/common_dir
Common subdirectories : ['dir1', 'dir2']

diff example/dir1/common_dir/dir2 example/dir2/common_dir/dir2
Identical files : ['common_file', 'file_only_in_dir2', 'not_the_same']
Common subdirectories : ['common_dir', 'dir_only_in_dir2', 'file_in_dir1']

diff example/dir1/common_dir/dir2/common_dir example/dir2/common_dir/dir2/common_dir

diff example/dir1/common_dir/dir2/dir_only_in_dir2 example/dir2/common_dir/dir2/dir_only_in_dir2

diff example/dir1/common_dir/dir2/file_in_dir1 example/dir2/common_dir/dir2/file_in_dir1

diff example/dir1/common_dir/dir1 example/dir2/common_dir/dir1
Identical files : ['common_file', 'file_in_dir1', 'file_only_in_dir1', 'not_the_same']
Common subdirectories : ['common_dir', 'dir_only_in_dir1']

diff example/dir1/common_dir/dir1/common_dir example/dir2/common_dir/dir1/common_dir

diff example/dir1/common_dir/dir1/dir_only_in_dir1 example/dir2/common_dir/dir1/dir_only_in_dir1
```

12.3.4 Using differences in your program

Besides producing printed reports, dircmp calculates useful lists of files you can use in your programs directly. Each of the following attributes is calculated only when requested, so instantiating a dircmp does not incur a lot of extra overhead.

The files and subdirectories contained in the directories being compared are listed in left_list and right_list:

```
import filecmp

dc = filecmp.dircmp('example/dir1', 'example/dir2')
print 'Left :', dc.left_list
print 'Right:', dc.right_list
```

```
$ python filecmp_dircmp_list.py

Left : ['common_dir', 'common_file', 'dir_only_in_dir1', 'file_in_dir1', 'file_only_in_dir1', 'not_th
Right: ['common_dir', 'common_file', 'dir_only_in_dir2', 'file_in_dir1', 'file_only_in_dir2', 'not_th
```

The inputs can be filtered by passing a list of names to ignore to the constructor. By default the names RCS, CVS, and tags are ignored.

```
import filecmp

dc = filecmp.dircmp('example/dir1', 'example/dir2', ignore=['common_file'])
print 'Left :', dc.left_list
print 'Right:', dc.right_list
```

In this case, the “common_file” is left out of the list of files to be compared.

```
$ python filecmp_dircmp_list_filter.py

Left : ['common_dir', 'dir_only_in_dir1', 'file_in_dir1', 'file_only_in_dir1', 'not_the_same']
Right: ['common_dir', 'dir_only_in_dir2', 'file_in_dir1', 'file_only_in_dir2', 'not_the_same']
```

The set of files common to both input directories is maintained in common, and the files unique to each directory are listed in left_only, and right_only.

```
import filecmp

dc = filecmp.dircmp('example/dir1', 'example/dir2')
print 'Common:', dc.common
print 'Left  :', dc.left_only
print 'Right :', dc.right_only
```

```
$ python filecmp_dircmp_membership.py

Common: ['not_the_same', 'common_file', 'file_in_dir1', 'common_dir']
Left  : ['dir_only_in_dir1', 'file_only_in_dir1']
Right : ['dir_only_in_dir2', 'file_only_in_dir2']
```

The common members can be further broken down into files, directories and “funny” items (anything that has a different type in the two directories or where there is an error from os.stat()).

```
import filecmp

dc = filecmp.dircmp('example/dir1', 'example/dir2')
print 'Common     :', dc.common
print 'Directories:', dc.common_dirs
print 'Files      :', dc.common_files
print 'Funny      :', dc.common_funny
```

In the example data, the item named “file_in_dir1” is a file in one directory and a subdirectory in the other, so it shows up in the “funny” list.

```
$ python filecmp_dircmp_common.py

Common     : ['not_the_same', 'common_file', 'file_in_dir1', 'common_dir']
Directories: ['common_dir']
Files      : ['not_the_same', 'common_file']
Funny      : ['file_in_dir1']
```

The differences between files are broken down similarly:

```
import filecmp

dc = filecmp.dircmp('example/dir1', 'example/dir2')
print 'Same      :', dc.same_files
print 'Different :', dc.diff_files
print 'Funny     :', dc.funny_files
```

Remember, the file “not_the_same” is only being compared via os.stat, and the contents are not examined.

```
$ python filecmp_dircmp_diff.py

Same      : ['not_the_same', 'common_file']
Different : []
Funny     : []
```

Finally, the subdirectories are also mapped to new dircmp objects in the attribute subdirs to allow easy recursive comparison.

```
import filecmp

dc = filecmp.dircmp('example/dir1', 'example/dir2')
print 'Subdirectories:'
print dc.subdirs
```

```
$ python filecmp_dircmp_subdirs.py
Subdirectories:
{'common_dir': <filecmp.dircmp instance at 0x85da0>}
```

See also:

filecmp (http://docs.python.org/library/filecmp.html) The standard library documentation for this module.

Directories **from** `os` Listing the contents of a directory.

`difflib` Computing the differences between two sequences.

12.4 tempfile – Create temporary filesystem resources.

Purpose Create temporary filesystem resources.

Available In Since 1.4 with major security revisions in 2.3

Many programs need to create files to write intermediate data. Creating files with unique names securely, so they cannot be guessed by someone wanting to break the application, is challenging. The `tempfile` module provides several functions for creating filesystem resources securely. `TemporaryFile()` opens and returns an un-named file, `NamedTemporaryFile()` opens and returns a named file, and `mkdtemp()` creates a temporary directory and returns its name.

12.4.1 TemporaryFile

If your application needs a temporary file to store data, but does not need to share that file with other programs, the best option for creating the file is the `TemporaryFile()` function. It creates a file, and on platforms where it is possible, unlinks it immediately. This makes it impossible for another program to find or open the file, since there is no reference to it in the filesystem table. The file created by `TemporaryFile()` is removed automatically when it is closed.

```
import os
import tempfile

print 'Building a file name yourself:'
filename = '/tmp/guess_my_name.%s.txt' % os.getpid()
temp = open(filename, 'w+b')
try:
    print 'temp:', temp
    print 'temp.name:', temp.name
finally:
    temp.close()
    # Clean up the temporary file yourself
    os.remove(filename)

print
```

```
print 'TemporaryFile:'
temp = tempfile.TemporaryFile()
try:
    print 'temp:', temp
    print 'temp.name:', temp.name
finally:
    # Automatically cleans up the file
    temp.close()
```

This example illustrates the difference in creating a temporary file using a common pattern for making up a name, versus using the `TemporaryFile()` function. Notice that the file returned by `TemporaryFile()` has no name.

```
$ python tempfile_TemporaryFile.py

Building a file name yourself:
temp: <open file '/tmp/guess_my_name.14891.txt', mode 'w+b' at 0x100458270>
temp.name: /tmp/guess_my_name.14891.txt

TemporaryFile:
temp: <open file '<fdopen>', mode 'w+b' at 0x100458780>
temp.name: <fdopen>
```

By default, the file handle is created with mode `'w+b'` so it behaves consistently on all platforms and your program can write to it and read from it.

```
import os
import tempfile

temp = tempfile.TemporaryFile()
try:
    temp.write('Some data')
    temp.seek(0)

    print temp.read()
finally:
    temp.close()
```

After writing, you have to rewind the file handle using `seek()` in order to read the data back from it.

```
$ python tempfile_TemporaryFile_binary.py

Some data
```

If you want the file to work in text mode, set *mode* to `'w+t'` when you create it:

```
import tempfile

f = tempfile.TemporaryFile(mode='w+t')
try:
    f.writelines(['first\n', 'second\n'])
    f.seek(0)

    for line in f:
        print line.rstrip()
finally:
    f.close()
```

The file handle treats the data as text:

```
$ python tempfile_TemporaryFile_text.py

first
second
```

12.4.2 NamedTemporaryFile

There are situations, however, where having a named temporary file is important. If your application spans multiple processes, or even hosts, naming the file is the simplest way to pass it between parts of the application. The `NamedTemporaryFile()` function creates a file with a name, accessed from the name attribute.

```
import os
import tempfile

temp = tempfile.NamedTemporaryFile()
try:
    print 'temp:', temp
    print 'temp.name:', temp.name
finally:
    # Automatically cleans up the file
    temp.close()
print 'Exists after close:', os.path.exists(temp.name)
```

Even though the file is named, it is still removed after the handle is closed.

```
$ python tempfile_NamedTemporaryFile.py

temp: <open file '<fdopen>', mode 'w+b' at 0x100458270>
temp.name: /var/folders/5q/8gk0wq888xlggz008k8dr7180000hg/T/tmpIIkknb
Exists after close: False
```

12.4.3 mkdtemp

If you need several temporary files, it may be more convenient to create a single temporary directory and then open all of the files in that directory. To create a temporary directory, use `mkdtemp()`.

```
import os
import tempfile

directory_name = tempfile.mkdtemp()
print directory_name
# Clean up the directory yourself
os.removedirs(directory_name)
```

Since the directory is not "opened" per se, you have to remove it yourself when you are done with it.

```
$ python tempfile_mkdtemp.py

/var/folders/5q/8gk0wq888xlggz008k8dr7180000hg/T/tmpE4plSY
```

12.4.4 Predicting Names

For debugging purposes, it is useful to be able to include some indication of the origin of the temporary files. While obviously less secure than strictly anonymous temporary files, including a predictable portion in the name lets you find the file to examine it while your program is using it. All of the functions described so far take three arguments to allow you to control the filenames to some degree. Names are generated using the formula:

```
dir + prefix + random + suffix
```

where all of the values except random can be passed as arguments to `TemporaryFile()`, `NamedTemporaryFile()`, and `mkdtemp()`. For example:

```
import tempfile

temp = tempfile.NamedTemporaryFile(suffix='_suffix',
                                   prefix='prefix_',
                                   dir='/tmp',
                                   )
try:
    print 'temp:', temp
    print 'temp.name:', temp.name
finally:
    temp.close()
```

The *prefix* and *suffix* arguments are combined with a random string of characters to build the file name, and the *dir* argument is taken as-is and used as the location of the new file.

```
$ python tempfile_NamedTemporaryFile_args.py

temp: <open file '<fdopen>', mode 'w+b' at 0x100458270>
temp.name: /tmp/prefix_SMkGcX_suffix
```

12.4.5 Temporary File Location

If you don't specify an explicit destination using the *dir* argument, the actual path used for the temporary files will vary based on your platform and settings. The tempfile module includes two functions for querying the settings being used at runtime:

```
import tempfile

print 'gettempdir():', tempfile.gettempdir()
print 'gettempprefix():', tempfile.gettempprefix()
```

`gettempdir()` returns the default directory that will hold all of the temporary files and `gettempprefix()` returns the string prefix for new file and directory names.

```
$ python tempfile_settings.py

gettempdir(): /var/folders/5q/8gk0wq888xlggz008k8dr7180000hg/T
gettempprefix(): tmp
```

The value returned by `gettempdir()` is set based on a straightforward algorithm of looking through a list of locations for the first place the current process can create a file. From the library documentation:

Python searches a standard list of directories and sets tempdir to the first one which the calling user can create files in. The list is:

1. The directory named by the `TMPDIR` environment variable.
2. The directory named by the `TEMP` environment variable.
3. The directory named by the `TMP` environment variable.
4. A platform-specific location:

   - On RiscOS, the directory named by the `Wimp$ScrapDir` environment variable.
   - On Windows, the directories `C:\TEMP`, `C:\TMP`, `\TEMP`, and `\TMP`, in that order.
   - On all other platforms, the directories `/tmp`, `/var/tmp`, and `/usr/tmp`, in that order.

5. As a last resort, the current working directory.

If your program needs to use a global location for all temporary files that you need to set explicitly but do not want to set through one of these environment variables, you can set `tempfile.tempdir` directly.

```
import tempfile

tempfile.tempdir = '/I/changed/this/path'
print 'gettempdir():', tempfile.gettempdir()
```

```
$ python tempfile_tempdir.py

gettempdir(): /I/changed/this/path
```

See also:

tempfile (http://docs.python.org/lib/module-tempfile.html) Standard library documentation for this module.

File Access More modules for working with files.

12.5 glob – Filename pattern matching

Purpose Use Unix shell rules to fine filenames matching a pattern.

Available In 1.4

Even though the glob API is very simple, the module packs a lot of power. It is useful in any situation where your program needs to look for a list of files on the filesystem with names matching a pattern. If you need a list of filenames that all have a certain extension, prefix, or any common string in the middle, use `glob` instead of writing code to scan the directory contents yourself.

The pattern rules for glob are not regular expressions. Instead, they follow standard Unix path expansion rules. There are only a few special characters: two different wild-cards, and character ranges are supported. The patterns rules are applied to segments of the filename (stopping at the path separator, `/`). Paths in the pattern can be relative or absolute. Shell variable names and tilde (~) are not expanded.

12.5.1 Example Data

The examples below assume the following test files are present in the current working directory:

```
$ python glob_maketestdata.py

dir
dir/file.txt
dir/file1.txt
dir/file2.txt
dir/filea.txt
dir/fileb.txt
dir/subdir
dir/subdir/subfile.txt
```

Note: Use `glob_maketestdata.py` in the sample code to create these files if you want to run the examples.

12.5.2 Wildcards

An asterisk (`*`) matches zero or more characters in a segment of a name. For example, `dir/*`.

```
import glob
for name in glob.glob('dir/*'):
    print name
```

The pattern matches every pathname (file or directory) in the directory dir, without recursing further into subdirectories.

```
$ python glob_asterisk.py

dir/file.txt
dir/file1.txt
dir/file2.txt
dir/filea.txt
dir/fileb.txt
dir/subdir
```

To list files in a subdirectory, you must include the subdirectory in the pattern:

```
import glob

print 'Named explicitly:'
for name in glob.glob('dir/subdir/*'):
    print '\t', name

print 'Named with wildcard:'
for name in glob.glob('dir/*/*'):
    print '\t', name
```

The first case above lists the subdirectory name explicitly, while the second case depends on a wildcard to find the directory.

```
$ python glob_subdir.py

Named explicitly:
        dir/subdir/subfile.txt
Named with wildcard:
        dir/subdir/subfile.txt
```

The results, in this case, are the same. If there was another subdirectory, the wildcard would match both subdirectories and include the filenames from both.

12.5.3 Single Character Wildcard

The other wildcard character supported is the question mark (`?`). It matches any single character in that position in the name. For example,

```
import glob

for name in glob.glob('dir/file?.txt'):
    print name
```

Matches all of the filenames which begin with "file", have one more character of any type, then end with ".txt".

```
$ python glob_question.py

dir/file1.txt
dir/file2.txt
dir/filea.txt
dir/fileb.txt
```

12.5.4 Character Ranges

When you need to match a specific character, use a character range instead of a question mark. For example, to find all of the files which have a digit in the name before the extension:

```
import glob
for name in glob.glob('dir/*[0-9].*'):
    print name
```

The character range `[0-9]` matches any single digit. The range is ordered based on the character code for each letter/digit, and the dash indicates an unbroken range of sequential characters. The same range value could be written `[0123456789]`.

```
$ python glob_charrange.py

dir/file1.txt
dir/file2.txt
```

See also:

glob **(http://docs.python.org/library/glob.html)** The standard library documentation for this module.

Pattern Matching Notation **(http://www.opengroup.org/onlinepubs/000095399/utilities/xcu_chap02.html#tag_02_13)**
An explanation of globbing from The Open Group's Shell Command Language specification.

fnmatch Filename matching implementation.

File Access Other tools for working with files.

12.6 fnmatch – Compare filenames against Unix-style glob patterns.

Purpose Handle Unix-style filename comparison with the fnmatch module.

Available In 1.4 and later.

The fnmatch module is used to compare filenames against glob-style patterns such as used by Unix shells.

12.6.1 Simple Matching

`fnmatch()` compares a single filename against a pattern and returns a boolean indicating whether or not they match. The comparison is case-sensitive when the operating system uses a case-sensitive filesystem.

```
import fnmatch
import os

pattern = 'fnmatch_*.py'
print 'Pattern :', pattern
```

```
print

files = os.listdir('.')
for name in files:
    print 'Filename: %-25s %s' % (name, fnmatch.fnmatch(name, pattern))
```

In this example, the pattern matches all files starting with 'fnmatch (http://docs.python.org/library/fnmatch.html)' and ending in '.py'.

```
$ python fnmatch_fnmatch.py

Pattern : fnmatch_*.py

Filename: __init__.py               False
Filename: fnmatch_filter.py         True
Filename: fnmatch_fnmatch.py        True
Filename: fnmatch_fnmatchcase.py    True
Filename: fnmatch_translate.py      True
Filename: index.rst                 False
```

To force a case-sensitive comparison, regardless of the filesystem and operating system settings, use `fnmatchcase()`.

```
import fnmatch
import os

pattern = 'FNMATCH_*.PY'
print 'Pattern :', pattern
print

files = os.listdir('.')

for name in files:
    print 'Filename: %-25s %s' % (name, fnmatch.fnmatchcase(name, pattern))
```

Since my laptop uses a case-sensitive filesystem, no files match the modified pattern.

```
$ python fnmatch_fnmatchcase.py

Pattern : FNMATCH_*.PY

Filename: __init__.py               False
Filename: fnmatch_filter.py         False
Filename: fnmatch_fnmatch.py        False
Filename: fnmatch_fnmatchcase.py    False
Filename: fnmatch_translate.py      False
Filename: index.rst                 False
```

12.6.2 Filtering

To test a sequence of filenames, you can use `filter()`. It returns a list of the names that match the pattern argument.

```
import fnmatch
import os

pattern = 'fnmatch_*.py'
print 'Pattern :', pattern
```

```
files = os.listdir('.')
print 'Files   :', files

print 'Matches :', fnmatch.filter(files, pattern)
```

In this example, `filter()` returns the list of names of the example source files associated with this post.

```
$ python fnmatch_filter.py

Pattern : fnmatch_*.py
Files   : ['__init__.py', 'fnmatch_filter.py', 'fnmatch_fnmatch.py', 'fnmatch_fnmatchcase.py', 'fnmat
Matches : ['fnmatch_filter.py', 'fnmatch_fnmatch.py', 'fnmatch_fnmatchcase.py', 'fnmatch_translate.py
```

12.6.3 Translating Patterns

Internally, fnmatch converts the glob pattern to a regular expression and uses the `re` module to compare the name and pattern. The `translate()` function is the public API for converting glob patterns to regular expressions.

```
import fnmatch

pattern = 'fnmatch_*.py'
print 'Pattern :', pattern
print 'Regex   :', fnmatch.translate(pattern)
```

Notice that some of the characters are escaped to make a valid expression.

```
$ python fnmatch_translate.py

Pattern : fnmatch_*.py
Regex   : fnmatch\_.*\.py\Z(?ms)
```

See also:

fnmatch (http://docs.python.org/library/fnmatch.html) The standard library documentation for this module.

`glob` The glob module combines `fnmatch` matching with `os.listdir()` to produce lists of files and directories matching patterns.

File Access More modules for working with files.

12.7 linecache – Read text files efficiently

Purpose Retrieve lines of text from files or imported python modules, holding a cache of the results to make reading many lines from the same file more efficient.

Available In 1.4

The linecache module is used extensively throughout the Python standard library when dealing with Python source files. The implementation of the cache simply holds the contents of files, parsed into separate lines, in a dictionary in memory. The API returns the requested line(s) by indexing into a list. The time savings is from (repeatedly) reading the file and parsing lines to find the one desired. This is especially useful when looking for multiple lines from the same file, such as when producing a traceback for an error report.

12.7.1 Test Data

We will use some text produced by the Lorem Ipsum generator as sample input.

```
import os
import tempfile

lorem = '''Lorem ipsum dolor sit amet, consectetuer adipiscing elit.
Vivamus eget elit. In posuere mi non risus. Mauris id quam posuere
lectus sollicitudin varius. Praesent at mi. Nunc eu velit. Sed augue
massa, fermentum id, nonummy a, nonummy sit amet, ligula. Curabitur
eros pede, egestas at, ultricies ac, pellentesque eu, tellus.

Sed sed odio sed mi luctus mollis. Integer et nulla ac augue convallis
accumsan. Ut felis. Donec lectus sapien, elementum nec, condimentum ac,
interdum non, tellus. Aenean viverra, mauris vehicula semper porttitor,
ipsum odio consectetuer lorem, ac imperdiet eros odio a sapien. Nulla
mauris tellus, aliquam non, egestas a, nonummy et, erat. Vivamus
sagittis porttitor eros.'''

def make_tempfile():
    fd, temp_file_name = tempfile.mkstemp()
    os.close(fd)
    f = open(temp_file_name, 'wt')
    try:
        f.write(lorem)
    finally:
        f.close()
    return temp_file_name

def cleanup(filename):
    os.unlink(filename)
```

12.7.2 Reading Specific Lines

Reading the 5th line from the file is a simple one-liner. Notice that the line numbers in the linecache module start with 1, but if we split the string ourselves we start indexing the array from 0. We also need to strip the trailing newline from the value returned from the cache.

```
import linecache
from linecache_data import *

filename = make_tempfile()

# Pick out the same line from source and cache.
# (Notice that linecache counts from 1)
print 'SOURCE: ', lorem.split('\n')[4]
print 'CACHE : ', linecache.getline(filename, 5).rstrip()

cleanup(filename)
```

```
$ python linecache_getline.py

SOURCE:  eros pede, egestas at, ultricies ac, pellentesque eu, tellus.
CACHE :  eros pede, egestas at, ultricies ac, pellentesque eu, tellus.
```

12.7.3 Handling Blank Lines

Next let's see what happens if the line we want is empty:

```
import linecache
from linecache_data import *

filename = make_tempfile()

# Blank lines include the newline
print '\nBLANK : "%s"' % linecache.getline(filename, 6)

cleanup(filename)
```

```
$ python linecache_empty_line.py


BLANK : "
"
```

12.7.4 Error Handling

If the requested line number falls out of the range of valid lines in the file, linecache returns an empty string.

```
import linecache
from linecache_data import *

filename = make_tempfile()

# The cache always returns a string, and uses
# an empty string to indicate a line which does
# not exist.
not_there = linecache.getline(filename, 500)
print '\nNOT THERE: "%s" includes %d characters' %  (not_there, len(not_there))

cleanup(filename)
```

```
$ python linecache_out_of_range.py


NOT THERE: "" includes 0 characters
```

The module never raises an exception, even if the file does not exist:

```
import linecache

# Errors are even hidden if linecache cannot find the file
no_such_file = linecache.getline('this_file_does_not_exist.txt', 1)
print '\nNO FILE: ', no_such_file
```

```
$ python linecache_missing_file.py


NO FILE:
```

12.7.5 Python Source

Since `linecache` is used so heavily when producing tracebacks, one of the key features is the ability to find Python source modules in the *import path* by specifying the base name of the module. The cache population code in `linecache` searches `sys.path` for the module if it cannot find the file directly.

```
import linecache

# Look for the linecache module, using
# the built in sys.path search.
module_line = linecache.getline('linecache.py', 3)
print '\nMODULE : ', module_line
```

```
$ python linecache_path_search.py


MODULE :  This is intended to read lines from modules imported -- hence if a filename
```

See also:

linecache (http://docs.python.org/library/linecache.html) The standard library documentation for this module.

http://www.ipsum.com/ Lorem Ipsum generator.

File Access Other tools for working with files.

12.8 shutil – High-level file operations.

Purpose High-level file operations.

Available In 1.4 and later

The `shutil` module includes high-level file operations such as copying, setting permissions, etc.

12.8.1 Copying Files

`copyfile()` copies the contents of the source to the destination. Raises *IOError* if you do not have permission to write to the destination file. Because the function opens the input file for reading, regardless of its type, special files cannot be copied as new special files with `copyfile()`.

```
from shutil import *
from glob import glob

print 'BEFORE:', glob('shutil_copyfile.*')
copyfile('shutil_copyfile.py', 'shutil_copyfile.py.copy')
print 'AFTER:', glob('shutil_copyfile.*')
```

```
$ python shutil_copyfile.py

BEFORE: ['shutil_copyfile.py']
AFTER: ['shutil_copyfile.py', 'shutil_copyfile.py.copy']
```

`copyfile()` is written using the lower-level function `copyfileobj()`. While the arguments to `copyfile()` are file names, the arguments to `copyfileobj()` are open file handles. The optional third argument is a buffer length to use for reading in chunks (by default, the entire file is read at one time).

```
from shutil import *
import os
from StringIO import StringIO
import sys

class VerboseStringIO(StringIO):
    def read(self, n=-1):
        next = StringIO.read(self, n)
        print 'read(%d) =>' % n, next
        return next

lorem_ipsum = '''Lorem ipsum dolor sit amet, consectetuer adipiscing elit.
Vestibulum aliquam mollis dolor. Donec vulputate nunc ut diam.
Ut rutrum mi vel sem. Vestibulum ante ipsum.'''

print 'Default:'
input = VerboseStringIO(lorem_ipsum)
output = StringIO()
copyfileobj(input, output)

print

print 'All at once:'
input = VerboseStringIO(lorem_ipsum)
output = StringIO()
copyfileobj(input, output, -1)

print

print 'Blocks of 20:'
input = VerboseStringIO(lorem_ipsum)
output = StringIO()
copyfileobj(input, output, 20)
```

The default behavior is to read using large blocks. Use `-1` to read all of the input at one time or another positive integer to set your own block size.

```
$ python shutil_copyfileobj.py

Default:
read(16384) => Lorem ipsum dolor sit amet, consectetuer adipiscing elit.
Vestibulum aliquam mollis dolor. Donec vulputate nunc ut diam.
Ut rutrum mi vel sem. Vestibulum ante ipsum.
read(16384) =>

All at once:
read(-1) => Lorem ipsum dolor sit amet, consectetuer adipiscing elit.
Vestibulum aliquam mollis dolor. Donec vulputate nunc ut diam.
Ut rutrum mi vel sem. Vestibulum ante ipsum.
read(-1) =>

Blocks of 20:
read(20) => Lorem ipsum dolor si
read(20) => t amet, consectetuer
read(20) =>  adipiscing elit.
V
read(20) => estibulum aliquam mo
read(20) => llis dolor. Donec vu
read(20) => lputate nunc ut diam
read(20) => .
Ut rutrum mi vel
read(20) => sem. Vestibulum ante
read(20) =>  ipsum.
read(20) =>
```

The `copy()` function interprets the output name like the Unix command line tool `cp`. If the named destination refers to a directory instead of a file, a new file is created in the directory using the base name of the source. The permissions of the file are copied along with the contents.

```
from shutil import *
import os

os.mkdir('example')
print 'BEFORE:', os.listdir('example')
copy('shutil_copy.py', 'example')
print 'AFTER:', os.listdir('example')
```

```
$ python shutil_copy.py

BEFORE: []
AFTER: ['shutil_copy.py']
```

`copy2()` works like `copy()`, but includes the access and modification times in the meta-data copied to the new file.

```
from shutil import *
import os
import time

def show_file_info(filename):
    stat_info = os.stat(filename)
    print '\tMode    :', stat_info.st_mode
    print '\tCreated :', time.ctime(stat_info.st_ctime)
    print '\tAccessed:', time.ctime(stat_info.st_atime)
    print '\tModified:', time.ctime(stat_info.st_mtime)

os.mkdir('example')
print 'SOURCE:'
show_file_info('shutil_copy2.py')
copy2('shutil_copy2.py', 'example')
print 'DEST:'
show_file_info('example/shutil_copy2.py')
```

```
$ python shutil_copy2.py

SOURCE:
        Mode    : 33188
        Created : Sat Jul 16 12:28:43 2011
        Accessed: Thu Feb 21 06:36:54 2013
        Modified: Sat Feb 19 19:18:23 2011
DEST:
        Mode    : 33188
        Created : Thu Feb 21 06:36:54 2013
        Accessed: Thu Feb 21 06:36:54 2013
        Modified: Sat Feb 19 19:18:23 2011
```

12.8.2 Copying File Meta-data

By default when a new file is created under Unix, it receives permissions based on the umask of the current user. To copy the permissions from one file to another, use `copymode()`.

```
from shutil import *
from commands import *
import os

f = open('file_to_change.txt', 'wt')
f.write('content')
f.close()
os.chmod('file_to_change.txt', 0444)

print 'BEFORE:', getstatus('file_to_change.txt')
copymode('shutil_copymode.py', 'file_to_change.txt')
print 'AFTER :', getstatus('file_to_change.txt')
```

First, create a file to be modified:

```
#!/bin/sh
# Set up file needed by shutil_copymode.py
touch file_to_change.txt
chmod ugo+w file_to_change.txt
```

Then run the example script to change the permissions.

```
$ python shutil_copymode.py

BEFORE: -r--r--r--  1 dhellmann  dhellmann  7 Feb 21 06:36 file_to_change.txt
AFTER : -rw-r--r--  1 dhellmann  dhellmann  7 Feb 21 06:36 file_to_change.txt
```

To copy other meta-data about the file (permissions, last access time, and last modified time), use `copystat()`.

```
from shutil import *
import os
import time

def show_file_info(filename):
    stat_info = os.stat(filename)
    print '\tMode    :', stat_info.st_mode
    print '\tCreated :', time.ctime(stat_info.st_ctime)
    print '\tAccessed:', time.ctime(stat_info.st_atime)
    print '\tModified:', time.ctime(stat_info.st_mtime)

f = open('file_to_change.txt', 'wt')
f.write('content')
f.close()
os.chmod('file_to_change.txt', 0444)

print 'BEFORE:'
show_file_info('file_to_change.txt')
copystat('shutil_copystat.py', 'file_to_change.txt')
print 'AFTER :'
show_file_info('file_to_change.txt')
```

```
$ python shutil_copystat.py

BEFORE:
        Mode    : 33060
        Created : Thu Feb 21 06:36:54 2013
        Accessed: Thu Feb 21 06:36:54 2013
        Modified: Thu Feb 21 06:36:54 2013
AFTER :
        Mode    : 33188
        Created : Thu Feb 21 06:36:54 2013
        Accessed: Thu Feb 21 06:36:54 2013
        Modified: Sat Feb 19 19:18:23 2011
```

12.8.3 Working With Directory Trees

`shutil` includes 3 functions for working with directory trees. To copy a directory from one place to another, use `copytree()`. It recurses through the source directory tree, copying files to the destination. The destination directory must not exist in advance. The *symlinks* argument controls whether symbolic links are copied as links or as files. The default is to copy the contents to new files. If the option is true, new symlinks are created within the destination tree.

Note: The documentation for `copytree()` says it should be considered a sample implementation, rather than a tool. You may want to copy the implementation and make it more robust, or add features like a progress meter.

```
from shutil import *
from commands import *

print 'BEFORE:'
print getoutput('ls -rlast /tmp/example')
copytree('example', '/tmp/example')
print 'AFTER:'
print getoutput('ls -rlast /tmp/example')
```

```
$ python shutil_copytree.py

BEFORE:
ls: /tmp/example: No such file or directory
AFTER:
total 8
8 -rw-r--r--   1 dhellmann  wheel  1595 Feb 19  2011 shutil_copy2.py
0 drwxrwxrwt  19 root       wheel   646 Feb 21 06:36 ..
0 drwxr-xr-x   3 dhellmann  wheel   102 Feb 21 06:36 .
```

To remove a directory and its contents, use `rmtree()`. Errors are raised as exceptions by default, but can be ignored if the second argument is true, and a special error handler function can be provided in the third argument.

```
from shutil import *
from commands import *

print 'BEFORE:'
print getoutput('ls -rlast /tmp/example')
rmtree('/tmp/example')
print 'AFTER:'
print getoutput('ls -rlast /tmp/example')
```

```
$ python shutil_rmtree.py

BEFORE:
total 8
8 -rw-r--r--   1 dhellmann  wheel  1595 Feb 19  2011 shutil_copy2.py
```

```
0 drwxrwxrwt  19 root       wheel   646 Feb 21 06:36 ..
0 drwxr-xr-x   3 dhellmann  wheel   102 Feb 21 06:36 .
AFTER:
ls: /tmp/example: No such file or directory
```

To move a file or directory from one place to another, use `move()`. The semantics are similar to those of the Unix command `mv`. If the source and destination are within the same filesystem, the source is simply renamed. Otherwise the source is copied to the destination and then the source is removed.

```
from shutil import *
from glob import glob

f = open('example.txt', 'wt')
f.write('contents')
f.close()

print 'BEFORE: ', glob('example*')
move('example.txt', 'example.out')
print 'AFTER : ', glob('example*')
```

```
$ python shutil_move.py

BEFORE:  ['example.txt']
AFTER :  ['example.out']
```

See also:

shutil (http://docs.python.org/lib/module-shutil.html) Standard library documentation for this module.

File Access Other utilities for working with files.

12.9 dircache – Cache directory listings

Purpose Cache directory listings, updating when the modification time of a directory changes.

Available In 1.4 and later

12.9.1 Listing Directory Contents

The main function in the `dircache` API is `listdir()`, a wrapper around `os.listdir()` that caches the results and returns the same `list` each time it is called with a given path, unless the modification date of the named directory changes.

```
import dircache

path = '.'
first = dircache.listdir(path)
second = dircache.listdir(path)

print 'Contents :', first
print 'Identical:', first is second
print 'Equal    :', first == second
```

It is important to recognize that the exact same `list` is returned each time, so it should not be modified in place.

```
$ python dircache_listdir.py

Contents : ['__init__.py', 'dircache_annotate.py', 'dircache_listdir.py', 'dircache_listdir_file_adde
Identical: True
Equal    : True
```

If the contents of the directory changes, it is rescanned.

```
import dircache
import os

path = '/tmp'
file_to_create = os.path.join(path, 'pymotw_tmp.txt')

# Look at the directory contents
first = dircache.listdir(path)

# Create the new file
open(file_to_create, 'wt').close()

# Rescan the directory
second = dircache.listdir(path)

# Remove the file we created
os.unlink(file_to_create)

print 'Identical :', first is second
print 'Equal     :', first == second
print 'Difference:', list(set(second) - set(first))
```

In this case the new file causes a new `list` to be constructed.

```
$ python dircache_listdir_file_added.py

Identical : False
Equal     : False
Difference: ['pymotw_tmp.txt']
```

It is also possible to reset the entire cache, discarding its contents so that each path will be rechecked.

```
import dircache

path = '/tmp'
first = dircache.listdir(path)
dircache.reset()
second = dircache.listdir(path)

print 'Identical :', first is second
print 'Equal     :', first == second
print 'Difference:', list(set(second) - set(first))
```

After resetting, a new `list` instance is returned.

```
$ python dircache_reset.py

Identical : False
Equal     : True
Difference: []
```

12.9.2 Annotated Listings

The other interesting function provided by the dircache module is `annotate()`. When called, `annotate()` modifies a `list()` such as is returned by `listdir()`, adding a `'/'` to the end of the names that represent directories.

```
import dircache
from pprint import pprint
import os

path = '../..'

contents = dircache.listdir(path)

annotated = contents[:]
dircache.annotate(path, annotated)

fmt = '%25s\t%25s'

print fmt % ('ORIGINAL', 'ANNOTATED')
print fmt % (('-' * 25,)*2)

for o, a in zip(contents, annotated):
    print fmt % (o, a)
```

Unfortunately for Windows users, although `annotate()` uses `os.path.join()` to construct names to test, it always appends a `'/'`, not `os.sep`.

```
$ python dircache_annotate.py

                 ORIGINAL                       ANNOTATED
-------------------------       -------------------------
                      .hg                            .hg/
                 .hgcheck                       .hgcheck/
                .hgignore                       .hgignore
                  .hgtags                         .hgtags
              LICENSE.txt                     LICENSE.txt
              MANIFEST.in                     MANIFEST.in
                   PyMOTW                         PyMOTW/
          PyMOTW.egg-info                PyMOTW.egg-info/
               README.txt                      README.txt
                      bin                            bin/
                     dist                           dist/
                   module                          module
                     motw                            motw
              pavement.py                     pavement.py
             pavement.py~                    pavement.py~
         paver-minilib.zip               paver-minilib.zip
                 setup.py                        setup.py
     sitemap_gen_config.xml          sitemap_gen_config.xml
    sitemap_gen_config.xml~         sitemap_gen_config.xml~
                   sphinx                         sphinx/
                    utils                          utils/
                      web                            web/
```

See also:

dircache **(http://docs.python.org/library/dircache.html)** The standard library documentation for this module.

CHAPTER

THIRTEEN

DATA COMPRESSION AND ARCHIVING

13.1 bz2 – bzip2 compression

Purpose bzip2 compression

Available In 2.3 and later

The bz2 module is an interface for the bzip2 library, used to compress data for storage or transmission. There are three APIs provided:

- "one shot" compression/decompression functions for operating on a blob of data
- iterative compression/decompression objects for working with streams of data
- a file-like class that supports reading and writing as with an uncompressed file

13.1.1 One-shot Operations in Memory

The simplest way to work with bz2 requires holding all of the data to be compressed or decompressed in memory, and then using `compress()` and `decompress()`.

```
import bz2
import binascii

original_data = 'This is the original text.'
print 'Original     :', len(original_data), original_data

compressed = bz2.compress(original_data)
print 'Compressed   :', len(compressed), binascii.hexlify(compressed)

decompressed = bz2.decompress(compressed)
print 'Decompressed :', len(decompressed), decompressed
```

```
$ python bz2_memory.py

Original     : 26 This is the original text.
Compressed   : 62 425a683931415926535916be35a6000002938040010400022e59c402000314c000111e93d434da223028
Decompressed : 26 This is the original text.
```

Notice that for short text, the compressed version can be significantly longer. While the actual results depend on the input data, for short bits of text it is interesting to observe the compression overhead.

```
import bz2

original_data = 'This is the original text.'
```

```
fmt = '%15s  %15s'
print fmt % ('len(data)', 'len(compressed)')
print fmt % ('-' * 15, '-' * 15)

for i in xrange(20):
    data = original_data * i
    compressed = bz2.compress(data)
    print fmt % (len(data), len(compressed)), '*' if len(data) < len(compressed) else ''
```

```
$ python bz2_lengths.py

      len(data)  len(compressed)
---------------  ---------------
              0               14 *
             26               62 *
             52               68 *
             78               70
            104               72
            130               77
            156               77
            182               73
            208               75
            234               80
            260               80
            286               81
            312               80
            338               81
            364               81
            390               76
            416               78
            442               84
            468               84
            494               87
```

13.1.2 Working with Streams

The in-memory approach is not practical for real-world use cases, since you rarely want to hold both the entire compressed and uncompressed data sets in memory at the same time. The alternative is to use `BZ2Compressor` and `BZ2Decompressor` objects to work with streams of data, so that the entire data set does not have to fit into memory.

The simple server below responds to requests consisting of filenames by writing a compressed version of the file to the socket used to communicate with the client. It has some artificial chunking in place to illustrate the buffering behavior that happens when the data passed to `compress()` or `decompress()` doesn't result in a complete block of compressed or uncompressed output.

Warning: This implementation has obvious security implications. Do not run it on a server on the open internet or in any environment where security might be an issue.

```
import bz2
import logging
import SocketServer
import binascii

BLOCK_SIZE = 32
```

```
class Bz2RequestHandler(SocketServer.BaseRequestHandler):

    logger = logging.getLogger('Server')

    def handle(self):
        compressor = bz2.BZ2Compressor()

        # Find out what file the client wants
        filename = self.request.recv(1024)
        self.logger.debug('client asked for: "%s"', filename)

        # Send chunks of the file as they are compressed
        with open(filename, 'rb') as input:
            while True:
                block = input.read(BLOCK_SIZE)
                if not block:
                    break
                self.logger.debug('RAW "%s"', block)
                compressed = compressor.compress(block)
                if compressed:
                    self.logger.debug('SENDING "%s"', binascii.hexlify(compressed))
                    self.request.send(compressed)
                else:
                    self.logger.debug('BUFFERING')

        # Send any data being buffered by the compressor
        remaining = compressor.flush()
        while remaining:
            to_send = remaining[:BLOCK_SIZE]
            remaining = remaining[BLOCK_SIZE:]
            self.logger.debug('FLUSHING "%s"', binascii.hexlify(to_send))
            self.request.send(to_send)
        return


if __name__ == '__main__':
    import socket
    import threading
    from cStringIO import StringIO

    logging.basicConfig(level=logging.DEBUG,
                        format='%(name)s: %(message)s',
                        )
    logger = logging.getLogger('Client')

    # Set up a server, running in a separate thread
    address = ('localhost', 0) # let the kernel give us a port
    server = SocketServer.TCPServer(address, Bz2RequestHandler)
    ip, port = server.server_address # find out what port we were given

    t = threading.Thread(target=server.serve_forever)
    t.setDaemon(True)
    t.start()

    # Connect to the server
    logger.info('Contacting server on %s:%s', ip, port)
    s = socket.socket(socket.AF_INET, socket.SOCK_STREAM)
    s.connect((ip, port))
    # Ask for a file
    requested_file = 'lorem.txt'
    logger.debug('sending filename: "%s"', requested_file)
    len_sent = s.send(requested_file)

    # Receive a response
    buffer = StringIO()
    decompressor = bz2.BZ2Decompressor()
    while True:
        response = s.recv(BLOCK_SIZE)
        if not response:
            break
        logger.debug('READ "%s"', binascii.hexlify(response))

        # Include any unconsumed data when feeding the decompressor.
        decompressed = decompressor.decompress(response)
        if decompressed:
            logger.debug('DECOMPRESSED "%s"', decompressed)
            buffer.write(decompressed)
        else:
            logger.debug('BUFFERING')

    full_response = buffer.getvalue()
    lorem = open('lorem.txt', 'rt').read()
    logger.debug('response matches file contents: %s', full_response == lorem)

    # Clean up
    s.close()
    server.socket.close()
```

```
$ python bz2_server.py
Client: Contacting server on 127.0.0.1:54092
Client: sending filename: "lorem.txt"
Server: client asked for: "lorem.txt"
Server: RAW "Lorem ipsum dolor sit amet, cons"
Server: BUFFERING
Server: RAW "ectetuer adipiscing elit. Donec
"
Server: BUFFERING
Server: RAW "egestas, enim et consectetuer ul"
Server: BUFFERING
Server: RAW "lamcorper, lectus ligula rutrum "
Server: BUFFERING
Server: RAW "leo, a
elementum elit tortor eu "
Server: BUFFERING
Server: RAW "quam. Duis tincidunt nisi ut ant"
Server: BUFFERING
Server: RAW "e. Nulla
facilisi. Sed tristique"
Server: BUFFERING
Server: RAW " eros eu libero. Pellentesque ve"
Server: BUFFERING
Server: RAW "l arcu. Vivamus
purus orci, iacu"
Server: BUFFERING
Server: RAW "lis ac, suscipit sit amet, pulvi"
Server: BUFFERING
```

```
Server: RAW "nar eu,
lacus. Praesent placerat"
Server: BUFFERING
Server: RAW " tortor sed nisl. Nunc blandit d"
Server: BUFFERING
Server: RAW "iam egestas
dui. Pellentesque ha"
Server: BUFFERING
Server: RAW "bitant morbi tristique senectus "
Server: BUFFERING
Server: RAW "et netus et
malesuada fames ac t"
Server: BUFFERING
Server: RAW "urpis egestas. Aliquam viverra f"
Server: BUFFERING
Server: RAW "ringilla
leo. Nulla feugiat augu"
Server: BUFFERING
Server: RAW "e eleifend nulla. Vivamus mauris"
Server: BUFFERING
Server: RAW ". Vivamus sed
mauris in nibh pla"
Server: BUFFERING
Server: RAW "cerat egestas. Suspendisse poten"
Server: BUFFERING
Server: RAW "ti. Mauris massa. Ut
eget velit "
Server: BUFFERING
Server: RAW "auctor tortor blandit sollicitud"
Server: BUFFERING
Server: RAW "in. Suspendisse imperdiet
justo."
Server: BUFFERING
Server: RAW "
"
Server: BUFFERING
Server: FLUSHING "425a68393141592653590fd264ff00004357800010400524074b003ff7ff0040"
Server: FLUSHING "01dd936c1834269926d4d13d232640341a986935343534f5000018d311846980"
Client: READ "425a68393141592653590fd264ff00004357800010400524074b003ff7ff0040"
Server: FLUSHING "0001299084530d35434f51ea1ea13fce3df02cb7cde200b67bb8fca353727a30"
Client: BUFFERING
Server: FLUSHING "fe67cdcdd2307c455a3964fad491e9350de1a66b9458a40876613e7575a9d2de"
Client: READ "01dd936c1834269926d4d13d232640341a986935343534f5000018d311846980"
Server: FLUSHING "db28ab492d5893b99616ebae68b8a61294a48ba5d0a6c428f59ad9eb72e0c40f"
Client: BUFFERING
Server: FLUSHING "f449c4f64c35ad8a27caa2bbd9e35214df63183393aa35919a4f1573615c6ae3"
Client: READ "0001299084530d35434f51ea1ea13fce3df02cb7cde200b67bb8fca353727a30"
Server: FLUSHING "611f18917467ad690abb4cb67a3a5f1fd36c2511d105836a0fed317be03702ba"
Client: BUFFERING
Server: FLUSHING "394984c68a595d1cc2f5219a1ada69b6d6863cf5bd925f36626046d68c3a9921"
Client: READ "fe67cdcdd2307c455a3964fad491e9350de1a66b9458a40876613e7575a9d2de"
Server: FLUSHING "3103445c9d2438d03b5a675dfdc74e3bed98e8b72dec76c923afa395eb5ce61b"
Client: BUFFERING
Server: FLUSHING "50cfc0ccaaa726b293a50edc28b551261dd09a24aba682972bc75f1fae4c4765"
Client: READ "db28ab492d5893b99616ebae68b8a61294a48ba5d0a6c428f59ad9eb72e0c40f"
Server: FLUSHING "f3b7eeea36e771e577350970dab4baf07750ccf96494df9e63a9454b7133be1d"
Client: BUFFERING
Server: FLUSHING "ee330da50a869eea59f73319b18959262860897dafdc965ac4b79944c4cc3341"
```

```
Client: READ "f449c4f64c35ad8a27caa2bbd9e35214df63183393aa35919a4f1573615c6ae3"
Server: FLUSHING "5b23816d45912c8860f40ea930646fc8adbc48040cbb6cd4fc222f8c66d58256"
Client: BUFFERING
Server: FLUSHING "d508d8eb4f43986b9203e13f8bb9229c284807e9327f80"
Client: READ "611f18917467ad690abb4cb67a3a5f1fd36c2511d105836a0fed317be03702ba"
Client: BUFFERING
Client: READ "394984c68a595d1cc2f5219a1ada69b6d6863cf5bd925f36626046d68c3a9921"
Client: BUFFERING
Client: READ "3103445c9d2438d03b5a675dfdc74e3bed98e8b72dec76c923afa395eb5ce61b"
Client: BUFFERING
Client: READ "50cfc0ccaaa726b293a50edc28b551261dd09a24aba682972bc75f1fae4c4765"
Client: BUFFERING
Client: READ "f3b7eeea36e771e577350970dab4baf07750ccf96494df9e63a9454b7133be1d"
Client: BUFFERING
Client: READ "ee330da50a869eea59f73319b18959262860897dafdc965ac4b79944c4cc3341"
Client: BUFFERING
Client: READ "5b23816d45912c8860f40ea930646fc8adbc48040cbb6cd4fc222f8c66d58256"
Client: BUFFERING
Client: READ "d508d8eb4f43986b9203e13f8bb9229c284807e9327f80"
Client: DECOMPRESSED "Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Donec
egestas, enim et consectetuer ullamcorper, lectus ligula rutrum leo, a
elementum elit tortor eu quam. Duis tincidunt nisi ut ante. Nulla
facilisi. Sed tristique eros eu libero. Pellentesque vel arcu. Vivamus
purus orci, iaculis ac, suscipit sit amet, pulvinar eu,
lacus. Praesent placerat tortor sed nisl. Nunc blandit diam egestas
dui. Pellentesque habitant morbi tristique senectus et netus et
malesuada fames ac turpis egestas. Aliquam viverra fringilla
leo. Nulla feugiat augue eleifend nulla. Vivamus mauris. Vivamus sed
mauris in nibh placerat egestas. Suspendisse potenti. Mauris massa. Ut
eget velit auctor tortor blandit sollicitudin. Suspendisse imperdiet
justo.
"
Client: response matches file contents: True
```

13.1.3 Mixed Content Streams

`BZ2Decompressor` can also be used in situations where compressed and uncompressed data is mixed together. After decompressing all of the data, the *unused_data* attribute contains any data not used.

```python
import bz2

lorem = open('lorem.txt', 'rt').read()
compressed = bz2.compress(lorem)
combined = compressed + lorem

decompressor = bz2.BZ2Decompressor()
decompressed = decompressor.decompress(combined)

print 'Decompressed matches lorem:', decompressed == lorem
print 'Unused data matches lorem :', decompressor.unused_data == lorem
```

```
$ python bz2_mixed.py

Decompressed matches lorem: True
Unused data matches lorem : True
```

13.1.4 Writing Compressed Files

BZ2File can be used to write to and read from bzip2-compressed files using the usual methods for writing and reading data. To write data into a compressed file, open the file with mode 'w'.

```
import bz2
import os

output = bz2.BZ2File('example.txt.bz2', 'wb')
try:
    output.write('Contents of the example file go here.\n')
finally:
    output.close()

os.system('file example.txt.bz2')
```

```
$ python bz2_file_write.py

example.txt.bz2: bzip2 compressed data, block size = 900k
```

Different compression levels can be used by passing a *compresslevel* argument. Valid values range from 1 to 9, inclusive. Lower values are faster and result in less compression. Higher values are slower and compress more, up to a point.

```
import bz2
import os

data = open('lorem.txt', 'r').read() * 1024
print 'Input contains %d bytes' % len(data)

for i in xrange(1, 10):
    filename = 'compress-level-%s.bz2' % i
    output = bz2.BZ2File(filename, 'wb', compresslevel=i)
    try:
        output.write(data)
    finally:
        output.close()
    os.system('cksum %s' % filename)
```

The center column of numbers in the output of the script is the size in bytes of the files produced. As you see, for this input data, the higher compression values do not always pay off in decreased storage space for the same input data. Results will vary for other inputs.

```
$ python bz2_file_compresslevel.py
3018243926 8771 compress-level-1.bz2
1942389165 4949 compress-level-2.bz2
2596054176 3708 compress-level-3.bz2
1491394456 2705 compress-level-4.bz2
1425874420 2705 compress-level-5.bz2
2232840816 2574 compress-level-6.bz2
447681641 2394 compress-level-7.bz2
3699654768 1137 compress-level-8.bz2
3103658384 1137 compress-level-9.bz2
Input contains 754688 bytes
```

A BZ2File instance also includes a writelines() method that can be used to write a sequence of strings.

```
import bz2
import itertools
import os

output = bz2.BZ2File('example_lines.txt.bz2', 'wb')
try:
    output.writelines(itertools.repeat('The same line, over and over.\n', 10))
finally:
    output.close()

os.system('bzcat example_lines.txt.bz2')
```

```
$ python bz2_file_writelines.py

The same line, over and over.
The same line, over and over.
The same line, over and over.
The same line, over and over.
The same line, over and over.
The same line, over and over.
The same line, over and over.
The same line, over and over.
The same line, over and over.
The same line, over and over.
```

13.1.5 Reading Compressed Files

To read data back from previously compressed files, simply open the file with mode `'r'`.

```
import bz2

input_file = bz2.BZ2File('example.txt.bz2', 'rb')
try:
    print input_file.read()
finally:
    input_file.close()
```

This example reads the file written by `bz2_file_write.py` from the previous section.

```
$ python bz2_file_read.py

Contents of the example file go here.
```

While reading a file, it is also possible to seek and read only part of the data.

```
import bz2

input_file = bz2.BZ2File('example.txt.bz2', 'rb')
try:
    print 'Entire file:'
    all_data = input_file.read()
    print all_data

    expected = all_data[5:15]

    # rewind to beginning
    input_file.seek(0)

    # move ahead 5 bytes
    input_file.seek(5)
    print 'Starting at position 5 for 10 bytes:'
    partial = input_file.read(10)
    print partial

    print
    print expected == partial
finally:
    input_file.close()
```

The `seek()` position is relative to the *uncompressed* data, so the caller does not even need to know that the data file is compressed.

```
$ python bz2_file_seek.py

Entire file:
Contents of the example file go here.

Starting at position 5 for 10 bytes:
nts of the

True
```

See also:

bz2 (http://docs.python.org/library/bz2.html) The standard library documentation for this module.

bzip2.org (http://www.bzip.org/) The home page for bzip2.

`zlib` The zlib module for GNU zip compression.

`gzip` A file-like interface to GNU zip compressed files.

`SocketServer` Base classes for creating your own network servers.

13.2 gzip – Read and write GNU zip files

Purpose Read and write gzip files.

Available In 1.5.2 and later

The gzip module provides a file-like interface to GNU zip files, using `zlib` to compress and uncompress the data.

13.2.1 Writing Compressed Files

The module-level function `open()` creates an instance of the file-like class GzipFile. The usual methods for writing and reading data are provided. To write data into a compressed file, open the file with mode `'w'`.

```
import gzip
import os

outfilename = 'example.txt.gz'
output = gzip.open(outfilename, 'wb')
try:
    output.write('Contents of the example file go here.\n')
finally:
    output.close()
```

```
print outfilename, 'contains', os.stat(outfilename).st_size, 'bytes of compressed data'
os.system('file -b --mime %s' % outfilename)
```

```
$ python gzip_write.py

application/x-gzip; charset=binary
example.txt.gz contains 68 bytes of compressed data
```

Different amounts of compression can be used by passing a *compresslevel* argument. Valid values range from 1 to 9, inclusive. Lower values are faster and result in less compression. Higher values are slower and compress more, up to a point.

```
import gzip
import os
import hashlib

def get_hash(data):
    return hashlib.md5(data).hexdigest()

data = open('lorem.txt', 'r').read() * 1024
cksum = get_hash(data)

print 'Level  Size        Checksum'
print '-----  ----------  ---------------------------------'
print 'data   %10d  %s' % (len(data), cksum)

for i in xrange(1, 10):
    filename = 'compress-level-%s.gz' % i
    output = gzip.open(filename, 'wb', compresslevel=i)
    try:
        output.write(data)
    finally:
        output.close()
    size = os.stat(filename).st_size
    cksum = get_hash(open(filename, 'rb').read())
    print '%5d  %10d  %s' % (i, size, cksum)
```

The center column of numbers in the output of the script is the size in bytes of the files produced. As you see, for this input data, the higher compression values do not necessarily pay off in decreased storage space. Results will vary, depending on the input data.

```
$ python gzip_compresslevel.py

Level  Size        Checksum
-----  ----------  ---------------------------------
data       754688  e4c0f9433723971563f08a458715119c
    1        9839  9a7d983796832f354f8ed980d8f9490b
    2        8260  bfc400197e9fc1ee6d8fcf23055362b2
    3        8221  63a50795cf7e203339236233f473e23b
    4        4160  c3d7f661a98895a20e22b1c97e02a02a
    5        4160  800a904ede7007dacf7e6313d044a9c9
    6        4160  8904134bbd7e2f4cc87dbda39093835b
    7        4160  724bd069062b2adb0739d3ab427b8729
    8        4160  61504720d0e524d2b32689a3409d978d
    9        4160  538734caa5e4558c7da7c19ca2620573
```

A GzipFile instance also includes a `writelines()` method that can be used to write a sequence of strings.

```
import gzip
import itertools
import os

output = gzip.open('example_lines.txt.gz', 'wb')
try:
    output.writelines(itertools.repeat('The same line, over and over.\n', 10))
finally:
    output.close()

os.system('gzcat example_lines.txt.gz')
```

```
$ python gzip_writelines.py

The same line, over and over.
The same line, over and over.
The same line, over and over.
The same line, over and over.
The same line, over and over.
The same line, over and over.
The same line, over and over.
The same line, over and over.
The same line, over and over.
The same line, over and over.
```

13.2.2 Reading Compressed Data

To read data back from previously compressed files, simply open the file with mode `'r'`.

```
import gzip

input_file = gzip.open('example.txt.gz', 'rb')
try:
    print input_file.read()
finally:
    input_file.close()
```

This example reads the file written by `gzip_write.py` from the previous section.

```
$ python gzip_read.py

Contents of the example file go here.
```

While reading a file, it is also possible to seek and read only part of the data.

```
import gzip

input_file = gzip.open('example.txt.gz', 'rb')
try:
    print 'Entire file:'
    all_data = input_file.read()
    print all_data

    expected = all_data[5:15]

    # rewind to beginning
    input_file.seek(0)
    # move ahead 5 bytes
    input_file.seek(5)
    print 'Starting at position 5 for 10 bytes:'
    partial = input_file.read(10)
    print partial

    print
    print expected == partial
finally:
    input_file.close()
```

The `seek()` position is relative to the *uncompressed* data, so the caller does not even need to know that the data file is compressed.

```
$ python gzip_seek.py

Entire file:
Contents of the example file go here.

Starting at position 5 for 10 bytes:
nts of the

True
```

13.2.3 Working with Streams

When working with a data stream instead of a file, use the GzipFile class directly to compress or uncompress it. This is useful when the data is being transmitted over a socket or from read an existing (already open) file handle. A StringIO buffer can also be used.

```
import gzip
from cStringIO import StringIO
import binascii

uncompressed_data = 'The same line, over and over.\n' * 10
print 'UNCOMPRESSED:', len(uncompressed_data)
print uncompressed_data

buf = StringIO()
f = gzip.GzipFile(mode='wb', fileobj=buf)
try:
    f.write(uncompressed_data)
finally:
    f.close()

compressed_data = buf.getvalue()
print 'COMPRESSED:', len(compressed_data)
print binascii.hexlify(compressed_data)

inbuffer = StringIO(compressed_data)
f = gzip.GzipFile(mode='rb', fileobj=inbuffer)
try:
    reread_data = f.read(len(uncompressed_data))
finally:
    f.close()
```

```
print
print 'RE-READ:', len(reread_data)
print reread_data
```

Note: When re-reading the previously compressed data, I pass an explicit length to `read()`. Leaving the length off resulted in a CRC error, possibly because StringIO returned an empty string before reporting EOF. If you are working with streams of compressed data, you may want to prefix the data with an integer representing the actual amount of data to be read.

```
$ python gzip_StringIO.py

UNCOMPRESSED: 300
The same line, over and over.
The same line, over and over.
The same line, over and over.
The same line, over and over.
The same line, over and over.
The same line, over and over.
The same line, over and over.
The same line, over and over.
The same line, over and over.
The same line, over and over.

COMPRESSED: 51
1f8b08009706265102ff0bc94855284ecc4d55c8c9cc4bd551c82f4b2d5248cc4b0133f4b8424665916401d3e717802c0100

RE-READ: 300
The same line, over and over.
The same line, over and over.
The same line, over and over.
The same line, over and over.
The same line, over and over.
The same line, over and over.
The same line, over and over.
The same line, over and over.
The same line, over and over.
The same line, over and over.
```

See also:

gzip (http://docs.python.org/library/gzip.html) The standard library documentation for this module.

`zlib` The zlib module is a lower-level interface to gzip compression.

`zipfile` The zipfile module gives access to ZIP archives.

`bz2` The bz2 module uses the bzip2 compression format.

`tarfile` The tarfile module includes built-in support for reading compressed tar archives.

13.3 tarfile – Tar archive access

Purpose Tar archive access.

Available In 2.3 and later

The tarfile module provides read and write access to UNIX tar archives, including compressed files. In addition to the POSIX standards, several GNU tar extensions are supported. Various UNIX special file types (hard and soft links, device nodes, etc.) are also handled.

13.3.1 Testing Tar Files

The is_tarfile() function returns a boolean indicating whether or not the filename passed as an argument refers to a valid tar file.

```
import tarfile

for filename in [ 'README.txt', 'example.tar',
                  'bad_example.tar', 'notthere.tar' ]:
    try:
        print '%20s  %s' % (filename, tarfile.is_tarfile(filename))
    except IOError, err:
        print '%20s  %s' % (filename, err)
```

If the file does not exist, is_tarfile() raises an *IOError*.

```
$ python tarfile_is_tarfile.py

          README.txt  False
         example.tar  True
     bad_example.tar  False
        notthere.tar  [Errno 2] No such file or directory: 'notthere.tar'
```

13.3.2 Reading Meta-data from an Archive

Use the TarFile class to work directly with a tar archive. It supports methods for reading data about existing archives as well as modifying the archives by adding additional files.

To read the names of the files in an existing archive, use getnames():

```
import tarfile

t = tarfile.open('example.tar', 'r')
print t.getnames()
```

The return value is a list of strings with the names of the archive contents:

```
$ python tarfile_getnames.py

['README.txt']
```

In addition to names, meta-data about the archive members is available as instances of TarInfo objects. Load the meta-data via getmembers() and getmember().

```
import tarfile
import time

t = tarfile.open('example.tar', 'r')
for member_info in t.getmembers():
    print member_info.name
    print '\tModified:\t', time.ctime(member_info.mtime)
    print '\tMode    :\t', oct(member_info.mode)
    print '\tType    :\t', member_info.type
    print '\tSize    :\t', member_info.size, 'bytes'
    print
```

```
$ python tarfile_getmembers.py

README.txt
        Modified:       Sun Feb 22 11:13:55 2009
        Mode    :       0644
        Type    :       0
        Size    :       75 bytes
```

If you know in advance the name of the archive member, you can retrieve its `TarInfo` object with `getmember()`.

```
import tarfile
import time

t = tarfile.open('example.tar', 'r')
for filename in [ 'README.txt', 'notthere.txt' ]:
    try:
        info = t.getmember(filename)
    except KeyError:
        print 'ERROR: Did not find %s in tar archive' % filename
    else:
        print '%s is %d bytes' % (info.name, info.size)
```

If the archive member is not present, `getmember()` raises a *KeyError*.

```
$ python tarfile_getmember.py

README.txt is 75 bytes
ERROR: Did not find notthere.txt in tar archive
```

13.3.3 Extracting Files From an Archive

To access the data from an archive member within your program, use the `extractfile()` method, passing the member's name.

```
import tarfile

t = tarfile.open('example.tar', 'r')
for filename in [ 'README.txt', 'notthere.txt' ]:
    try:
        f = t.extractfile(filename)
    except KeyError:
        print 'ERROR: Did not find %s in tar archive' % filename
    else:
        print filename, ':', f.read()
```

```
$ python tarfile_extractfile.py

README.txt : The examples for the tarfile module use this file and example.tar as data.

ERROR: Did not find notthere.txt in tar archive
```

If you just want to unpack the archive and write the files to the filesystem, use `extract()` or `extractall()` instead.

```
import tarfile
import os

os.mkdir('outdir')
t = tarfile.open('example.tar', 'r')
t.extract('README.txt', 'outdir')
print os.listdir('outdir')
```

```
$ python tarfile_extract.py

['README.txt']
```

Note: The standard library documentation includes a note stating that `extractall()` is safer than `extract()`, and it should be used in most cases.

```
import tarfile
import os

os.mkdir('outdir')
t = tarfile.open('example.tar', 'r')
t.extractall('outdir')
print os.listdir('outdir')
```

```
$ python tarfile_extractall.py

['README.txt']
```

If you only want to extract certain files from the archive, their names can be passed to `extractall()`.

```
import tarfile
import os

os.mkdir('outdir')
t = tarfile.open('example.tar', 'r')
t.extractall('outdir', members=[t.getmember('README.txt')])
print os.listdir('outdir')
```

```
$ python tarfile_extractall_members.py

['README.txt']
```

13.3.4 Creating New Archives

To create a new archive, simply open the `TarFile` with a mode of `'w'`. Any existing file is truncated and a new archive is started. To add files, use the `add()` method.

```
import tarfile

print 'creating archive'
out = tarfile.open('tarfile_add.tar', mode='w')
try:
    print 'adding README.txt'
    out.add('README.txt')
finally:
    print 'closing'
    out.close()
```

```
print
print 'Contents:'
t = tarfile.open('tarfile_add.tar', 'r')
for member_info in t.getmembers():
    print member_info.name
```

```
$ python tarfile_add.py

creating archive
adding README.txt
closing

Contents:
README.txt
```

13.3.5 Using Alternate Archive Member Names

It is possible to add a file to an archive using a name other than the original file name, by constructing a `TarInfo` object with an alternate *arcname* and passing it to `addfile()`.

```
import tarfile

print 'creating archive'
out = tarfile.open('tarfile_addfile.tar', mode='w')
try:
    print 'adding README.txt as RENAMED.txt'
    info = out.gettarinfo('README.txt', arcname='RENAMED.txt')
    out.addfile(info)
finally:
    print 'closing'
    out.close()

print
print 'Contents:'
t = tarfile.open('tarfile_addfile.tar', 'r')
for member_info in t.getmembers():
    print member_info.name
```

The archive includes only the changed filename:

```
$ python tarfile_addfile.py

creating archive
adding README.txt as RENAMED.txt
closing

Contents:
RENAMED.txt
```

13.3.6 Writing Data from Sources Other Than Files

Sometimes you want to write data to an archive but the data is not in a file on the filesystem. Rather than writing the data to a file, then adding that file to the archive, you can use `addfile()` to add data from an open file-like handle.

```
import tarfile
from cStringIO import StringIO

data = 'This is the data to write to the archive.'

out = tarfile.open('tarfile_addfile_string.tar', mode='w')
try:
    info = tarfile.TarInfo('made_up_file.txt')
    info.size = len(data)
    out.addfile(info, StringIO(data))
finally:
    out.close()

print
print 'Contents:'
t = tarfile.open('tarfile_addfile_string.tar', 'r')
for member_info in t.getmembers():
    print member_info.name
    f = t.extractfile(member_info)
    print f.read()
```

By first constructing a `TarInfo` object ourselves, we can give the archive member any name we wish. After setting the size, we can write the data to the archive using `addfile()` and passing a `StringIO` buffer as a source of the data.

```
$ python tarfile_addfile_string.py


Contents:
made_up_file.txt
This is the data to write to the archive.
```

13.3.7 Appending to Archives

In addition to creating new archives, it is possible to append to an existing file. To open a file to append to it, use mode `'a'`.

```
import tarfile

print 'creating archive'
out = tarfile.open('tarfile_append.tar', mode='w')
try:
    out.add('README.txt')
finally:
    out.close()

print 'contents:', [m.name
                    for m in tarfile.open('tarfile_append.tar', 'r').getmembers()]

print 'adding index.rst'
out = tarfile.open('tarfile_append.tar', mode='a')
try:
    out.add('index.rst')
finally:
    out.close()
```

```
print 'contents:', [m.name
                    for m in tarfile.open('tarfile_append.tar', 'r').getmembers()]
```

The resulting archive ends up with two members:

```
$ python tarfile_append.py

creating archive
contents: ['README.txt']
adding index.rst
contents: ['README.txt', 'index.rst']
```

13.3.8 Working with Compressed Archives

Besides regular tar archive files, the `tarfile` module can work with archives compressed via the gzip or bzip2 protocols. To open a compressed archive, modify the mode string passed to open() to include `":gz"` or `":bz2"`, depending on the compression method you want to use.

```
import tarfile
import os

fmt = '%-30s %-10s'
print fmt % ('FILENAME', 'SIZE')
print fmt % ('README.txt', os.stat('README.txt').st_size)

for filename, write_mode in [
    ('tarfile_compression.tar', 'w'),
    ('tarfile_compression.tar.gz', 'w:gz'),
    ('tarfile_compression.tar.bz2', 'w:bz2'),
    ]:
    out = tarfile.open(filename, mode=write_mode)
    try:
        out.add('README.txt')
    finally:
        out.close()

    print fmt % (filename, os.stat(filename).st_size),
    print [m.name for m in tarfile.open(filename, 'r:*').getmembers()]
```

When opening an existing archive for reading, you can specify `"r:*"` to have `tarfile` determine the compression method to use automatically.

```
$ python tarfile_compression.py

FILENAME                       SIZE
README.txt                     75
tarfile_compression.tar        10240      ['README.txt']
tarfile_compression.tar.gz     211        ['README.txt']
tarfile_compression.tar.bz2    188        ['README.txt']
```

See also:

tarfile **(http://docs.python.org/library/tarfile.html)** The standard library documentation for this module.

GNU tar manual **(http://www.gnu.org/software/tar/manual/html_node/Standard.html)** Documentation of the tar format, including extensions.

`zipfile` Similar access for ZIP archives.

gzip GNU zip compression

bz2 bzip2 compression

13.4 zipfile – Read and write ZIP archive files

Purpose Read and write ZIP archive files.

Available In 1.6 and later

The zipfile module can be used to manipulate ZIP archive files.

13.4.1 Limitations

The zipfile module does not support ZIP files with appended comments, or multi-disk ZIP files. It does support ZIP files larger than 4 GB that use the ZIP64 extensions.

13.4.2 Testing ZIP Files

The is_zipfile() function returns a boolean indicating whether or not the filename passed as an argument refers to a valid ZIP file.

```
import zipfile

for filename in [ 'README.txt', 'example.zip',
                  'bad_example.zip', 'notthere.zip' ]:
    print '%20s  %s' % (filename, zipfile.is_zipfile(filename))
```

Notice that if the file does not exist at all, is_zipfile() returns False.

```
$ python zipfile_is_zipfile.py

          README.txt  False
         example.zip  True
     bad_example.zip  False
        notthere.zip  False
```

13.4.3 Reading Meta-data from a ZIP Archive

Use the ZipFile class to work directly with a ZIP archive. It supports methods for reading data about existing archives as well as modifying the archives by adding additional files.

To read the names of the files in an existing archive, use namelist():

```
import zipfile

zf = zipfile.ZipFile('example.zip', 'r')
print zf.namelist()
```

The return value is a list of strings with the names of the archive contents:

```
$ python zipfile_namelist.py

['README.txt']
```

The list of names is only part of the information available from the archive, though. To access all of the meta-data about the ZIP contents, use the `infolist()` or `getinfo()` methods.

```
import datetime
import zipfile

def print_info(archive_name):
    zf = zipfile.ZipFile(archive_name)
    for info in zf.infolist():
        print info.filename
        print '\tComment:\t', info.comment
        print '\tModified:\t', datetime.datetime(*info.date_time)
        print '\tSystem:\t\t', info.create_system, '(0 = Windows, 3 = Unix)'
        print '\tZIP version:\t', info.create_version
        print '\tCompressed:\t', info.compress_size, 'bytes'
        print '\tUncompressed:\t', info.file_size, 'bytes'
        print

if __name__ == '__main__':
    print_info('example.zip')
```

There are additional fields other than those printed here, but deciphering the values into anything useful requires careful reading of the PKZIP Application Note (http://www.pkware.com/documents/casestudies/APPNOTE.TXT) with the ZIP file specification.

```
$ python zipfile_infolist.py

README.txt
        Comment:
        Modified:       2007-12-16 10:08:52
        System:         3 (0 = Windows, 3 = Unix)
        ZIP version:    23
        Compressed:     63 bytes
        Uncompressed:   75 bytes
```

If you know in advance the name of the archive member, you can retrieve its `ZipInfo` object with `getinfo()`.

```
import zipfile

zf = zipfile.ZipFile('example.zip')
for filename in [ 'README.txt', 'notthere.txt' ]:
    try:
        info = zf.getinfo(filename)
    except KeyError:
        print 'ERROR: Did not find %s in zip file' % filename
    else:
        print '%s is %d bytes' % (info.filename, info.file_size)
```

If the archive member is not present, `getinfo()` raises a *KeyError*.

```
$ python zipfile_getinfo.py

README.txt is 75 bytes
ERROR: Did not find notthere.txt in zip file
```

13.4.4 Extracting Archived Files From a ZIP Archive

To access the data from an archive member, use the `read()` method, passing the member's name.

```
import zipfile

zf = zipfile.ZipFile('example.zip')
for filename in [ 'README.txt', 'notthere.txt' ]:
    try:
        data = zf.read(filename)
    except KeyError:
        print 'ERROR: Did not find %s in zip file' % filename
    else:
        print filename, ':'
        print repr(data)
    print
```

The data is automatically decompressed for you, if necessary.

```
$ python zipfile_read.py

README.txt :
'The examples for the zipfile module use this file and example.zip as data.\n'

ERROR: Did not find notthere.txt in zip file
```

13.4.5 Creating New Archives

To create a new archive, simple instantiate the `ZipFile` with a mode of `'w'`. Any existing file is truncated and a new archive is started. To add files, use the `write()` method.

```
from zipfile_infolist import print_info
import zipfile

print 'creating archive'
zf = zipfile.ZipFile('zipfile_write.zip', mode='w')
try:
    print 'adding README.txt'
    zf.write('README.txt')
finally:
    print 'closing'
    zf.close()

print
print_info('zipfile_write.zip')
```

By default, the contents of the archive are not compressed:

```
$ python zipfile_write.py
creating archive
adding README.txt
closing

README.txt
        Comment:
        Modified:       2007-12-16 10:08:50
        System:         3 (0 = Windows, 3 = Unix)
        ZIP version:    20
        Compressed:     75 bytes
        Uncompressed:   75 bytes
```

To add compression, the zlib module is required. If zlib is available, you can set the compression mode for individual files or for the archive as a whole using zipfile.ZIP_DEFLATED. The default compression mode is zipfile.ZIP_STORED.

```
from zipfile_infolist import print_info
import zipfile
try:
    import zlib
    compression = zipfile.ZIP_DEFLATED
except:
    compression = zipfile.ZIP_STORED

modes = { zipfile.ZIP_DEFLATED: 'deflated',
          zipfile.ZIP_STORED:   'stored',
          }

print 'creating archive'
zf = zipfile.ZipFile('zipfile_write_compression.zip', mode='w')
try:
    print 'adding README.txt with compression mode', modes[compression]
    zf.write('README.txt', compress_type=compression)
finally:
    print 'closing'
    zf.close()

print
print_info('zipfile_write_compression.zip')
```

This time the archive member is compressed:

```
$ python zipfile_write_compression.py
creating archive
adding README.txt with compression mode deflated
closing

README.txt
        Comment:
        Modified:       2007-12-16 10:08:50
        System:         3 (0 = Windows, 3 = Unix)
        ZIP version:    20
        Compressed:     63 bytes
        Uncompressed:   75 bytes
```

13.4.6 Using Alternate Archive Member Names

It is easy to add a file to an archive using a name other than the original file name, by passing the arcname argument to write().

```
from zipfile_infolist import print_info
import zipfile

zf = zipfile.ZipFile('zipfile_write_arcname.zip', mode='w')
try:
    zf.write('README.txt', arcname='NOT_README.txt')
finally:
    zf.close()
print_info('zipfile_write_arcname.zip')
```

There is no sign of the original filename in the archive:

```
$ python zipfile_write_arcname.py
NOT_README.txt
        Comment:
        Modified:       2007-12-16 10:08:50
        System:         3 (0 = Windows, 3 = Unix)
        ZIP version:    20
        Compressed:     75 bytes
        Uncompressed:   75 bytes
```

13.4.7 Writing Data from Sources Other Than Files

Sometimes it is necessary to write to a ZIP archive using data that did not come from an existing file. Rather than writing the data to a file, then adding that file to the ZIP archive, you can use the `writestr()` method to add a string of bytes to the archive directly.

```
from zipfile_infolist import print_info
import zipfile

msg = 'This data did not exist in a file before being added to the ZIP file'
zf = zipfile.ZipFile('zipfile_writestr.zip',
                     mode='w',
                     compression=zipfile.ZIP_DEFLATED,
                     )
try:
    zf.writestr('from_string.txt', msg)
finally:
    zf.close()

print_info('zipfile_writestr.zip')

zf = zipfile.ZipFile('zipfile_writestr.zip', 'r')
print zf.read('from_string.txt')
```

In this case, I used the compress argument to `ZipFile` to compress the data, since `writestr()` does not take compress as an argument.

```
$ python zipfile_writestr.py
from_string.txt
        Comment:
        Modified:       2007-12-16 11:38:14
        System:         3 (0 = Windows, 3 = Unix)
        ZIP version:    20
        Compressed:     62 bytes
        Uncompressed:   68 bytes
```

This data did not exist in a file before being added to the ZIP file

13.4.8 Writing with a ZipInfo Instance

Normally, the modification date is computed for you when you add a file or string to the archive. When using `writestr()`, you can also pass a `ZipInfo` instance to define the modification date and other meta-data yourself.

```
import time
import zipfile
```

```
from zipfile_infolist import print_info

msg = 'This data did not exist in a file before being added to the ZIP file'
zf = zipfile.ZipFile('zipfile_writestr_zipinfo.zip',
                     mode='w',
                     )
try:
    info = zipfile.ZipInfo('from_string.txt',
                           date_time=time.localtime(time.time()),
                           )
    info.compress_type=zipfile.ZIP_DEFLATED
    info.comment='Remarks go here'
    info.create_system=0
    zf.writestr(info, msg)
finally:
    zf.close()

print_info('zipfile_writestr_zipinfo.zip')
```

In this example, I set the modified time to the current time, compress the data, provide a false value for `create_system`, and add a comment.

```
$ python zipfile_writestr_zipinfo.py
from_string.txt
        Comment:        Remarks go here
        Modified:       2007-12-16 11:44:14
        System:         0 (0 = Windows, 3 = Unix)
        ZIP version:    20
        Compressed:     62 bytes
        Uncompressed:   68 bytes
```

13.4.9 Appending to Files

In addition to creating new archives, it is possible to append to an existing archive or add an archive at the end of an existing file (such as a .exe file for a self-extracting archive). To open a file to append to it, use mode `'a'`.

```
from zipfile_infolist import print_info
import zipfile

print 'creating archive'
zf = zipfile.ZipFile('zipfile_append.zip', mode='w')
try:
    zf.write('README.txt')
finally:
    zf.close()

print
print_info('zipfile_append.zip')

print 'appending to the archive'
zf = zipfile.ZipFile('zipfile_append.zip', mode='a')
try:
    zf.write('README.txt', arcname='README2.txt')
finally:
    zf.close()
```

```
print
print_info('zipfile_append.zip')
```

The resulting archive ends up with 2 members:

```
$ python zipfile_append.py
creating archive

README.txt
        Comment:
        Modified:       2007-12-16 10:08:50
        System:         3 (0 = Windows, 3 = Unix)
        ZIP version:    20
        Compressed:     75 bytes
        Uncompressed:   75 bytes

appending to the archive

README.txt
        Comment:
        Modified:       2007-12-16 10:08:50
        System:         3 (0 = Windows, 3 = Unix)
        ZIP version:    20
        Compressed:     75 bytes
        Uncompressed:   75 bytes

README2.txt
        Comment:
        Modified:       2007-12-16 10:08:50
        System:         3 (0 = Windows, 3 = Unix)
        ZIP version:    20
        Compressed:     75 bytes
        Uncompressed:   75 bytes
```

13.4.10 Python ZIP Archives

Since version 2.3 Python has had the ability to *import modules from inside ZIP archives* if those archives appear in *sys.path*. The `PyZipFile` class can be used to construct a module suitable for use in this way. When you use the extra method `writepy()`, `PyZipFile` scans a directory for `.py` files and adds the corresponding `.pyo` or `.pyc` file to the archive. If neither compiled form exists, a `.pyc` file is created and added.

```
import sys
import zipfile

if __name__ == '__main__':
    zf = zipfile.PyZipFile('zipfile_pyzipfile.zip', mode='w')
    try:
        zf.debug = 3
        print 'Adding python files'
        zf.writepy('.')
    finally:
        zf.close()
    for name in zf.namelist():
        print name

    print
    sys.path.insert(0, 'zipfile_pyzipfile.zip')
    import zipfile_pyzipfile
    print 'Imported from:', zipfile_pyzipfile.__file__
```

With the debug attribute of the `PyZipFile` set to 3, verbose debugging is enabled and you can observe as it compiles each `.py` file it finds.

```
$ python zipfile_pyzipfile.py
Adding python files
Adding package in . as .
Compiling ./__init__.py
Adding ./__init__.pyc
Compiling ./zipfile_append.py
Adding ./zipfile_append.pyc
Compiling ./zipfile_getinfo.py
Adding ./zipfile_getinfo.pyc
Compiling ./zipfile_infolist.py
Adding ./zipfile_infolist.pyc
Compiling ./zipfile_is_zipfile.py
Adding ./zipfile_is_zipfile.pyc
Compiling ./zipfile_namelist.py
Adding ./zipfile_namelist.pyc
Compiling ./zipfile_printdir.py
Adding ./zipfile_printdir.pyc
Compiling ./zipfile_pyzipfile.py
Adding ./zipfile_pyzipfile.pyc
Compiling ./zipfile_read.py
Adding ./zipfile_read.pyc
Compiling ./zipfile_write.py
Adding ./zipfile_write.pyc
Compiling ./zipfile_write_arcname.py
Adding ./zipfile_write_arcname.pyc
Compiling ./zipfile_write_compression.py
Adding ./zipfile_write_compression.pyc
Compiling ./zipfile_writestr.py
Adding ./zipfile_writestr.pyc
Compiling ./zipfile_writestr_zipinfo.py
Adding ./zipfile_writestr_zipinfo.pyc
__init__.pyc
zipfile_append.pyc
zipfile_getinfo.pyc
zipfile_infolist.pyc
zipfile_is_zipfile.pyc
zipfile_namelist.pyc
zipfile_printdir.pyc
zipfile_pyzipfile.pyc
zipfile_read.pyc
zipfile_write.pyc
zipfile_write_arcname.pyc
zipfile_write_compression.pyc
zipfile_writestr.pyc
zipfile_writestr_zipinfo.pyc

Imported from: zipfile_pyzipfile.zip/zipfile_pyzipfile.pyc
```

See also:

zipfile (http://docs.python.org/library/zipfile.html) The standard library documentation for this module.

`zlib` ZIP compression library

tarfile Read and write tar archives

zipimport Import Python modules from ZIP archive.

PKZIP Application Note (http://www.pkware.com/documents/casestudies/APPNOTE.TXT) Official specification for the ZIP archive format.

13.5 zlib – Low-level access to GNU zlib compression library

Purpose Low-level access to GNU zlib compression library

Available In 2.5 and later

The `zlib` module provides a lower-level interface to many of the functions in the `zlib` compression library from GNU.

13.5.1 Working with Data in Memory

The simplest way to work with `zlib` requires holding all of the data to be compressed or decompressed in memory, and then using `compress()` and `decompress()`.

```
import zlib
import binascii

original_data = 'This is the original text.'
print 'Original     :', len(original_data), original_data

compressed = zlib.compress(original_data)
print 'Compressed   :', len(compressed), binascii.hexlify(compressed)

decompressed = zlib.decompress(compressed)
print 'Decompressed :', len(decompressed), decompressed
```

```
$ python zlib_memory.py

Original     : 26 This is the original text.
Compressed   : 32 789c0bc9c82c5600a2928c5485fca2ccf4ccbcc41c8592d48a123d007f2f097e
Decompressed : 26 This is the original text.
```

Notice that for short text, the compressed version can be longer. While the actual results depend on the input data, for short bits of text it is interesting to observe the compression overhead.

```
import zlib

original_data = 'This is the original text.'

fmt = '%15s  %15s'
print fmt % ('len(data)', 'len(compressed)')
print fmt % ('-' * 15, '-' * 15)

for i in xrange(20):
    data = original_data * i
    compressed = zlib.compress(data)
    print fmt % (len(data), len(compressed)), '*' if len(data) < len(compressed) else ''
```

```
$ python zlib_lengths.py

      len(data)  len(compressed)
---------------  ----------------
              0                8 *
             26               32 *
             52               35
             78               35
            104               36
            130               36
            156               36
            182               36
            208               36
            234               36
            260               36
            286               36
            312               37
            338               37
            364               38
            390               38
            416               38
            442               38
            468               38
            494               38
```

13.5.2 Working with Streams

The in-memory approach has obvious drawbacks that make it impractical for real-world use cases. The alternative is to use `Compress` and `Decompress` objects to manipulate streams of data, so that the entire data set does not have to fit into memory.

The simple server below responds to requests consisting of filenames by writing a compressed version of the file to the socket used to communicate with the client. It has some artificial chunking in place to illustrate the buffering behavior that happens when the data passed to `compress()` or `decompress()` doesn't result in a complete block of compressed or uncompressed output.

Warning: This server has obvious security implications. Do not run it on a system on the open internet or in any environment where security might be an issue.

```
import zlib
import logging
import SocketServer
import binascii

BLOCK_SIZE = 64

class ZlibRequestHandler(SocketServer.BaseRequestHandler):

    logger = logging.getLogger('Server')

    def handle(self):
        compressor = zlib.compressobj(1)

        # Find out what file the client wants
        filename = self.request.recv(1024)
        self.logger.debug('client asked for: "%s"', filename)
        # Send chunks of the file as they are compressed
        with open(filename, 'rb') as input:
            while True:
                block = input.read(BLOCK_SIZE)
                if not block:
                    break
                self.logger.debug('RAW "%s"', block)
                compressed = compressor.compress(block)
                if compressed:
                    self.logger.debug('SENDING "%s"', binascii.hexlify(compressed))
                    self.request.send(compressed)
                else:
                    self.logger.debug('BUFFERING')

        # Send any data being buffered by the compressor
        remaining = compressor.flush()
        while remaining:
            to_send = remaining[:BLOCK_SIZE]
            remaining = remaining[BLOCK_SIZE:]
            self.logger.debug('FLUSHING "%s"', binascii.hexlify(to_send))
            self.request.send(to_send)
        return


if __name__ == '__main__':
    import socket
    import threading
    from cStringIO import StringIO

    logging.basicConfig(level=logging.DEBUG,
                        format='%(name)s: %(message)s',
                        )
    logger = logging.getLogger('Client')

    # Set up a server, running in a separate thread
    address = ('localhost', 0) # let the kernel give us a port
    server = SocketServer.TCPServer(address, ZlibRequestHandler)
    ip, port = server.server_address # find out what port we were given

    t = threading.Thread(target=server.serve_forever)
    t.setDaemon(True)
    t.start()

    # Connect to the server
    logger.info('Contacting server on %s:%s', ip, port)
    s = socket.socket(socket.AF_INET, socket.SOCK_STREAM)
    s.connect((ip, port))

    # Ask for a file
    requested_file = 'lorem.txt'
    logger.debug('sending filename: "%s"', requested_file)
    len_sent = s.send(requested_file)

    # Receive a response
    buffer = StringIO()
    decompressor = zlib.decompressobj()
    while True:
        response = s.recv(BLOCK_SIZE)
        if not response:
            break
        logger.debug('READ "%s"', binascii.hexlify(response))

        # Include any unconsumed data when feeding the decompressor.
        to_decompress = decompressor.unconsumed_tail + response
        while to_decompress:
            decompressed = decompressor.decompress(to_decompress)
            if decompressed:
                logger.debug('DECOMPRESSED "%s"', decompressed)
                buffer.write(decompressed)
                # Look for unconsumed data due to buffer overflow
                to_decompress = decompressor.unconsumed_tail
            else:
                logger.debug('BUFFERING')
                to_decompress = None

    # deal with data reamining inside the decompressor buffer
    remainder = decompressor.flush()
    if remainder:
        logger.debug('FLUSHED "%s"', remainder)
        buffer.write(reaminder)

    full_response = buffer.getvalue()
    lorem = open('lorem.txt', 'rt').read()
    logger.debug('response matches file contents: %s', full_response == lorem)

    # Clean up
    s.close()
    server.socket.close()
```

```
$ python zlib_server.py

Client: Contacting server on 127.0.0.1:56229
Client: sending filename: "lorem.txt"
Server: client asked for: "lorem.txt"
Server: RAW "Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Donec
"
Server: SENDING "7801"
Server: RAW "egestas, enim et consectetuer ullamcorper, lectus ligula rutrum "
Server: BUFFERING
Client: READ "7801"
Server: RAW "leo, a
elementum elit tortor eu quam. Duis tincidunt nisi ut ant"
Client: BUFFERING
Server: BUFFERING
Server: RAW "e. Nulla
facilisi. Sed tristique eros eu libero. Pellentesque ve"
Server: BUFFERING
Server: RAW "l arcu. Vivamus
purus orci, iaculis ac, suscipit sit amet, pulvi"
Server: BUFFERING
Server: RAW "nar eu,
lacus. Praesent placerat tortor sed nisl. Nunc blandit d"
Server: BUFFERING
Server: RAW "iam egestas
dui. Pellentesque habitant morbi tristique senectus "
Server: BUFFERING
```

```
Server: RAW "et netus et
malesuada fames ac turpis egestas. Aliquam viverra f"
Server: BUFFERING
Server: RAW "ringilla
leo. Nulla feugiat augue eleifend nulla. Vivamus mauris"
Server: BUFFERING
Server: RAW ". Vivamus sed
mauris in nibh placerat egestas. Suspendisse poten"
Server: BUFFERING
Server: RAW "ti. Mauris massa. Ut
eget velit auctor tortor blandit sollicitud"
Server: BUFFERING
Server: RAW "in. Suspendisse imperdiet
justo.
"
Server: BUFFERING
Server: FLUSHING "5592418edb300c45f73e050f60f80e05ba6c8b0245bb676426c382923c22e9f3f70bc94c1ac00b9b96
Server: FLUSHING "25245206f1ae877ad17623318d8dbef62665919b78b0af244d2b49bc5e4a33aea58f43c64a06ad7432
Client: READ "5592418edb300c45f73e050f60f80e05ba6c8b0245bb676426c382923c22e9f3f70bc94c1ac00b9b963eff
Server: FLUSHING "de932b7aa53a85b6a27bb6a0a6ae94b0d94236fa31bb2c572e6aa86ff44b768aa11efa9e4232ba4f21
Client: DECOMPRESSED "Lorem ipsum dolor sit amet, conse"
Server: FLUSHING "39e0b18fa22b299784247159c913d90f587be239d24e6d3c6dae8be1ac437db038e4e94041067f4671
Client: READ "25245206f1ae877ad17623318d8dbef62665919b78b0af244d2b49bc5e4a33aea58f43c64a06ad7432bda5
Server: FLUSHING "e38b065252ede3a2ffa5428f3b4d106f181022c652d9c49377a62b06387d53e4c0d43e3a6cf4c50005
Client: DECOMPRESSED "ctetuer adipiscing elit. Donec
egestas, enim et consectetuer ullamcorper, lectus ligula rutrum leo, a
elementum elit tortor eu"
Server: FLUSHING "d044afd2607f72fe24459513909fdf480807b346da90f5f2f684f04888d9a41fd05277a1a3074821f2
Client: READ "de932b7aa53a85b6a27bb6a0a6ae94b0d94236fa31bb2c572e6aa86ff44b768aa11efa9e4232ba4f21d30b
Server: FLUSHING "dd4c8b46eeda5e45b562d776058dbfe9d1b7e51f6f370ea5"
Client: DECOMPRESSED " quam. Duis tincidunt nisi ut ante. Nulla
facilisi. Sed tristique eros eu libero. Pellentesque vel arcu. Vivamus
p"
Client: READ "39e0b18fa22b299784247159c913d90f587be239d24e6d3c6dae8be1ac437db038e4e94041067f46719882
Client: DECOMPRESSED "urus orci, iaculis ac, suscipit sit amet, pulvinar eu,
lacus. Praesent placerat tortor sed nisl. Nunc blandit diam egestas
dui. Pellentesque "
Client: READ "e38b065252ede3a2ffa5428f3b4d106f181022c652d9c49377a62b06387d53e4c0d43e3a6cf4c500052d4f
Client: DECOMPRESSED "habitant morbi tristique senectus et netus et
malesuada fames ac turpis egestas. Aliquam viverra fringilla
leo. Nulla feugiat aug"
Client: READ "d044afd2607f72fe24459513909fdf480807b346da90f5f2f684f04888d9a41fd05277a1a3074821f2f7fb
Client: DECOMPRESSED "ue eleifend nulla. Vivamus mauris. Vivamus sed
mauris in nibh placerat egestas. Suspendisse potenti. Mauris massa. Ut
eget velit auctor tortor blandit s"
Client: READ "dd4c8b46eeda5e45b562d776058dbfe9d1b7e51f6f370ea5"
Client: DECOMPRESSED "ollicitudin. Suspendisse imperdiet
justo.
"
Client: response matches file contents: True
```

13.5.3 Mixed Content Streams

The `Decompress` class returned by `decompressobj()` can also be used in situations where compressed and uncompressed data is mixed together. After decompressing all of the data, the *unused_data* attribute contains any data not used.

```
import zlib

lorem = open('lorem.txt', 'rt').read()
compressed = zlib.compress(lorem)
combined = compressed + lorem

decompressor = zlib.decompressobj()
decompressed = decompressor.decompress(combined)

print 'Decompressed matches lorem:', decompressed == lorem
print 'Unused data matches lorem :', decompressor.unused_data == lorem
```

```
$ python zlib_mixed.py

Decompressed matches lorem: True
Unused data matches lorem : True
```

13.5.4 Checksums

In addition to compression and decompression functions, `zlib` includes two functions for computing checksums of data, `adler32()` and `crc32()`. Neither checksum is billed as cryptographically secure, and they are only intended for use for data integrity verification.

Both functions take the same arguments, a string of data and an optional value to be used as a starting point for the checksum. They return a 32-bit signed integer value which can also be passed back on subsequent calls as a new starting point argument to produce a *running* checksum.

```
import zlib

data = open('lorem.txt', 'r').read()

cksum = zlib.adler32(data)
print 'Adler32: %12d' % cksum
print '       : %12d' % zlib.adler32(data, cksum)

cksum = zlib.crc32(data)
print 'CRC-32 : %12d' % cksum
print '       : %12d' % zlib.crc32(data, cksum)
```

```
$ python zlib_checksums.py

Adler32:   1865879205
       :    118955337
CRC-32 :   1878123957
       :  -1940264325
```

The Adler32 algorithm is said to be faster than a standard CRC, but I found it to be slower in my own tests.

```
import timeit

iterations = 1000

def show_results(title, result, iterations):
    "Print results in terms of microseconds per pass and per item."
    per_pass = 1000000 * (result / iterations)
    print '%s:\t%.2f usec/pass' % (title, per_pass)
```

```
adler32 = timeit.Timer(
    stmt="zlib.adler32(data)",
    setup="import zlib; data=open('lorem.txt','r').read() * 10",
    )
show_results('Adler32, separate', adler32.timeit(iterations), iterations)

adler32_running = timeit.Timer(
    stmt="cksum = zlib.adler32(data, cksum)",
    setup="import zlib; data=open('lorem.txt','r').read() * 10; cksum = zlib.adler32(data)",
    )
show_results('Adler32, running', adler32_running.timeit(iterations), iterations)

crc32 = timeit.Timer(
    stmt="zlib.crc32(data)",
    setup="import zlib; data=open('lorem.txt','r').read() * 10",
    )
show_results('CRC-32, separate', crc32.timeit(iterations), iterations)

crc32_running = timeit.Timer(
    stmt="cksum = zlib.crc32(data, cksum)",
    setup="import zlib; data=open('lorem.txt','r').read() * 10; cksum = zlib.crc32(data)",
    )
show_results('CRC-32, running', crc32_running.timeit(iterations), iterations)
```

```
$ python zlib_checksum_tests.py

Adler32, separate:      1.07 usec/pass
Adler32, running:       1.10 usec/pass
CRC-32, separate:       9.78 usec/pass
CRC-32, running:        9.73 usec/pass
```

See also:

zlib **(http://docs.python.org/library/zlib.html)** The standard library documentation for this module.

`gzip` The gzip module includes a higher level (file-based) interface to the zlib library.

http://www.zlib.net/ Home page for zlib library.

http://www.zlib.net/manual.html Complete zlib documentation.

`bz2` The bz2 module provides a similar interface to the bzip2 compression library.

CHAPTER FOURTEEN

DATA PERSISTENCE

The standard library includes a variety of modules for persisting data. The most common pattern for storing data from Python objects for reuse is to serialize them with pickle and then either write them directly to a file or store them using one of the many key-value pair database formats available with the *dbm* API. If you don't care about the underlying dbm format, the best persistence interface is provided by shelve. If you do care, you can use one of the other dbm-based modules directly.

14.1 anydbm – Access to DBM-style databases

Purpose anydbm provides a generic dictionary-like interface to DBM-style, string-keyed databases

Available In 1.4 and later

anydbm is a front-end for DBM-style databases that use simple string values as keys to access records containing strings. It uses the whichdb module to identify dbhash, gdbm, and dbm databases, then opens them with the appropriate module. It is used as a backend for shelve, which knows how to store objects using pickle.

14.1.1 Creating a New Database

The storage format for new databases is selected by looking for each of these modules in order:

- dbhash
- gdbm
- dbm
- dumbdbm

The `open()` function takes *flags* to control how the database file is managed. To create a new database when necessary, use `'c'`. To always create a new database, use `'n'`.

```
import anydbm

db = anydbm.open('/tmp/example.db', 'n')
db['key'] = 'value'
db['today'] = 'Sunday'
db['author'] = 'Doug'
db.close()
```

```
$ python anydbm_new.py
```

In this example, the file is always re-initialized. To see what type of database was created, we can use whichdb.

```
import whichdb

print whichdb.whichdb('/tmp/example.db')
```

Your results may vary, depending on what modules are installed on your system.

```
$ python anydbm_whichdb.py

dbhash
```

14.1.2 Opening an Existing Database

To open an existing database, use *flags* of either `'r'` (for read-only) or `'w'` (for read-write). You don't need to worry about the format, because existing databases are automatically given to `whichdb` to identify. If a file can be identified, the appropriate module is used to open it.

```
import anydbm

db = anydbm.open('/tmp/example.db', 'r')
try:
    print 'keys():', db.keys()
    for k, v in db.iteritems():
        print 'iterating:', k, v
    print 'db["author"] =', db['author']
finally:
    db.close()
```

Once open, `db` is a dictionary-like object, with support for the usual methods:

```
$ python anydbm_existing.py

keys(): ['author', 'key', 'today']
iterating: author Doug
iterating: key value
iterating: today Sunday
db["author"] = Doug
```

14.1.3 Error Cases

The keys of the database need to be strings.

```
import anydbm

db = anydbm.open('/tmp/example.db', 'w')
try:
    db[1] = 'one'
except TypeError, err:
    print '%s: %s' % (err.__class__.__name__, err)
finally:
    db.close()
```

Passing another type results in a *TypeError*.

```
$ python anydbm_intkeys.py

TypeError: Integer keys only allowed for Recno and Queue DB's
```

Values must be strings or `None`.

```
import anydbm

db = anydbm.open('/tmp/example.db', 'w')
try:
    db['one'] = 1
except TypeError, err:
    print '%s: %s' % (err.__class__.__name__, err)
finally:
    db.close()
```

A similar *TypeError* is raised if a value is not a string.

```
$ python anydbm_intvalue.py

TypeError: Data values must be of type string or None.
```

See also:

Module `shelve` Examples for the `shelve` module, which uses `anydbm` to store data.

anydbm (http://docs.python.org/library/anydbm.html) The standard library documentation for this module.

Data Persistence and Exchange Descriptions of other modules for storing data.

14.2 dbhash – DBM-style API for the BSD database library

Purpose Provides a dictionary-like API for accessing BSD `db` files.

Available In 1.4 and later

The `dbhash` module is the primary backend for `anydbm`. It uses the `bsddb` library to manage database files. The semantics are the same as `anydbm`, so refer to the examples on that page for details.

See also:

dbhash (http://docs.python.org/library/dbhash.html) The standard library documentation for this module.

`anydbm` The `anydbm` module.

14.3 dbm – Simple database interface

Purpose Provides an interface to the Unix (n)dbm library.

Available In 1.4 and later

The `dbm` module provides an interface to one of the dbm libraries, depending on how the module was configured during compilation.

14.3.1 Examples

The `library` attribute identifies the library being used, by name.

```
import dbm

print dbm.library
```

Your results will depend on what library `configure` was able to find when the interpreter was built.

```
$ python dbm_library.py

GNU gdbm
```

The `open()` function follows the same semantics as the `anydbm` module.

See also:

dbm (http://docs.python.org/library/dbm.html) The standard library documentation for this module.

`anydbm` The `anydbm` module.

14.4 dumbdbm – Portable DBM Implementation

Purpose Last-resort backend implementation for `anydbm`.

Available In 1.4 and later

The `dumbdbm` module is a portable fallback implementation of the DBM API when no other implementations are available. No external dependencies are required to use `dumbdbm`, but it is slower than most other implementations.

It follows the semantics of the `anydbm` module.

See also:

dumbdbm (http://docs.python.org/library/dumbdbm.html) The standard library documentation for this module.

`anydbm` The `anydbm` module.

14.5 gdbm – GNU's version of the dbm library

Purpose GNU's version of the dbm library

Available In 1.4 and later

`gdbm` is GNU's updated version of the `dbm` library. It follows the same semantics as the other DBM implementations described under `anydbm`, with a few changes to the *flags* supported by `open()`.

Besides the standard `'r'`, `'w'`, `'c'`, and `'n'` flags, `gdbm.open()` supports:

- `'f'` to open the database in *fast* mode. In fast mode, writes to the database are not synchronized.
- `'s'` to open the database in *synchronized* mode. Changes to the database are written to the file as they are made, rather than being delayed until the database is closed or synced explicitly.
- `'u'` to open the database unlocked.

See also:

gdbm (http://docs.python.org/library/gdbm.html) The standard library documentation for this module.

`dbm` The `dbm` module.

`anydbm` The `anydbm` module.

14.6 pickle and cPickle – Python object serialization

Purpose Python object serialization

Available In pickle at least 1.4, cPickle 1.5

The `pickle` module implements an algorithm for turning an arbitrary Python object into a series of bytes. This process is also called *serializing*" the object. The byte stream representing the object can then be transmitted or stored, and later reconstructed to create a new object with the same characteristics.

The `cPickle` module implements the same algorithm, in C instead of Python. It is many times faster than the Python implementation, but does not allow the user to subclass from Pickle. If subclassing is not important for your use, you probably want to use cPickle.

Warning: The documentation for pickle makes clear that it offers no security guarantees. Be careful if you use pickle for inter-process communication or data storage. Do not trust data you cannot verify as secure.

14.6.1 Importing

It is common to first try to import cPickle, giving an alias of "pickle". If that import fails for any reason, you can then fall back on the native Python implementation in the pickle module. This gives you the faster implementation, if it is available, and the portable implementation otherwise.

```
try:
   import cPickle as pickle
except:
   import pickle
```

14.6.2 Encoding and Decoding Data in Strings

This first example encodes a data structure as a string, then prints the string to the console. It uses a data structure made up of entirely native types. Instances of any class can be pickled, as will be illustrated in a later example. Use `pickle.dumps()` to create a string representation of the value of the object.

```
try:
    import cPickle as pickle
except:
    import pickle
import pprint

data = [ { 'a':'A', 'b':2, 'c':3.0 } ]
print 'DATA:',
pprint.pprint(data)

data_string = pickle.dumps(data)
print 'PICKLE:', data_string
```

By default, the pickle will contain only ASCII characters. A more efficient binary format is also available, but all of the examples here use the ASCII output because it is easier to understand in print.

```
$ python pickle_string.py

DATA:[{'a': 'A', 'b': 2, 'c': 3.0}]
PICKLE: (lp1
(dp2
S'a'
S'A'
sS'c'
F3
sS'b'
I2
sa.
```

Once the data is serialized, you can write it to a file, socket, pipe, etc. Then later you can read the file and unpickle the data to construct a new object with the same values.

```
try:
    import cPickle as pickle
except:
    import pickle
import pprint

data1 = [ { 'a':'A', 'b':2, 'c':3.0 } ]
print 'BEFORE:',
pprint.pprint(data1)

data1_string = pickle.dumps(data1)

data2 = pickle.loads(data1_string)
print 'AFTER:',
pprint.pprint(data2)

print 'SAME?:', (data1 is data2)
print 'EQUAL?:', (data1 == data2)
```

As you see, the newly constructed object is the equal to but not the same object as the original. No surprise there.

```
$ python pickle_unpickle.py

BEFORE:[{'a': 'A', 'b': 2, 'c': 3.0}]
AFTER:[{'a': 'A', 'b': 2, 'c': 3.0}]
SAME?: False
EQUAL?: True
```

14.6.3 Working with Streams

In addition to `dumps()` and `loads()`, pickle provides a couple of convenience functions for working with file-like streams. It is possible to write multiple objects to a stream, and then read them from the stream without knowing in advance how many objects are written or how big they are.

```
try:
    import cPickle as pickle
except:
    import pickle
import pprint
from StringIO import StringIO

class SimpleObject(object):

    def __init__(self, name):
        self.name = name
        l = list(name)
        l.reverse()
        self.name_backwards = ''.join(l)
        return

data = []
data.append(SimpleObject('pickle'))
data.append(SimpleObject('cPickle'))
data.append(SimpleObject('last'))

# Simulate a file with StringIO
out_s = StringIO()

# Write to the stream
for o in data:
    print 'WRITING: %s (%s)' % (o.name, o.name_backwards)
    pickle.dump(o, out_s)
    out_s.flush()

# Set up a read-able stream
in_s = StringIO(out_s.getvalue())

# Read the data
while True:
    try:
        o = pickle.load(in_s)
    except EOFError:
        break
    else:
        print 'READ: %s (%s)' % (o.name, o.name_backwards)
```

The example simulates streams using StringIO buffers, so we have to play a little trickery to establish the readable stream. A simple database format could use pickles to store objects, too, though `shelve` would be easier to work with.

```
$ python pickle_stream.py

WRITING: pickle (elkcip)
WRITING: cPickle (elkciPc)
WRITING: last (tsal)
READ: pickle (elkcip)
READ: cPickle (elkciPc)
READ: last (tsal)
```

Besides storing data, pickles are very handy for inter-process communication. For example, using `os.fork()` and `os.pipe()`, one can establish worker processes that read job instructions from one pipe and write the results to another pipe. The core code for managing the worker pool and sending jobs in and receiving responses can be reused, since the job and response objects don't have to be of a particular class. If you are using pipes or sockets, do not forget to flush after dumping each object, to push the data through the connection to the other end. See `multiprocessing` if you don't want to write your own worker pool manager.

14.6.4 Problems Reconstructing Objects

When working with your own classes, you must ensure that the class being pickled appears in the namespace of the process reading the pickle. Only the data for the instance is pickled, not the class definition. The class name is used to find the constructor to create the new object when unpickling. Take this example, which writes instances of a class to a file:

```
try:
    import cPickle as pickle
except:
    import pickle
import sys

class SimpleObject(object):

    def __init__(self, name):
        self.name = name
        l = list(name)
        l.reverse()
        self.name_backwards = ''.join(l)
        return

if __name__ == '__main__':
    data = []
    data.append(SimpleObject('pickle'))
    data.append(SimpleObject('cPickle'))
    data.append(SimpleObject('last'))

    try:
        filename = sys.argv[1]
    except IndexError:
        raise RuntimeError('Please specify a filename as an argument to %s' % sys.argv[0])

    out_s = open(filename, 'wb')
    try:
        # Write to the stream
        for o in data:
            print 'WRITING: %s (%s)' % (o.name, o.name_backwards)
            pickle.dump(o, out_s)
    finally:
        out_s.close()
```

When run, the script creates a file based on the name given as argument on the command line:

```
$ python pickle_dump_to_file_1.py test.dat

WRITING: pickle (elkcip)
WRITING: cPickle (elkciPc)
WRITING: last (tsal)
```

A simplistic attempt to load the resulting pickled objects fails:

```
try:
    import cPickle as pickle
except:
    import pickle
import pprint
from StringIO import StringIO
import sys


try:
    filename = sys.argv[1]
except IndexError:
    raise RuntimeError('Please specify a filename as an argument to %s' % sys.argv[0])
```

```
in_s = open(filename, 'rb')
try:
    # Read the data
    while True:
        try:
            o = pickle.load(in_s)
        except EOFError:
            break
        else:
            print 'READ: %s (%s)' % (o.name, o.name_backwards)
finally:
    in_s.close()
```

This version fails because there is no SimpleObject class available:

```
$ python pickle_load_from_file_1.py test.dat

Traceback (most recent call last):
  File "pickle_load_from_file_1.py", line 52, in <module>
    o = pickle.load(in_s)
AttributeError: 'module' object has no attribute 'SimpleObject'
```

The corrected version, which imports SimpleObject from the original script, succeeds.

Add:

```
from pickle_dump_to_file_1 import SimpleObject
```

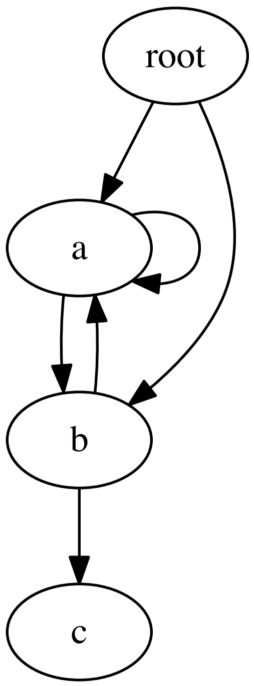
to the end of the import list, then re-run the script:

```
$ python pickle_load_from_file_2.py test.dat

READ: pickle (elkcip)
READ: cPickle (elkciPc)
READ: last (tsal)
```

There are some special considerations when pickling data types with values that cannot be pickled (sockets, file handles, database connections, etc.). Classes that use values which cannot be pickled can define `__getstate__()` and `__setstate__()` to return a subset of the state of the instance to be pickled. New-style classes can also define `__getnewargs__()`, which should return arguments to be passed to the class memory allocator (`C.__new__()`). Use of these features is covered in more detail in the standard library documentation.

14.6.5 Circular References

The pickle protocol automatically handles circular references between objects, so you don't need to do anything special with complex data structures. Consider the digraph:



Even though the graph includes several cycles, the correct structure can be pickled and then reloaded.

```
import pickle

class Node(object):
    """A simple digraph where each node knows about the other nodes
    it leads to.
    """
    def __init__(self, name):
        self.name = name
        self.connections = []
        return

    def add_edge(self, node):
        "Create an edge between this node and the other."
        self.connections.append(node)
        return

    def __iter__(self):
        return iter(self.connections)

def preorder_traversal(root, seen=None, parent=None):
    """Generator function to yield the edges via a preorder traversal."""
    if seen is None:
        seen = set()
    yield (parent, root)
    if root in seen:
        return
    seen.add(root)
    for node in root:
        for (parent, subnode) in preorder_traversal(node, seen, root):
            yield (parent, subnode)
    return

def show_edges(root):
    "Print all of the edges in the graph."
    for parent, child in preorder_traversal(root):
        if not parent:
            continue
        print '%5s -> %2s (%s)' % (parent.name, child.name, id(child))

# Set up the nodes.
root = Node('root')
a = Node('a')
b = Node('b')
c = Node('c')

# Add edges between them.
root.add_edge(a)
root.add_edge(b)
a.add_edge(b)
b.add_edge(a)
b.add_edge(c)
a.add_edge(a)

print 'ORIGINAL GRAPH:'
show_edges(root)

# Pickle and unpickle the graph to create
# a new set of nodes.
dumped = pickle.dumps(root)
reloaded = pickle.loads(dumped)

print
print 'RELOADED GRAPH:'
show_edges(reloaded)
```

The reloaded nodes are not the same object, but the relationship between the nodes is maintained and only one copy of the object with multiple reference is reloaded. Both of these statements can be verified by examining the `id()` values for the nodes before and after being passed through pickle.

```
$ python pickle_cycle.py

ORIGINAL GRAPH:
 root ->  a (4299721744)
    a ->  b (4299721808)
    b ->  a (4299721744)
    b ->  c (4299721872)
    a ->  a (4299721744)
 root ->  b (4299721808)

RELOADED GRAPH:
 root ->  a (4299722000)
    a ->  b (4299722064)
    b ->  a (4299722000)
    b ->  c (4299722128)
    a ->  a (4299722000)
 root ->  b (4299722064)
```

See also:

pickle (http://docs.python.org/lib/module-pickle.html) Standard library documentation for this module.

shelve The shelve module.

Pickle: An interesting stack language. (http://peadrop.com/blog/2007/06/18/pickle-an-interesting-stack-language/) by Alexandre Vassalotti

Data Persistence and Exchange

14.7 shelve – Persistent storage of arbitrary Python objects

Purpose The shelve module implements persistent storage for arbitrary Python objects which can be pickled, using a dictionary-like API.

The `shelve` module can be used as a simple persistent storage option for Python objects when a relational database is overkill. The shelf is accessed by keys, just as with a dictionary. The values are pickled and written to a database created and managed by `anydbm`.

14.7.1 Creating a new Shelf

The simplest way to use shelve is via the `DbfilenameShelf` class. It uses anydbm to store the data. You can use the class directly, or simply call `shelve.open()`:

```
import shelve

s = shelve.open('test_shelf.db')
try:
    s['key1'] = { 'int': 10, 'float':9.5, 'string':'Sample data' }
finally:
    s.close()
```

To access the data again, open the shelf and use it like a dictionary:

```
import shelve

s = shelve.open('test_shelf.db')
try:
    existing = s['key1']
finally:
    s.close()

print existing
```

If you run both sample scripts, you should see:

```
$ python shelve_create.py
$ python shelve_existing.py

{'int': 10, 'float': 9.5, 'string': 'Sample data'}
```

The `dbm` module does not support multiple applications writing to the same database at the same time. If you know your client will not be modifying the shelf, you can tell shelve to open the database read-only.

```
import shelve

s = shelve.open('test_shelf.db', flag='r')
try:
    existing = s['key1']
finally:
    s.close()

print existing
```

If your program tries to modify the database while it is opened read-only, an access error exception is generated. The exception type depends on the database module selected by anydbm when the database was created.

14.7.2 Write-back

Shelves do not track modifications to volatile objects, by default. That means if you change the contents of an item stored in the shelf, you must update the shelf explicitly by storing the item again.

```
import shelve

s = shelve.open('test_shelf.db')
try:
    print s['key1']
    s['key1']['new_value'] = 'this was not here before'
finally:
    s.close()

s = shelve.open('test_shelf.db', writeback=True)
try:
    print s['key1']
finally:
    s.close()
```

In this example, the dictionary at 'key1' is not stored again, so when the shelf is re-opened, the changes have not been preserved.

```
$ python shelve_create.py
$ python shelve_withoutwriteback.py

{'int': 10, 'float': 9.5, 'string': 'Sample data'}
{'int': 10, 'float': 9.5, 'string': 'Sample data'}
```

To automatically catch changes to volatile objects stored in the shelf, open the shelf with writeback enabled. The writeback flag causes the shelf to remember all of the objects retrieved from the database using an in-memory cache. Each cache object is also written back to the database when the shelf is closed.

```
import shelve

s = shelve.open('test_shelf.db', writeback=True)
try:
    print s['key1']
    s['key1']['new_value'] = 'this was not here before'
    print s['key1']
finally:
    s.close()

s = shelve.open('test_shelf.db', writeback=True)
```

```
try:
    print s['key1']
finally:
    s.close()
```

Although it reduces the chance of programmer error, and can make object persistence more transparent, using write-back mode may not be desirable in every situation. The cache consumes extra memory while the shelf is open, and pausing to write every cached object back to the database when it is closed can take extra time. Since there is no way to tell if the cached objects have been modified, they are all written back. If your application reads data more than it writes, writeback will add more overhead than you might want.

```
$ python shelve_create.py
$ python shelve_writeback.py

{'int': 10, 'float': 9.5, 'string': 'Sample data'}
{'int': 10, 'new_value': 'this was not here before', 'float': 9.5, 'string': 'Sample data'}
{'int': 10, 'new_value': 'this was not here before', 'float': 9.5, 'string': 'Sample data'}
```

14.7.3 Specific Shelf Types

The examples above all use the default shelf implementation. Using `shelve.open()` instead of one of the shelf implementations directly is a common usage pattern, especially if you do not care what type of database is used to store the data. There are times, however, when you do care. In those situations, you may want to use `DbfilenameShelf` or `BsdDbShelf` directly, or even subclass `Shelf` for a custom solution.

See also:

shelve (http://docs.python.org/lib/module-shelve.html) Standard library documentation for this module.

anydbm The anydbm module.

feedcache (http://www.doughellmann.com/projects/feedcache/) The feedcache module uses shelve as a default storage option.

shove (http://pypi.python.org/pypi/shove/) Shove implements a similar API with more backend formats.

Data Persistence and Exchange Other mechanisms for storing data using standard library modules.

14.8 whichdb – Identify DBM-style database formats

Purpose Examine existing DBM-style database file to determine what library should be used to open it.

Available In 1.4 and later

The `whichdb` module contains one function, `whichdb()`. It can be used to examine an existing database file to determine which dbm library should be used to open it. It returns `None` if there is a problem opening the file, or the string name of the module to use to open the file. If it can open the file but cannot determine the library to use, it returns the empty string.

```
import anydbm
import whichdb

db = anydbm.open('/tmp/example.db', 'n')
db['key'] = 'value'
db.close()

print whichdb.whichdb('/tmp/example.db')
```

Your results will vary, depending on what modules are available in your PYTHONPATH.

```
$ python whichdb_whichdb.py

dbhash
```

See also:

whichdb (http://docs.python.org/lib/module-whichdb.html) Standard library documentation for this module.

anydbm The anydbm module uses the best available DBM implementation when creating new databases.

shelve The shelve module provides a mapping-style API for DBM databases.

14.9 sqlite3 – Embedded Relational Database

Purpose Implements an embedded relational database with SQL support.

Available In 2.5 and later

The `sqlite3` module provides a DB-API 2.0 compliant interface to the SQLite (http://www.sqlite.org/) relational database. SQLite is an in-process database, designed to be embedded in applications, instead of using a separate database server program such as MySQL, PostgreSQL, or Oracle. SQLite is fast, rigorously tested, and flexible, making it suitable for prototyping and production deployment for some applications.

14.9.1 Creating a Database

An SQLite database is stored as a single file on the filesystem. The library manages access to the file, including locking it to prevent corruption when multiple writers use it. The database is created the first time the file is accessed, but the application is responsible for managing the table definitions, or *schema*, within the database.

This example looks for the database file before opening it with `connect()` so it knows when to create the schema for new databases.

```python
import os
import sqlite3

db_filename = 'todo.db'

db_is_new = not os.path.exists(db_filename)

conn = sqlite3.connect(db_filename)

if db_is_new:
    print 'Need to create schema'
else:
    print 'Database exists, assume schema does, too.'

conn.close()
```

Running the script twice shows that it creates the empty file if it does not exist.

```
$ ls *.db

ls: *.db: No such file or directory

$ python sqlite3_createdb.py
```

```
Need to create schema

$ ls *.db

todo.db

$ python sqlite3_createdb.py

Database exists, assume schema does, too.
```

After creating the new database file, the next step is to create the schema to define the tables within the database. The remaining examples in this section all use the same database schema with tables for managing tasks. The tables are:

project

Column	Type	Description
name	text	Project name
description	text	Long project description
deadline	date	Due date for the entire project

task

Column	Type	Description
id	number	Unique task identifier
priority	integer	Numerical priority, lower is more important
details	text	Full task details
status	text	Task status (one of 'new', 'pending', 'done', or 'canceled').
deadline	date	Due date for this task
completed_on	date	When the task was completed.
project	text	The name of the project for this task.

The *data definition language* (DDL) statements to create the tables are:

```
-- Schema for to-do application examples.

-- Projects are high-level activities made up of tasks
create table project (
    name        text primary key,
    description text,
    deadline    date
);

-- Tasks are steps that can be taken to complete a project
create table task (
    id           integer primary key autoincrement not null,
    priority     integer default 1,
    details      text,
    status       text,
    deadline     date,
    completed_on date,
    project      text not null references project(name)
);
```

The `executescript()` method of the `Connection` can be used to run the DDL instructions to create the schema.

```
import os
import sqlite3

db_filename = 'todo.db'
schema_filename = 'todo_schema.sql'
```

```
db_is_new = not os.path.exists(db_filename)

with sqlite3.connect(db_filename) as conn:
    if db_is_new:
        print 'Creating schema'
        with open(schema_filename, 'rt') as f:
            schema = f.read()
        conn.executescript(schema)

        print 'Inserting initial data'

        conn.execute("""
        insert into project (name, description, deadline)
        values ('pymotw', 'Python Module of the Week', '2010-11-01')
        """)

        conn.execute("""
        insert into task (details, status, deadline, project)
        values ('write about select', 'done', '2010-10-03', 'pymotw')
        """)

        conn.execute("""
        insert into task (details, status, deadline, project)
        values ('write about random', 'waiting', '2010-10-10', 'pymotw')
        """)

        conn.execute("""
        insert into task (details, status, deadline, project)
        values ('write about sqlite3', 'active', '2010-10-17', 'pymotw')
        """)
    else:
        print 'Database exists, assume schema does, too.'
```

After the tables are created, a few **insert** statements create a sample project and related tasks. The **sqlite3** command line program can be used to examine the contents of the database.

```
$ python sqlite3_create_schema.py

Creating schema
Inserting initial data

$ sqlite3 todo.db 'select * from task'

1|1|write about select|done|2010-10-03||pymotw
2|1|write about random|waiting|2010-10-10||pymotw
3|1|write about sqlite3|active|2010-10-17||pymotw
```

14.9.2 Retrieving Data

To retrieve the values saved in the `task` table from within a Python program, create a `Cursor` from a database connection using the `cursor()` method. A cursor produces a consistent view of the data, and is the primary means of interacting with a transactional database system like SQLite.

```
import sqlite3

db_filename = 'todo.db'
```

```
with sqlite3.connect(db_filename) as conn:
    cursor = conn.cursor()

    cursor.execute("""
    select id, priority, details, status, deadline from task where project = 'pymotw'
    """)

    for row in cursor.fetchall():
        task_id, priority, details, status, deadline = row
        print '%2d {%d} %-20s [%-8s] (%s)' % (task_id, priority, details, status, deadline)
```

Querying is a two step process. First, run the query with the cursor's `execute()` method to tell the database engine what data to collect. Then, use `fetchall()` to retrieve the results. The return value is a sequence of tuples containing the values for the columns included in the **select** clause of the query.

```
$ python sqlite3_select_tasks.py

 1 {1} write about select   [done    ] (2010-10-03)
 2 {1} write about random   [waiting ] (2010-10-10)
 3 {1} write about sqlite3  [active  ] (2010-10-17)
```

The results can be retrieved one at a time with `fetchone()`, or in fixed-size batches with `fetchmany()`.

```
import sqlite3

db_filename = 'todo.db'

with sqlite3.connect(db_filename) as conn:
    cursor = conn.cursor()

    cursor.execute("""
    select name, description, deadline from project where name = 'pymotw'
    """)
    name, description, deadline = cursor.fetchone()

    print 'Project details for %s (%s) due %s' % (description, name, deadline)

    cursor.execute("""
    select id, priority, details, status, deadline from task
    where project = 'pymotw' order by deadline
    """)

    print '\nNext 5 tasks:'

    for row in cursor.fetchmany(5):
        task_id, priority, details, status, deadline = row
        print '%2d {%d} %-25s [%-8s] (%s)' % (task_id, priority, details, status, deadline)
```

The value passed to `fetchmany()` is the maximum number of items to return. If fewer items are available, the sequence returned will be smaller than the maximum value.

```
$ python sqlite3_select_variations.py

Project details for Python Module of the Week (pymotw) due 2010-11-01

Next 5 tasks:
 1 {1} write about select        [done    ] (2010-10-03)
 2 {1} write about random        [waiting ] (2010-10-10)
 3 {1} write about sqlite3       [active  ] (2010-10-17)
```

Query Metadata

The DB-API 2.0 specification says that after `execute()` has been called, the `Cursor` should set its `description` attribute to hold information about the data that will be returned by the fetch methods. The API specification say that the description value is a sequence of tuples containing the column name, type, display size, internal size, precision, scale, and a flag that says whether null values are accepted.

```
import sqlite3

db_filename = 'todo.db'

with sqlite3.connect(db_filename) as conn:
    cursor = conn.cursor()

    cursor.execute("""
    select * from task where project = 'pymotw'
    """)

    print 'Task table has these columns:'
    for colinfo in cursor.description:
        print colinfo
```

Because `sqlite3` does not enforce type or size constraints on data inserted into a database, only the column name value is filled in.

```
$ python sqlite3_cursor_description.py

Task table has these columns:
('id', None, None, None, None, None, None)
('priority', None, None, None, None, None, None)
('details', None, None, None, None, None, None)
('status', None, None, None, None, None, None)
('deadline', None, None, None, None, None, None)
('completed_on', None, None, None, None, None, None)
('project', None, None, None, None, None, None)
```

Row Objects

By default, the values returned by the fetch methods as "rows" from the database are tuples. The caller is responsible for knowing the order of the columns in the query and extracting individual values from the tuple. When the number of values in a query grows, or the code working with the data is spread out in a library, it is usually easier to work with an object and access the column values using their column names, since that way the number and order of the tuple elements can change over time as the query is edited, and code depending on the query results is less likely to break.

`Connection` objects have a `row_factory` property that allows the calling code to control the type of object created to represent each row in the query result set. `sqlite3` also includes a `Row` class intended to be used as a row factory. `Row` instances can be accessed by column index and name.

```
import sqlite3

db_filename = 'todo.db'

with sqlite3.connect(db_filename) as conn:
```

```
# Change the row factory to use Row
conn.row_factory = sqlite3.Row

cursor = conn.cursor()

cursor.execute("""
select name, description, deadline from project where name = 'pymotw'
""")
name, description, deadline = cursor.fetchone()

print 'Project details for %s (%s) due %s' % (description, name, deadline)

cursor.execute("""
select id, priority, status, deadline, details from task
where project = 'pymotw' order by deadline
""")

print '\nNext 5 tasks:'

for row in cursor.fetchmany(5):
    print '%2d {%d} %-25s [%-8s] (%s)' % (
        row['id'], row['priority'], row['details'], row['status'], row['deadline'],
        )
```

This version of the `sqlite3_select_variations.py` example has been re-written using `Row` instances instead of tuples. The project row is still printed by accessing the column values through position, but the **print** statement for tasks uses keyword lookup instead, so it does not matter that the order of the columns in the query has been changed.

```
$ python sqlite3_row_factory.py

Project details for Python Module of the Week (pymotw) due 2010-11-01

Next 5 tasks:
 1 {1} write about select        [done    ] (2010-10-03)
 2 {1} write about random        [waiting ] (2010-10-10)
 3 {1} write about sqlite3       [active  ] (2010-10-17)
```

14.9.3 Using Variables with Queries

Using queries defined as literal strings embedded in a program is inflexible. For example, when another project is added to the database the query to show the top five tasks should be updated to work with either project. One way to add more flexibility is to build an SQL statement with the desired query by combining values in Python. However, building a query string in this way is dangerous, and should be avoided. Failing to correctly escape special characters in the variable parts of the query can result in SQL parsing errors, or worse, a class of security vulnerabilities known as *SQL-injection attacks*.

The proper way to use dynamic values with queries is through *host variables* passed to `execute()` along with the SQL instruction. A placeholder value in the SQL is replaced with the value of the host variable when the statement is executed. Using host variables instead of inserting arbitrary values into the SQL before it is parsed avoids injection attacks because there is no chance that the untrusted values will affect how the SQL is parsed. SQLite supports two forms for queries with placeholders, positional and named.

Positional Parameters

A question mark (`?`) denotes a positional argument, passed to `execute()` as a member of a tuple.

```
import sqlite3
import sys

db_filename = 'todo.db'
project_name = sys.argv[1]

with sqlite3.connect(db_filename) as conn:
    cursor = conn.cursor()

    query = "select id, priority, details, status, deadline from task where project = ?"

    cursor.execute(query, (project_name,))

    for row in cursor.fetchall():
        task_id, priority, details, status, deadline = row
        print '%2d {%d} %-20s [%-8s] (%s)' % (task_id, priority, details, status, deadline)
```

The command line argument is passed safely to the query as a positional argument, and there is no chance for bad data to corrupt the database.

```
$ python sqlite3_argument_positional.py pymotw

 1 {1} write about select   [done    ] (2010-10-03)
 2 {1} write about random   [waiting ] (2010-10-10)
 3 {1} write about sqlite3  [active  ] (2010-10-17)
```

Named Parameters

Use named parameters for more complex queries with a lot of parameters or where some parameters are repeated multiple times within the query. Named parameters are prefixed with a colon, like `:param_name`.

```
import sqlite3
import sys

db_filename = 'todo.db'
project_name = sys.argv[1]

with sqlite3.connect(db_filename) as conn:
    cursor = conn.cursor()

    query = """select id, priority, details, status, deadline from task
            where project = :project_name
            order by deadline, priority
            """

    cursor.execute(query, {'project_name':project_name})

    for row in cursor.fetchall():
        task_id, priority, details, status, deadline = row
        print '%2d {%d} %-25s [%-8s] (%s)' % (task_id, priority, details, status, deadline)
```

Neither positional nor named parameters need to be quoted or escaped, since they are given special treatment by the query parser.

```
$ python sqlite3_argument_named.py pymotw

 1 {1} write about select        [done    ] (2010-10-03)
 2 {1} write about random        [waiting ] (2010-10-10)
 3 {1} write about sqlite3       [active  ] (2010-10-17)
```

Query parameters can be used with **select**, **insert**, and **update** statements. They can appear in any part of the query where a literal value is legal.

```
import sqlite3
import sys

db_filename = 'todo.db'
id = int(sys.argv[1])
status = sys.argv[2]

with sqlite3.connect(db_filename) as conn:
    cursor = conn.cursor()
    query = "update task set status = :status where id = :id"
    cursor.execute(query, {'status':status, 'id':id})
```

This **update** statement uses two named parameters. The `id` value is used to find the right row to modify, and the `status` value is written to the table.

```
$ python sqlite3_argument_update.py 2 done
$ python sqlite3_argument_named.py pymotw

 1 {1} write about select        [done    ] (2010-10-03)
 2 {1} write about random        [done    ] (2010-10-10)
 3 {1} write about sqlite3       [active  ] (2010-10-17)
```

Bulk Loading

To apply the same SQL instruction to a lot of data use `executemany()`. This is useful for loading data, since it avoids looping over the inputs in Python and lets the underlying library apply loop optimizations. This example program reads a list of tasks from a comma-separated value file using the `csv` module and loads them into the database.

```
import csv
import sqlite3
import sys

db_filename = 'todo.db'
data_filename = sys.argv[1]

SQL = """insert into task (details, priority, status, deadline, project)
         values (:details, :priority, 'active', :deadline, :project)
      """

with open(data_filename, 'rt') as csv_file:
    csv_reader = csv.DictReader(csv_file)

    with sqlite3.connect(db_filename) as conn:
        cursor = conn.cursor()
        cursor.executemany(SQL, csv_reader)
```

The sample data file `tasks.csv` contains:

```
deadline,project,priority,details
2010-10-02,pymotw,2,"finish reviewing markup"
```

```
2010-10-03,pymotw,2,"revise chapter intros"
2010-10-03,pymotw,1,"subtitle"
```

Running the program produces:

```
$ python sqlite3_load_csv.py tasks.csv
$ python sqlite3_argument_named.py pymotw

 4 {2} finish reviewing markup    [active  ] (2010-10-02)
 6 {1} subtitle                   [active  ] (2010-10-03)
 1 {1} write about select         [done    ] (2010-10-03)
 5 {2} revise chapter intros      [active  ] (2010-10-03)
 2 {1} write about random         [done    ] (2010-10-10)
 3 {1} write about sqlite3        [active  ] (2010-10-17)
```

14.9.4 Column Types

SQLite has native support for integer, floating point, and text columns. Data of these types is converted automatically by `sqlite3` from Python's representation to a value that can be stored in the database, and back again, as needed. Integer values are loaded from the database into `int` or `long` variables, depending on the size of the value. Text is saved and retrieved as `unicode`, unless the `Connection` `text_factory` has been changed.

Although SQLite only supports a few data types internally, `sqlite3` includes facilities for defining custom types to allow a Python application to store any type of data in a column. Conversion for types beyond those supported by default is enabled in the database connection using the `detect_types` flag. Use `PARSE_DECLTYPES` is the column was declared using the desired type when the table was defined.

```
import sqlite3
import sys

db_filename = 'todo.db'

sql = "select id, details, deadline from task"

def show_deadline(conn):
    conn.row_factory = sqlite3.Row
    cursor = conn.cursor()
    cursor.execute(sql)
    row = cursor.fetchone()
    for col in ['id', 'details', 'deadline']:
        print '  column:', col
        print '    value :', row[col]
        print '    type  :', type(row[col])
    return

print 'Without type detection:'

with sqlite3.connect(db_filename) as conn:
    show_deadline(conn)

print '\nWith type detection:'

with sqlite3.connect(db_filename, detect_types=sqlite3.PARSE_DECLTYPES) as conn:
    show_deadline(conn)
```

`sqlite3` provides converters for date and timestamp columns, using `date` and `datetime` from the `datetime` module to represent the values in Python. Both date-related converters are enabled automatically when type-detection is turned on.

```
$ python sqlite3_date_types.py

Without type detection:
  column: id
    value : 1
    type  : <type 'int'>
  column: details
    value : write about select
    type  : <type 'unicode'>
  column: deadline
    value : 2010-10-03
    type  : <type 'unicode'>

With type detection:
  column: id
    value : 1
    type  : <type 'int'>
  column: details
    value : write about select
    type  : <type 'unicode'>
  column: deadline
    value : 2010-10-03
    type  : <type 'datetime.date'>
```

Custom Types

Two functions need to be registered to define a new type. The *adapter* takes the Python object as input and returns a byte string that can be stored in the database. The *converter* receives the string from the database and returns a Python object. Use `register_adapter()` to define an adapter function, and `register_converter()` for a converter function.

```python
import sqlite3
try:
    import cPickle as pickle
except:
    import pickle

db_filename = 'todo.db'

def adapter_func(obj):
    """Convert from in-memory to storage representation.
    """
    print 'adapter_func(%s)\n' % obj
    return pickle.dumps(obj)

def converter_func(data):
    """Convert from storage to in-memory representation.
    """
    print 'converter_func(%r)\n' % data
    return pickle.loads(data)


class MyObj(object):
    def __init__(self, arg):
        self.arg = arg
    def __str__(self):
        return 'MyObj(%r)' % self.arg

# Register the functions for manipulating the type.
sqlite3.register_adapter(MyObj, adapter_func)
sqlite3.register_converter("MyObj", converter_func)

# Create some objects to save.  Use a list of tuples so we can pass
# this sequence directly to executemany().
to_save = [ (MyObj('this is a value to save'),),
            (MyObj(42),),
            ]

with sqlite3.connect(db_filename, detect_types=sqlite3.PARSE_DECLTYPES) as conn:
    # Create a table with column of type "MyObj"
    conn.execute("""
    create table if not exists obj (
        id    integer primary key autoincrement not null,
        data  MyObj
    )
    """)
    cursor = conn.cursor()

    # Insert the objects into the database
    cursor.executemany("insert into obj (data) values (?)", to_save)

    # Query the database for the objects just saved
    cursor.execute("select id, data from obj")
    for obj_id, obj in cursor.fetchall():
        print 'Retrieved', obj_id, obj, type(obj)
        print
```

This example uses `pickle` to save an object to a string that can be stored in the database. This technique is useful for storing arbitrary objects, but does not allow querying based on object attributes. A real *object-relational mapper* such as SQLAlchemy that stores attribute values in their own columns will be more useful for large amounts of data.

```
$ python sqlite3_custom_type.py

adapter_func(MyObj('this is a value to save'))

adapter_func(MyObj(42))

converter_func("ccopy_reg\n_reconstructor\np1\n(c__main__\nMyObj\np2\n
c__builtin__\nobject\np3\nNtRp4\n(dp5\nS'arg'\np6\nS'this is a value t
o save'\np7\nsb.")

converter_func("ccopy_reg\n_reconstructor\np1\n(c__main__\nMyObj\np2\n
c__builtin__\nobject\np3\nNtRp4\n(dp5\nS'arg'\np6\nI42\nsb.")

Retrieved 1 MyObj('this is a value to save') <class '__main__.MyObj'>

Retrieved 2 MyObj(42) <class '__main__.MyObj'>
```

Deriving Types from Column Names

There are two sources for types information about the data for a query. The original table declaration can be used to identify the type of a real column, as shown above. A type specifier can also be included in the **select** clause of the query itself using the form `as "name [type]"`.

```
import sqlite3
try:
    import cPickle as pickle
except:
    import pickle

db_filename = 'todo.db'

def adapter_func(obj):
    """Convert from in-memory to storage representation.
    """
    print 'adapter_func(%s)\n' % obj
    return pickle.dumps(obj)

def converter_func(data):
    """Convert from storage to in-memory representation.
    """
    print 'converter_func(%r)\n' % data
    return pickle.loads(data)


class MyObj(object):
    def __init__(self, arg):
        self.arg = arg
    def __str__(self):
        return 'MyObj(%r)' % self.arg

# Register the functions for manipulating the type.
sqlite3.register_adapter(MyObj, adapter_func)
sqlite3.register_converter("MyObj", converter_func)

# Create some objects to save.  Use a list of tuples so we can pass
# this sequence directly to executemany().
to_save = [ (MyObj('this is a value to save'),),
            (MyObj(42),),
            ]

with sqlite3.connect(db_filename, detect_types=sqlite3.PARSE_COLNAMES) as conn:
    # Create a table with column of type "MyObj"
    conn.execute("""
    create table if not exists obj2 (
        id    integer primary key autoincrement not null,
        data  text
    )
    """)
    cursor = conn.cursor()

    # Insert the objects into the database
    cursor.executemany("insert into obj2 (data) values (?)", to_save)

    # Query the database for the objects just saved
    cursor.execute('select id, data as "pickle [MyObj]" from obj2')
    for obj_id, obj in cursor.fetchall():
        print 'Retrieved', obj_id, obj, type(obj)
        print
```

Use the `detect_types` flag `PARSE_COLNAMES` when type is part of the query instead of the original table definition.

```
$ python sqlite3_custom_type_column.py

adapter_func(MyObj('this is a value to save'))

adapter_func(MyObj(42))

converter_func("ccopy_reg\n_reconstructor\np1\n(c__main__\nMyObj\np2\n
c__builtin__\nobject\np3\nNtRp4\n(dp5\nS'arg'\np6\nS'this is a value t
o save'\np7\nsb.")

converter_func("ccopy_reg\n_reconstructor\np1\n(c__main__\nMyObj\np2\n
c__builtin__\nobject\np3\nNtRp4\n(dp5\nS'arg'\np6\nI42\nsb.")

Retrieved 1 MyObj('this is a value to save') <class '__main__.MyObj'>

Retrieved 2 MyObj(42) <class '__main__.MyObj'>
```

14.9.5 Transactions

One of the key features of relational databases is the use of *transactions* to maintain a consistent internal state. With transactions enabled, several changes can be made through one connection without effecting any other users until the results are *committed* and flushed to the actual database.

Preserving Changes

Changes to the database, either through **insert** or **update** statements, need to be saved by explicitly calling `commit()`. This requirement gives an application an opportinity to make several related changes together, and have them stored *atomically* instead of incrementally, and avoids a situation where partial updates are seen by different clients connecting to the database.

The effect of calling `commit()` can be seen with a program that uses several connections to the database. A new row is inserted with the first connection, and then two attempts are made to read it back using separate connections.

```python
import sqlite3

db_filename = 'todo.db'

def show_projects(conn):
    cursor = conn.cursor()
    cursor.execute('select name, description from project')
    for name, desc in cursor.fetchall():
        print '   ', name
    return

with sqlite3.connect(db_filename) as conn1:

    print 'Before changes:'
    show_projects(conn1)

    # Insert in one cursor
    cursor1 = conn1.cursor()
    cursor1.execute("""
    insert into project (name, description, deadline)
    values ('virtualenvwrapper', 'Virtualenv Extensions', '2011-01-01')
    """)

    print '\nAfter changes in conn1:'
    show_projects(conn1)

    # Select from another connection, without committing first
    print '\nBefore commit:'
    with sqlite3.connect(db_filename) as conn2:
        show_projects(conn2)

    # Commit then select from another connection
    conn1.commit()
    print '\nAfter commit:'
    with sqlite3.connect(db_filename) as conn3:
        show_projects(conn3)
```

When `show_projects()` is called before `conn1` has been committed, the results depend on which connection is used. Since the change was made through `conn1`, it sees the altered data. However, `conn2` does not. After committing, the new connection `conn3` sees the inserted row.

```
$ python sqlite3_transaction_commit.py

Before changes:
   pymotw

After changes in conn1:
   pymotw
   virtualenvwrapper

Before commit:
   pymotw

After commit:
   pymotw
   virtualenvwrapper
```

Discarding Changes

Uncommitted changes can also be discarded entirely using `rollback()`. The `commit()` and `rollback()` methods are usually called from different parts of the same `try:except` block, with errors triggering a rollback.

```
import sqlite3

db_filename = 'todo.db'

def show_projects(conn):
    cursor = conn.cursor()
    cursor.execute('select name, description from project')
    for name, desc in cursor.fetchall():
        print '   ', name
    return

with sqlite3.connect(db_filename) as conn:

    print 'Before changes:'
    show_projects(conn)
    try:

        # Insert
        cursor = conn.cursor()
        cursor.execute("delete from project where name = 'virtualenvwrapper'")

        # Show the settings
        print '\nAfter delete:'
        show_projects(conn)

        # Pretend the processing caused an error
        raise RuntimeError('simulated error')

    except Exception, err:
        # Discard the changes
        print 'ERROR:', err
        conn.rollback()

    else:
        # Save the changes
        conn.commit()

    # Show the results
    print '\nAfter rollback:'
    show_projects(conn)
```

After calling `rollback()`, the changes to the database are no longer present.

```
$ python sqlite3_transaction_rollback.py

Before changes:
   pymotw
   virtualenvwrapper

After delete:
   pymotw
ERROR: simulated error

After rollback:
   pymotw
   virtualenvwrapper
```

Isolation Levels

`sqlite3` supports three locking modes, called *isolation levels*, that control the locks used to prevent incompatible changes between connections. The isolation level is set by passing a string as the *isolation_level* argument when a connection is opened, so different connections can use different values.

This program demonstrates the effect of different isolation levels on the order of events in threads using separate connections to the same database. Four threads are created. Two threads write changes to the database by updating existing rows. The other two threads attempt to read all of the rows from the `task` table.

```
import logging
import sqlite3
import sys
import threading
import time
```

```
logging.basicConfig(level=logging.DEBUG,
                    format='%(asctime)s (%(threadName)-10s) %(message)s',
                    )

db_filename = 'todo.db'
isolation_level = sys.argv[1]

def writer():
    my_name = threading.currentThread().name
    logging.debug('connecting')
    with sqlite3.connect(db_filename, isolation_level=isolation_level) as conn:
        cursor = conn.cursor()
        logging.debug('connected')
        cursor.execute('update task set priority = priority + 1')
        logging.debug('changes made')
        logging.debug('waiting to synchronize')
        ready.wait() # synchronize
        logging.debug('PAUSING')
        time.sleep(1)
        conn.commit()
        logging.debug('CHANGES COMMITTED')
    return

def reader():
    my_name = threading.currentThread().name
    with sqlite3.connect(db_filename, isolation_level=isolation_level) as conn:
        cursor = conn.cursor()
        logging.debug('waiting to synchronize')
        ready.wait() # synchronize
        logging.debug('wait over')
        cursor.execute('select * from task')
        logging.debug('SELECT EXECUTED')
        results = cursor.fetchall()
        logging.debug('results fetched')
    return

if __name__ == '__main__':
    ready = threading.Event()

    threads = [
        threading.Thread(name='Reader 1', target=reader),
        threading.Thread(name='Reader 2', target=reader),
        threading.Thread(name='Writer 1', target=writer),
        threading.Thread(name='Writer 2', target=writer),
        ]

    [ t.start() for t in threads ]

    time.sleep(1)
    logging.debug('setting ready')
    ready.set()

    [ t.join() for t in threads ]
```

The threads are synchronized using a `Event` from the `threading` module. The `writer()` function connects and make changes to the database, but does not commit before the event fires. The `reader()` function connects, then waits to query the database until after the synchronization event occurs.

Deferred

The default isolation level is DEFERRED. Using deferred mode locks the database, but only once a change is begun. All of the previous examples use deferred mode.

```
$ python sqlite3_isolation_levels.py DEFERRED

2013-02-21 06:36:58,573 (Reader 1  ) waiting to synchronize
2013-02-21 06:36:58,573 (Reader 2  ) waiting to synchronize
2013-02-21 06:36:58,573 (Writer 1  ) connecting
2013-02-21 06:36:58,574 (Writer 2  ) connecting
2013-02-21 06:36:58,574 (Writer 1  ) connected
2013-02-21 06:36:58,574 (Writer 2  ) connected
2013-02-21 06:36:58,574 (Writer 1  ) changes made
2013-02-21 06:36:58,575 (Writer 1  ) waiting to synchronize
2013-02-21 06:36:59,574 (MainThread) setting ready
2013-02-21 06:36:59,575 (Writer 1  ) PAUSING
2013-02-21 06:36:59,575 (Reader 2  ) wait over
2013-02-21 06:36:59,575 (Reader 1  ) wait over
2013-02-21 06:36:59,576 (Reader 2  ) SELECT EXECUTED
2013-02-21 06:36:59,576 (Reader 1  ) SELECT EXECUTED
2013-02-21 06:36:59,577 (Reader 2  ) results fetched
2013-02-21 06:36:59,577 (Reader 1  ) results fetched
2013-02-21 06:37:00,579 (Writer 1  ) CHANGES COMMITTED
2013-02-21 06:37:00,625 (Writer 2  ) changes made
2013-02-21 06:37:00,626 (Writer 2  ) waiting to synchronize
2013-02-21 06:37:00,626 (Writer 2  ) PAUSING
2013-02-21 06:37:01,629 (Writer 2  ) CHANGES COMMITTED
```

Immediate

Immediate mode locks the database as soon as a change starts and prevents other cursors from making changes until the transaction is committed. It is suitable for a database with complicated writes but more readers than writers, since the readers are not blocked while the transaction is ongoing.

```
$ python sqlite3_isolation_levels.py IMMEDIATE

2013-02-21 06:37:01,668 (Reader 2  ) waiting to synchronize
2013-02-21 06:37:01,668 (Reader 1  ) waiting to synchronize
2013-02-21 06:37:01,669 (Writer 1  ) connecting
2013-02-21 06:37:01,669 (Writer 2  ) connecting
2013-02-21 06:37:01,669 (Writer 1  ) connected
2013-02-21 06:37:01,669 (Writer 2  ) connected
2013-02-21 06:37:01,670 (Writer 1  ) changes made
2013-02-21 06:37:01,670 (Writer 1  ) waiting to synchronize
2013-02-21 06:37:02,670 (MainThread) setting ready
2013-02-21 06:37:02,671 (Writer 1  ) PAUSING
2013-02-21 06:37:02,671 (Reader 2  ) wait over
2013-02-21 06:37:02,671 (Reader 1  ) wait over
2013-02-21 06:37:02,672 (Reader 2  ) SELECT EXECUTED
2013-02-21 06:37:02,672 (Reader 1  ) SELECT EXECUTED
2013-02-21 06:37:02,673 (Reader 2  ) results fetched
2013-02-21 06:37:02,673 (Reader 1  ) results fetched
2013-02-21 06:37:03,675 (Writer 1  ) CHANGES COMMITTED
2013-02-21 06:37:03,724 (Writer 2  ) changes made
2013-02-21 06:37:03,724 (Writer 2  ) waiting to synchronize
```

```
2013-02-21 06:37:03,725 (Writer 2  ) PAUSING
2013-02-21 06:37:04,729 (Writer 2  ) CHANGES COMMITTED
```

Exclusive

Exclusive mode locks the database to all readers and writers. Its use should be limited in situations where database performance is important, since each exclusive connection blocks all other users.

```
$ python sqlite3_isolation_levels.py EXCLUSIVE

2013-02-21 06:37:04,769 (Reader 2  ) waiting to synchronize
2013-02-21 06:37:04,769 (Writer 1  ) connecting
2013-02-21 06:37:04,768 (Reader 1  ) waiting to synchronize
2013-02-21 06:37:04,769 (Writer 2  ) connecting
2013-02-21 06:37:04,769 (Writer 1  ) connected
2013-02-21 06:37:04,769 (Writer 2  ) connected
2013-02-21 06:37:04,771 (Writer 1  ) changes made
2013-02-21 06:37:04,771 (Writer 1  ) waiting to synchronize
2013-02-21 06:37:05,770 (MainThread) setting ready
2013-02-21 06:37:05,771 (Reader 1  ) wait over
2013-02-21 06:37:05,771 (Reader 2  ) wait over
2013-02-21 06:37:05,771 (Writer 1  ) PAUSING
2013-02-21 06:37:06,775 (Writer 1  ) CHANGES COMMITTED
2013-02-21 06:37:06,816 (Reader 2  ) SELECT EXECUTED
2013-02-21 06:37:06,816 (Reader 1  ) SELECT EXECUTED
2013-02-21 06:37:06,817 (Reader 2  ) results fetched
2013-02-21 06:37:06,817 (Reader 1  ) results fetched
2013-02-21 06:37:06,819 (Writer 2  ) changes made
2013-02-21 06:37:06,819 (Writer 2  ) waiting to synchronize
2013-02-21 06:37:06,819 (Writer 2  ) PAUSING
2013-02-21 06:37:07,822 (Writer 2  ) CHANGES COMMITTED
```

Because the first writer has started making changes, the readers and second writer block until it commits. The `sleep()` call introduces an artificial delay in the writer thread to highlight the fact that the other connections are blocking.

Autocommit

The *isolation_level* parameter for the connection can also be set to `None` to enable autocommit mode. With autocommit enabled, each `execute()` call is committed immediately when the statement finishes. Autocommit mode is suited for short transactions, such as those that insert a small amount of data into a single table. The database is locked for as little time as possible, so there is less chance of contention between threads.

```
import logging
import sqlite3
import sys
import threading
import time

logging.basicConfig(level=logging.DEBUG,
                    format='%(asctime)s (%(threadName)-10s) %(message)s',
                    )

db_filename = 'todo.db'
isolation_level = None # autocommit mode
```

```
def writer():
    my_name = threading.currentThread().name
    logging.debug('connecting')
    with sqlite3.connect(db_filename, isolation_level=isolation_level) as conn:
        cursor = conn.cursor()
        logging.debug('connected')
        cursor.execute('update task set priority = priority + 1')
        logging.debug('changes made')
        logging.debug('waiting to synchronize')
        ready.wait() # synchronize
        logging.debug('PAUSING')
        time.sleep(1)
    return

def reader():
    my_name = threading.currentThread().name
    with sqlite3.connect(db_filename, isolation_level=isolation_level) as conn:
        cursor = conn.cursor()
        logging.debug('waiting to synchronize')
        ready.wait() # synchronize
        logging.debug('wait over')
        cursor.execute('select * from task')
        logging.debug('SELECT EXECUTED')
        results = cursor.fetchall()
        logging.debug('results fetched')
    return

if __name__ == '__main__':
    ready = threading.Event()

    threads = [
        threading.Thread(name='Reader 1', target=reader),
        threading.Thread(name='Reader 2', target=reader),
        threading.Thread(name='Writer 1', target=writer),
        threading.Thread(name='Writer 2', target=writer),
        ]

    [ t.start() for t in threads ]

    time.sleep(1)
    logging.debug('setting ready')
    ready.set()

    [ t.join() for t in threads ]
```

The explicit call to `commit()` has been removed, but otherwise `sqlite3_autocommit.py` is the same as `sqlite3_isolation_levels.py`. The output is different, however, since both writer threads finish their work before either reader starts querying.

```
$ python sqlite3_autocommit.py

2013-02-21 06:37:07,878 (Reader 1  ) waiting to synchronize
2013-02-21 06:37:07,878 (Reader 2  ) waiting to synchronize
2013-02-21 06:37:07,878 (Writer 1  ) connecting
2013-02-21 06:37:07,878 (Writer 2  ) connecting
2013-02-21 06:37:07,878 (Writer 1  ) connected
2013-02-21 06:37:07,879 (Writer 2  ) connected
2013-02-21 06:37:07,880 (Writer 2  ) changes made
```

```
2013-02-21 06:37:07,880 (Writer 2  ) waiting to synchronize
2013-02-21 06:37:07,881 (Writer 1  ) changes made
2013-02-21 06:37:07,881 (Writer 1  ) waiting to synchronize
2013-02-21 06:37:08,879 (MainThread) setting ready
2013-02-21 06:37:08,880 (Writer 1  ) PAUSING
2013-02-21 06:37:08,880 (Writer 2  ) PAUSING
2013-02-21 06:37:08,880 (Reader 1  ) wait over
2013-02-21 06:37:08,881 (Reader 2  ) wait over
2013-02-21 06:37:08,882 (Reader 2  ) SELECT EXECUTED
2013-02-21 06:37:08,882 (Reader 1  ) SELECT EXECUTED
2013-02-21 06:37:08,882 (Reader 2  ) results fetched
2013-02-21 06:37:08,882 (Reader 1  ) results fetched
```

14.9.6 User-defined Behaviors

`sqlite3` supports several extension mechanisms, with support for extending the database features with functions and classes implemented in Python.

Using Python Functions in SQL

SQL syntax supports calling functions with during queries, either in the column list or **where** clause of the **select** statement. This feature makes it possible to process data before returning it from the query, and can be used to convert between different formats, perform calculations that would be clumsy in pure SQL, and reuse application code.

```
import sqlite3

db_filename = 'todo.db'

def encrypt(s):
    print 'Encrypting %r' % s
    return s.encode('rot-13')

def decrypt(s):
    print 'Decrypting %r' % s
    return s.encode('rot-13')


with sqlite3.connect(db_filename) as conn:

    conn.create_function('encrypt', 1, encrypt)
    conn.create_function('decrypt', 1, decrypt)
    cursor = conn.cursor()

    # Raw values
    print 'Original values:'
    query = "select id, details from task"
    cursor.execute(query)
    for row in cursor.fetchall():
        print row

    print '\nEncrypting...'
    query = "update task set details = encrypt(details)"
    cursor.execute(query)

    print '\nRaw encrypted values:'
    query = "select id, details from task"
    cursor.execute(query)
    for row in cursor.fetchall():
        print row

    print '\nDecrypting in query...'
    query = "select id, decrypt(details) from task"
    cursor.execute(query)
    for row in cursor.fetchall():
        print row
```

Functions are exposed using the `create_function()` method of the `Connection`. The parameters are the name of the function (as it should be used from within SQL), the number of arguments the function takes, and the Python function to expose.

```
$ python sqlite3_create_function.py

Original values:
(1, u'write about select')
(2, u'write about random')
(3, u'write about sqlite3')
(4, u'finish reviewing markup')
(5, u'revise chapter intros')
(6, u'subtitle')

Encrypting...
Encrypting u'write about select'
Encrypting u'write about random'
Encrypting u'write about sqlite3'
Encrypting u'finish reviewing markup'
Encrypting u'revise chapter intros'
Encrypting u'subtitle'

Raw encrypted values:
(1, u'jevgr nobhg fryrpg')
(2, u'jevgr nobhg enaqbz')
(3, u'jevgr nobhg fdyvgr3')
(4, u'svavfu erivrjvat znexhc')
(5, u'erivfr puncgre vagebf')
(6, u'fhogvgyr')

Decrypting in query...
Decrypting u'jevgr nobhg fryrpg'
Decrypting u'jevgr nobhg enaqbz'
Decrypting u'jevgr nobhg fdyvgr3'
Decrypting u'svavfu erivrjvat znexhc'
Decrypting u'erivfr puncgre vagebf'
Decrypting u'fhogvgyr'
(1, u'write about select')
(2, u'write about random')
(3, u'write about sqlite3')
(4, u'finish reviewing markup')
(5, u'revise chapter intros')
(6, u'subtitle')
```

Custom Aggregation

An aggregation function collects many pieces of individual data and summarizes it in some way. Examples of built-in aggregation functions are `avg()` (average), `min()`, `max()`, and `count()`.

The API for aggregators used by `sqlite3` is defined in terms of a class with two methods. The `step()` method is called once for each data value as the query is processed. The `finalize()` method is called one time at the end of the query and should return the aggregate value. This example implements an aggregator for the arithmetic *mode*. It returns the value that appears most frequently in the input.

```
import sqlite3
import collections

db_filename = 'todo.db'

class Mode(object):
    def __init__(self):
        self.counter = collections.Counter()
    def step(self, value):
        print 'step(%r)' % value
        self.counter[value] += 1
    def finalize(self):
        result, count = self.counter.most_common(1)[0]
        print 'finalize() -> %r (%d times)' % (result, count)
        return result

with sqlite3.connect(db_filename) as conn:

    conn.create_aggregate('mode', 1, Mode)

    cursor = conn.cursor()
    cursor.execute("select mode(deadline) from task where project = 'pymotw'")
    row = cursor.fetchone()
    print 'mode(deadline) is:', row[0]
```

The aggregator class is registered with the `create_aggregate()` method of the `Connection`. The parameters are the name of the function (as it should be used from within SQL), the number of arguments the `step()` method takes, and the class to use.

```
$ python sqlite3_create_aggregate.py

step(u'2010-10-03')
step(u'2010-10-10')
step(u'2010-10-17')
step(u'2010-10-02')
step(u'2010-10-03')
step(u'2010-10-03')
finalize() -> u'2010-10-03' (3 times)
mode(deadline) is: 2010-10-03
```

Custom Sorting

A *collation* is a comparison function used in the **order by** section of an SQL query. Custom collations can be used to compare data types that could not otherwise be sorted by SQLite internally. For example, a custom collation would be needed to sort the pickled objects saved in `sqlite3_custom_type.py` above.

```
import sqlite3
try:
    import cPickle as pickle
except:
    import pickle

db_filename = 'todo.db'

def adapter_func(obj):
    return pickle.dumps(obj)

def converter_func(data):
    return pickle.loads(data)

class MyObj(object):
    def __init__(self, arg):
        self.arg = arg
    def __str__(self):
        return 'MyObj(%r)' % self.arg
    def __cmp__(self, other):
        return cmp(self.arg, other.arg)

# Register the functions for manipulating the type.
sqlite3.register_adapter(MyObj, adapter_func)
sqlite3.register_converter("MyObj", converter_func)

def collation_func(a, b):
    a_obj = converter_func(a)
    b_obj = converter_func(b)
    print 'collation_func(%s, %s)' % (a_obj, b_obj)
    return cmp(a_obj, b_obj)

with sqlite3.connect(db_filename, detect_types=sqlite3.PARSE_DECLTYPES) as conn:
    # Define the collation
    conn.create_collation('unpickle', collation_func)

    # Clear the table and insert new values
    conn.execute('delete from obj')
    conn.executemany('insert into obj (data) values (?)',
                     [(MyObj(x),) for x in xrange(5, 0, -1)],
                     )

    # Query the database for the objects just saved
    print '\nQuerying:'
    cursor = conn.cursor()
    cursor.execute("select id, data from obj order by data collate unpickle")
    for obj_id, obj in cursor.fetchall():
        print obj_id, obj
        print
```

The arguments to the collation function are byte strings, so they must be unpickled and converted to `MyObj` instances before the comparison can be performed.

```
$ python sqlite3_create_collation.py


Querying:
collation_func(MyObj(5), MyObj(4))
collation_func(MyObj(4), MyObj(3))
collation_func(MyObj(4), MyObj(2))
collation_func(MyObj(3), MyObj(2))
collation_func(MyObj(3), MyObj(1))
collation_func(MyObj(2), MyObj(1))
7 MyObj(1)

6 MyObj(2)

5 MyObj(3)

4 MyObj(4)

3 MyObj(5)
```

14.9.7 Restricting Access to Data

Although SQLite does not have user access controls found in other, larger, relational databases, it does have a mechanism for limiting access to columns. Each connection can install an *authorizer function* to grant or deny access to columns at runtime based on any desired criteria. The authorizer function is invoked during the parsing of SQL statements, and is passed five arguments. The first is an action code indicating the type of operation being performed (reading, writing, deleting, etc.). The rest of the arguments depend on the action code. For `SQLITE_READ` operations, the arguments are the name of the table, the name of the column, the location in the SQL where the access is occuring (main query, trigger, etc.), and `None`.

```python
import sqlite3

db_filename = 'todo.db'

def authorizer_func(action_code, table, column, sql_location, ignore):
    print '\nauthorizer_func(%s, %s, %s, %s, %s)' % \
        (action_code, table, column, sql_location, ignore)

    response = sqlite3.SQLITE_OK # be permissive by default

    if action_code == sqlite3.SQLITE_SELECT:
        print 'requesting permission to run a select statement'
        response = sqlite3.SQLITE_OK

    elif action_code == sqlite3.SQLITE_READ:
        print 'requesting permission to access the column %s.%s from %s' % \
            (table, column, sql_location)
        if column == 'details':
            print '  ignoring details column'
            response = sqlite3.SQLITE_IGNORE
        elif column == 'priority':
            print '  preventing access to priority column'
            response = sqlite3.SQLITE_DENY

    return response

with sqlite3.connect(db_filename) as conn:
    conn.row_factory = sqlite3.Row
    conn.set_authorizer(authorizer_func)

    print 'Using SQLITE_IGNORE to mask a column value:'
    cursor = conn.cursor()
    cursor.execute("select id, details from task where project = 'pymotw'")
    for row in cursor.fetchall():
        print row['id'], row['details']

    print '\nUsing SQLITE_DENY to deny access to a column:'
    cursor.execute("select id, priority from task where project = 'pymotw'")
    for row in cursor.fetchall():
        print row['id'], row['details']
```

This example uses `SQLITE_IGNORE` to cause the strings from the `task.details` column to be replaced with null values in the query results. It also prevents all access to the `task.priority` column by returning `SQLITE_DENY`, which in turn causes SQLite to raise an exception.

```
$ python sqlite3_set_authorizer.py

Using SQLITE_IGNORE to mask a column value:

authorizer_func(21, None, None, None, None)
requesting permission to run a select statement

authorizer_func(20, task, id, main, None)
requesting permission to access the column task.id from main

authorizer_func(20, task, details, main, None)
requesting permission to access the column task.details from main
  ignoring details column

authorizer_func(20, task, project, main, None)
requesting permission to access the column task.project from main
1 None
2 None
3 None
4 None
5 None
6 None

Using SQLITE_DENY to deny access to a column:

authorizer_func(21, None, None, None, None)
requesting permission to run a select statement

authorizer_func(20, task, id, main, None)
requesting permission to access the column task.id from main

authorizer_func(20, task, priority, main, None)
requesting permission to access the column task.priority from main
  preventing access to priority column
Traceback (most recent call last):
  File "sqlite3_set_authorizer.py", line 47, in <module>
    cursor.execute("select id, priority from task where project = 'pymotw'")
sqlite3.DatabaseError: access to task.priority is prohibited
```

The possible action codes are available as constants in `sqlite3`, with names prefixed `SQLITE_`. Each type of SQL statement can be flagged, and access to individual columns can be controlled as well.

14.9.8 In-Memory Databases

SQLite supports managing an entire database in RAM, instead of relying on a disk file. In-memory databases are useful for automated testing, where the database does not need to be preserved between test runs, or when experimenting with a schema or other database features. To open an in-memory database, use the string `':memory:'` instead of a filename when creating the `Connection`.

```
import sqlite3

schema_filename = 'todo_schema.sql'

with sqlite3.connect(':memory:') as conn:
    conn.row_factory = sqlite3.Row

    print 'Creating schema'
    with open(schema_filename, 'rt') as f:
        schema = f.read()
    conn.executescript(schema)

    print 'Inserting initial data'
    conn.execute("""
        insert into project (name, description, deadline)
        values ('pymotw', 'Python Module of the Week', '2010-11-01')
        """)
    data = [
        ('write about select', 'done', '2010-10-03', 'pymotw'),
        ('write about random', 'waiting', '2010-10-10', 'pymotw'),
        ('write about sqlite3', 'active', '2010-10-17', 'pymotw'),
        ]
    conn.executemany("""
        insert into task (details, status, deadline, project)
        values (?, ?, ?, ?)
        """, data)

    print 'Looking for tasks...'
    cursor = conn.cursor()
    cursor.execute("""
    select id, priority, status, deadline, details from task
    where project = 'pymotw' order by deadline
    """)
    for row in cursor.fetchall():
        print '%2d {%d} %-25s [%-8s] (%s)' % (
            row['id'], row['priority'], row['details'], row['status'], row['deadline'],
            )

with sqlite3.connect(':memory:') as conn2:
    print '\nLooking for tasks in second connection...'
    cursor = conn2.cursor()
    cursor.execute("""
    select id, priority, status, deadline, details from task
    where project = 'pymotw' order by deadline
    """)
    for row in cursor.fetchall():
        print '%2d {%d} %-25s [%-8s] (%s)' % (
            row['id'], row['priority'], row['details'], row['status'], row['deadline'],
            )
```

The second query attempt in this example fails with an error because the table does not exist. Each connection creates a separate database, so changes made by a cursor in one do not effect other connections.

```
$ python sqlite3_memory.py

Creating schema
Inserting initial data
Looking for tasks...
 1 {1} write about select        [done    ] (2010-10-03)
 2 {1} write about random        [waiting ] (2010-10-10)
 3 {1} write about sqlite3       [active  ] (2010-10-17)

Looking for tasks in second connection...
Traceback (most recent call last):
  File "sqlite3_memory.py", line 54, in <module>
    """)
sqlite3.OperationalError: no such table: task
```

14.9.9 Exporting the Contents of a Database

The contents of an in-memory database can be saved using the `iterdump()` method of the `Connection`. The iterator returned by `iterdump()` produces a series of strings which together build SQL instructions to recreate the state of the database.

```
import sqlite3

schema_filename = 'todo_schema.sql'

with sqlite3.connect(':memory:') as conn:
    conn.row_factory = sqlite3.Row

    print 'Creating schema'
    with open(schema_filename, 'rt') as f:
        schema = f.read()
    conn.executescript(schema)

    print 'Inserting initial data'
    conn.execute("""
        insert into project (name, description, deadline)
        values ('pymotw', 'Python Module of the Week', '2010-11-01')
        """)
    data = [
        ('write about select', 'done', '2010-10-03', 'pymotw'),
        ('write about random', 'waiting', '2010-10-10', 'pymotw'),
        ('write about sqlite3', 'active', '2010-10-17', 'pymotw'),
        ]
    conn.executemany("""
        insert into task (details, status, deadline, project)
        values (?, ?, ?, ?)
        """, data)

    print 'Dumping:'
    for text in conn.iterdump():
        print text
```

`iterdump()` can also be used with databases saved to files, but it is most useful for preserving a database that would not otherwise be saved.

```
$ python sqlite3_iterdump.py
```

```
Creating schema
Inserting initial data
Dumping:
BEGIN TRANSACTION;
CREATE TABLE project (
    name        text primary key,
    description text,
    deadline    date
);
INSERT INTO "project" VALUES('pymotw','Python Module of the Week','2010-11-01');
CREATE TABLE task (
    id           integer primary key autoincrement not null,
    priority     integer default 1,
    details      text,
    status       text,
    deadline     date,
    completed_on date,
    project      text not null references project(name)
);
INSERT INTO "task" VALUES(1,1,'write about select','done','2010-10-03',NULL,'pymotw');
INSERT INTO "task" VALUES(2,1,'write about random','waiting','2010-10-10',NULL,'pymotw');
INSERT INTO "task" VALUES(3,1,'write about sqlite3','active','2010-10-17',NULL,'pymotw');
DELETE FROM sqlite_sequence;
INSERT INTO "sqlite_sequence" VALUES('task',3);
COMMIT;
```

14.9.10 Threading and Connection Sharing

For historical reasons having to do with old versions of SQLite, `Connection` objects cannot be shared between threads. Each thread must create its own connection to the database.

```python
import sqlite3
import sys
import threading
import time

db_filename = 'todo.db'
isolation_level = None # autocommit mode

def reader(conn):
    my_name = threading.currentThread().name
    print 'Starting thread'
    try:
        cursor = conn.cursor()
        cursor.execute('select * from task')
        results = cursor.fetchall()
        print 'results fetched'
    except Exception, err:
        print 'ERROR:', err
    return

if __name__ == '__main__':

    with sqlite3.connect(db_filename, isolation_level=isolation_level) as conn:
        t = threading.Thread(name='Reader 1', target=reader, args=(conn,))
        t.start()
        t.join()
```

Attempts to share a connection between threads result in an exception.

```
$ python sqlite3_threading.py

Starting thread
ERROR: SQLite objects created in a thread can only be used in that same thread.The object was createc
```

See also:

sqlite3 (http://docs.python.org/library/sqlite3.html) The standard library documentation for this module.

PEP 249 (http://www.python.org/dev/peps/pep-0249) – DB API 2.0 Specificiation A standard interface for modules that provide access to relational databases.

SQLite (http://www.sqlite.org/) The official site of the SQLite library.

`shelve` Key-value store for saving arbitrary Python objects.

SQLAlchemy (http://sqlalchemy.org/) A popular object-relational mapper that supports SQLite among many other relational databases.

For serializing over the web, the `json` module may be a better choice since its format is more portable.

See also:

Data Persistence and Exchange

CHAPTER

FIFTEEN

GENERIC OPERATING SYSTEM SERVICES

15.1 os – Portable access to operating system specific features.

Purpose Portable access to operating system specific features.

Available In 1.4 (or earlier)

The os module provides a wrapper for platform specific modules such as posix, nt, and mac. The API for functions available on all platform should be the same, so using the os module offers some measure of portability. Not all functions are available on all platforms, however. Many of the process management functions described in this summary are not available for Windows.

The Python documentation for the os module is subtitled "Miscellaneous operating system interfaces". The module consists mostly of functions for creating and managing running processes or filesystem content (files and directories), with a few other bits of functionality thrown in besides.

Note: Some of the example code below will only work on Unix-like operating systems.

15.1.1 Process Owner

The first set of functions to cover are used for determining and changing the process owner ids. These are mostly useful to authors of daemons or special system programs which need to change permission level rather than running as root. This section does not try to explain all of the intricate details of Unix security, process owners, etc. See the References list below for more details.

This first script shows the real and effective user and group information for a process, and then changes the effective values. This is similar to what a daemon would need to do when it starts as root during a system boot, to lower the privilege level and run as a different user.

Note: Before running the example, change the TEST_GID and TEST_UID values to match a real user.

```
import os

TEST_GID=501
TEST_UID=527

def show_user_info():
    print 'Effective User  :', os.geteuid()
    print 'Effective Group :', os.getegid()
    print 'Actual User     :', os.getuid(), os.getlogin()
    print 'Actual Group    :', os.getgid()
    print 'Actual Groups   :', os.getgroups()
    return

print 'BEFORE CHANGE:'
show_user_info()
print

try:
    os.setegid(TEST_GID)
except OSError:
    print 'ERROR: Could not change effective group.  Re-run as root.'
else:
    print 'CHANGED GROUP:'
    show_user_info()
    print

try:
    os.seteuid(TEST_UID)
except OSError:
    print 'ERROR: Could not change effective user.  Re-run as root.'
else:
    print 'CHANGE USER:'
    show_user_info()
    print
```

When run as user with id of 527 and group 501 on OS X, this output is produced:

```
$ python os_process_user_example.py

BEFORE CHANGE:
Effective User  : 527
Effective Group : 501
Actual User     : 527 dhellmann
Actual Group    : 501
Actual Groups   : [501, 401, 101, 500, 12, 33, 61, 80, 98, 100, 204, 102]

CHANGED GROUP:
Effective User  : 527
Effective Group : 501
Actual User     : 527 dhellmann
Actual Group    : 501
Actual Groups   : [501, 401, 101, 500, 12, 33, 61, 80, 98, 100, 204, 102]

CHANGE USER:
Effective User  : 527
Effective Group : 501
Actual User     : 527 dhellmann
Actual Group    : 501
Actual Groups   : [501, 401, 101, 500, 12, 33, 61, 80, 98, 100, 204, 102]
```

Notice that the values do not change. When not running as root, processes cannot change their effective owner values. Any attempt to set the effective user id or group id to anything other than that of the current user causes an *OSError*.

Running the same script using **sudo** so that it starts out with root privileges is a different story.

```
$ sudo python os_process_user_example.py
BEFORE CHANGE:
Effective User  : 0
Effective Group : 0
Actual User      : 0 dhellmann
Actual Group    : 0
Actual Groups   : [0, 1, 2, 8, 29, 3, 9, 4, 5, 80, 20]

CHANGED GROUP:
Effective User  : 0
Effective Group : 501
Actual User      : 0 dhellmann
Actual Group    : 0
Actual Groups   : [501, 1, 2, 8, 29, 3, 9, 4, 5, 80, 20]

CHANGE USER:
Effective User  : 527
Effective Group : 501
Actual User      : 0 dhellmann
Actual Group    : 0
Actual Groups   : [501, 1, 2, 8, 29, 3, 9, 4, 5, 80, 20]
```

In this case, since it starts as root, it can change the effective user and group for the process. Once the effective UID is changed, the process is limited to the permissions of that user. Since non-root users cannot change their effective group, the program needs to change the group before changing the user.

Besides finding and changing the process owner, there are functions for determining the current and parent process id, finding and changing the process group and session ids, as well as finding the controlling terminal id. These can be useful for sending signals between processes or for complex applications such as writing a command line shell.

15.1.2 Process Environment

Another feature of the operating system exposed to a program though the `os` module is the environment. Variables set in the environment are visible as strings that can be read through `os.environ` or `getenv()`. Environment variables are commonly used for configuration values such as search paths, file locations, and debug flags. This example shows how to retrieve an environment variable, and pass a value through to a child process.

```python
import os

print 'Initial value:', os.environ.get('TESTVAR', None)
print 'Child process:'
os.system('echo $TESTVAR')

os.environ['TESTVAR'] = 'THIS VALUE WAS CHANGED'

print
print 'Changed value:', os.environ['TESTVAR']
print 'Child process:'
os.system('echo $TESTVAR')

del os.environ['TESTVAR']

print
print 'Removed value:', os.environ.get('TESTVAR', None)
print 'Child process:'
os.system('echo $TESTVAR')
```

The `os.environ` object follows the standard Python mapping API for retrieving and setting values. Changes to `os.environ` are exported for child processes.

```
$ python -u os_environ_example.py
```

```
Initial value: None
Child process:


Changed value: THIS VALUE WAS CHANGED
Child process:
THIS VALUE WAS CHANGED

Removed value: None
Child process:
```

15.1.3 Process Working Directory

Operating systems with hierarchical filesystems have a concept of the *current working directory* – the directory on the filesystem the process uses as the starting location when files are accessed with relative paths. The current working directory can be retrieved with `getcwd()` and changed with `chdir()`.

```
import os

print 'Starting:', os.getcwd()

print 'Moving up one:', os.pardir
os.chdir(os.pardir)

print 'After move:', os.getcwd()
```

`os.curdir` and `os.pardir` are used to refer to the current and parent directories in a portable manner. The output should not be surprising:

```
$ python os_cwd_example.py

Starting: /Users/dhellmann/Documents/PyMOTW/src/PyMOTW/os
Moving up one: ..
After move: /Users/dhellmann/Documents/PyMOTW/src/PyMOTW
```

15.1.4 Pipes

The `os` module provides several functions for managing the I/O of child processes using *pipes*. The functions all work essentially the same way, but return different file handles depending on the type of input or output desired. For the most part, these functions are made obsolete by the `subprocess` module (added in Python 2.4), but there is a good chance legacy code uses them.

The most commonly used pipe function is `popen()`. It creates a new process running the command given and attaches a single stream to the input or output of that process, depending on the *mode* argument. While `popen()` functions work on Windows, some of these examples assume a Unix-like shell.

```
import os

print 'popen, read:'
pipe_stdout = os.popen('echo "to stdout"', 'r')
try:
    stdout_value = pipe_stdout.read()
finally:
    pipe_stdout.close()
print '\tstdout:', repr(stdout_value)
print '\npopen, write:'
pipe_stdin = os.popen('cat -', 'w')
try:
    pipe_stdin.write('\tstdin: to stdin\n')
finally:
    pipe_stdin.close()
```

The descriptions of the streams also assume Unix-like terminology:

- stdin - The "standard input" stream for a process (file descriptor 0) is readable by the process. This is usually where terminal input goes.
- stdout - The "standard output" stream for a process (file descriptor 1) is writable by the process, and is used for displaying regular output to the user.
- stderr - The "standard error" stream for a process (file descriptor 2) is writable by the process, and is used for conveying error messages.

```
$ python -u os_popen.py

popen, read:
        stdout: 'to stdout\n'

popen, write:
        stdin: to stdin
```

The caller can only read from or write to the streams associated with the child process, which limits the usefulness. The other `popen()` variants provide additional streams so it is possible to work with stdin, stdout, and stderr as needed.

For example, `popen2()` returns a write-only stream attached to stdin of the child process, and a read-only stream attached to its stdout.

```
import os

print 'popen2:'
pipe_stdin, pipe_stdout = os.popen2('cat -')
try:
    pipe_stdin.write('through stdin to stdout')
finally:
    pipe_stdin.close()
try:
    stdout_value = pipe_stdout.read()
finally:
    pipe_stdout.close()
print '\tpass through:', repr(stdout_value)
```

This simplistic example illustrates bi-directional communication. The value written to stdin is read by `cat` (because of the `'-'` argument), then written back to stdout. A more complicated process could pass other types of messages back and forth through the pipe; even serialized objects.

```
$ python -u os_popen2.py

popen2:
        pass through: 'through stdin to stdout'
```

In most cases, it is desirable to have access to both stdout and stderr. The stdout stream is used for message passing and the stderr stream is used for errors, so reading from it separately reduces the complexity for parsing any error messages. The `popen3()` function returns three open streams tied to stdin, stdout, and stderr of the new process.

```
import os

print 'popen3:'
pipe_stdin, pipe_stdout, pipe_stderr = os.popen3('cat -; echo ";to stderr" 1>&2')
try:
    pipe_stdin.write('through stdin to stdout')
finally:
    pipe_stdin.close()
try:
    stdout_value = pipe_stdout.read()
finally:
    pipe_stdout.close()
print '\tpass through:', repr(stdout_value)
try:
    stderr_value = pipe_stderr.read()
finally:
    pipe_stderr.close()
print '\tstderr:', repr(stderr_value)
```

Notice that the program has to read from and close both stdout and stderr *separately*. There are some related to flow control and sequencing when dealing with I/O for multiple processes. The I/O is buffered, and if the caller expects to be able to read all of the data from a stream then the child process must close that stream to indicate the end-of-file. For more information on these issues, refer to the Flow Control Issues (http://docs.python.org/library/popen2.html#popen2-flow-control) section of the Python library documentation.

```
$ python -u os_popen3.py

popen3:
        pass through: 'through stdin to stdout'
        stderr: ';to stderr\n'
```

And finally, `popen4()` returns 2 streams, stdin and a merged stdout/stderr. This is useful when the results of the command need to be logged, but not parsed directly.

```
import os

print 'popen4:'
pipe_stdin, pipe_stdout_and_stderr = os.popen4('cat -; echo ";to stderr" 1>&2')
try:
    pipe_stdin.write('through stdin to stdout')
finally:
    pipe_stdin.close()
try:
    stdout_value = pipe_stdout_and_stderr.read()
finally:
    pipe_stdout_and_stderr.close()
print '\tcombined output:', repr(stdout_value)
```

All of the messages written to both stdout and stderr are read together.

```
$ python -u os_popen4.py

popen4:
        combined output: 'through stdin to stdout;to stderr\n'
```

Besides accepting a single string command to be given to the shell for parsing, `popen2()`, `popen3()`, and `popen4()` also accept a sequence of strings (command, followed by arguments).

```
import os

print 'popen2, cmd as sequence:'
pipe_stdin, pipe_stdout = os.popen2(['cat', '-'])
try:
    pipe_stdin.write('through stdin to stdout')
finally:
    pipe_stdin.close()
try:
    stdout_value = pipe_stdout.read()
finally:
    pipe_stdout.close()
print '\tpass through:', repr(stdout_value)
```

In this case, the arguments are not processed by the shell.

```
$ python -u os_popen2_seq.py

popen2, cmd as sequence:
        pass through: 'through stdin to stdout'
```

15.1.5 File Descriptors

`os` includes the standard set of functions for working with low-level *file descriptors* (integers representing open files owned by the current process). This is a lower-level API than is provided by `file` objects. They are not covered here because it is generally easier to work directly with `file` objects. Refer to the library documentation for details.

15.1.6 Filesystem Permissions

The function `access()` can be used to test the access rights a process has for a file.

```
import os

print 'Testing:', __file__
print 'Exists:', os.access(__file__, os.F_OK)
print 'Readable:', os.access(__file__, os.R_OK)
print 'Writable:', os.access(__file__, os.W_OK)
print 'Executable:', os.access(__file__, os.X_OK)
```

The results will vary depending on how the example code is installed, but it will look something like this:

```
$ python os_access.py

Testing: os_access.py
Exists: True
Readable: True
Writable: True
Executable: False
```

The library documentation for `access()` includes two special warnings. First, there isn't much sense in calling `access()` to test whether a file can be opened before actually calling `open()` on it. There is a small, but real, window of time between the two calls during which the permissions on the file could change. The other warning applies mostly to networked filesystems that extend the POSIX permission semantics. Some filesystem types may respond to the POSIX call that a process has permission to access a file, then report a failure when the attempt is made using `open()` for some reason not tested via the POSIX call. All in all, it is better to call `open()` with the required mode and catch the *IOError* raised if there is a problem.

More detailed information about the file can be accessed using `stat()` or `lstat()` (for checking the status of something that might be a symbolic link).

```
import os
import sys
import time

if len(sys.argv) == 1:
    filename = __file__
else:
    filename = sys.argv[1]

stat_info = os.stat(filename)

print 'os.stat(%s):' % filename
print '\tSize:', stat_info.st_size
print '\tPermissions:', oct(stat_info.st_mode)
print '\tOwner:', stat_info.st_uid
print '\tDevice:', stat_info.st_dev
print '\tLast modified:', time.ctime(stat_info.st_mtime)
```

Once again, the output will vary depending on how the example code was installed. Try passing different filenames on the command line to `os_stat.py`.

```
$ python os_stat.py

os.stat(os_stat.py):
        Size: 1516
        Permissions: 0100644
        Owner: 527
        Device: 234881026
        Last modified: Sat Feb 19 19:18:23 2011
```

On Unix-like systems, file permissions can be changed using `chmod()`, passing the mode as an integer. Mode values can be constructed using constants defined in the `stat` module. This example toggles the user's execute permission bit:

```
import os
import stat

filename = 'os_stat_chmod_example.txt'
if os.path.exists(filename):
    os.unlink(filename)
f = open(filename, 'wt')
f.write('contents')
f.close()

# Determine what permissions are already set using stat
existing_permissions = stat.S_IMODE(os.stat(filename).st_mode)

if not os.access(filename, os.X_OK):
    print 'Adding execute permission'
    new_permissions = existing_permissions | stat.S_IXUSR
else:
    print 'Removing execute permission'
    # use xor to remove the user execute permission
    new_permissions = existing_permissions ^ stat.S_IXUSR

os.chmod(filename, new_permissions)
```

The script assumes it has the permissions necessary to modify the mode of the file when run.

```
$ python os_stat_chmod.py

Adding execute permission
```

15.1.7 Directories

There are several functions for working with directories on the filesystem, including creating, listing contents, and removing them.

```
import os

dir_name = 'os_directories_example'

print 'Creating', dir_name
os.makedirs(dir_name)

file_name = os.path.join(dir_name, 'example.txt')
print 'Creating', file_name
f = open(file_name, 'wt')
try:
    f.write('example file')
finally:
    f.close()

print 'Listing', dir_name
print os.listdir(dir_name)

print 'Cleaning up'
os.unlink(file_name)
os.rmdir(dir_name)
```

There are two sets of functions for creating and deleting directories. When creating a new directory with `mkdir()`, all of the parent directories must already exist. When removing a directory with `rmdir()`, only the leaf directory (the last part of the path) is actually removed. In contrast, `makedirs()` and `removedirs()` operate on all of the nodes in the path. `makedirs()` will create any parts of the path which do not exist, and `removedirs()` will remove all of the parent directories (assuming it can).

```
$ python os_directories.py

Creating os_directories_example
Creating os_directories_example/example.txt
Listing os_directories_example
['example.txt']
Cleaning up
```

15.1.8 Symbolic Links

For platforms and filesystems that support them, there are functions for working with symlinks.

```
import os, tempfile

link_name = tempfile.mktemp()

print 'Creating link %s -> %s' % (link_name, __file__)
```

```
os.symlink(__file__, link_name)

stat_info = os.lstat(link_name)
print 'Permissions:', oct(stat_info.st_mode)

print 'Points to:', os.readlink(link_name)

# Cleanup
os.unlink(link_name)
```

Although `os` includes `tempnam()` for creating temporary filenames, it is not as secure as the `tempfile` module and produces a *RuntimeWarning* message when it is used. In general it is better to use `tempfile`, as in this example.

```
$ python os_symlinks.py

Creating link /var/folders/5q/8gk0wq888xlggz008k8dr7180000hg/T/tmpt1_Bsr -> os_symlinks.py
Permissions: 0120755
Points to: os_symlinks.py
```

15.1.9 Walking a Directory Tree

The function `walk()` traverses a directory recursively and for each directory generates a tuple containing the directory path, any immediate sub-directories of that path, and the names of any files in that directory.

```
import os, sys

# If we are not given a path to list, use /tmp
if len(sys.argv) == 1:
    root = '/tmp'
else:
    root = sys.argv[1]

for dir_name, sub_dirs, files in os.walk(root):
    print '\n', dir_name
    # Make the subdirectory names stand out with /
    sub_dirs = [ '%s/' % n for n in sub_dirs ]
    # Mix the directory contents together
    contents = sub_dirs + files
    contents.sort()
    # Show the contents
    for c in contents:
        print '\t%s' % c
```

This example shows a recursive directory listing.

```
$ python os_walk.py ../zipimport


../zipimport
        __init__.py
        __init__.pyc
        example_package/
        index.rst
        zipimport_example.zip
        zipimport_find_module.py
        zipimport_find_module.pyc
        zipimport_get_code.py
        zipimport_get_code.pyc
        zipimport_get_data.py
        zipimport_get_data.pyc
        zipimport_get_data_nozip.py
        zipimport_get_data_nozip.pyc
        zipimport_get_data_zip.py
        zipimport_get_data_zip.pyc
        zipimport_get_source.py
        zipimport_get_source.pyc
        zipimport_is_package.py
        zipimport_is_package.pyc
        zipimport_load_module.py
        zipimport_load_module.pyc
        zipimport_make_example.py
        zipimport_make_example.pyc

../zipimport/example_package
        README.txt
        __init__.py
        __init__.pyc
```

15.1.10 Running External Commands

Warning: Many of these functions for working with processes have limited portability. For a more consistent way to work with processes in a platform independent manner, see the `subprocess` module instead.

The simplest way to run a separate command, without interacting with it at all, is `system()`. It takes a single string which is the command line to be executed by a sub-process running a shell.

```
import os

# Simple command
os.system('ls -l')
```

The return value of `system()` is the exit value of the shell running the program packed into a 16 bit number, with the high byte the exit status and the low byte the signal number that caused the process to die, or zero.

```
$ python -u os_system_example.py

total 248
-rw-r--r--  1 dhellmann  dhellmann      0 Feb 19  2011 __init__.py
-rw-r--r--  1 dhellmann  dhellmann  22700 Jul  8  2011 index.rst
-rw-r--r--  1 dhellmann  dhellmann   1360 Feb 19  2011 os_access.py
-rw-r--r--  1 dhellmann  dhellmann   1292 Feb 19  2011 os_cwd_example.py
-rw-r--r--  1 dhellmann  dhellmann   1499 Feb 19  2011 os_directories.py
-rw-r--r--  1 dhellmann  dhellmann   1573 Feb 19  2011 os_environ_example.py
-rw-r--r--  1 dhellmann  dhellmann   1241 Feb 19  2011 os_exec_example.py
-rw-r--r--  1 dhellmann  dhellmann   1267 Feb 19  2011 os_fork_example.py
-rw-r--r--  1 dhellmann  dhellmann   1703 Feb 19  2011 os_kill_example.py
-rw-r--r--  1 dhellmann  dhellmann   1476 Feb 19  2011 os_popen.py
-rw-r--r--  1 dhellmann  dhellmann   1506 Feb 19  2011 os_popen2.py
-rw-r--r--  1 dhellmann  dhellmann   1528 Feb 19  2011 os_popen2_seq.py
-rw-r--r--  1 dhellmann  dhellmann   1658 Feb 19  2011 os_popen3.py
-rw-r--r--  1 dhellmann  dhellmann   1567 Feb 19  2011 os_popen4.py
-rw-r--r--  1 dhellmann  dhellmann   1395 Feb 19  2011 os_process_id_example.py
-rw-r--r--  1 dhellmann  dhellmann   1896 Feb 19  2011 os_process_user_example.py
```

```
-rw-r--r--  1 dhellmann  dhellmann   1206 Feb 19  2011 os_spawn_example.py
-rw-r--r--  1 dhellmann  dhellmann   1516 Feb 19  2011 os_stat.py
-rw-r--r--  1 dhellmann  dhellmann   1751 Feb 19  2011 os_stat_chmod.py
-rwxr--r--  1 dhellmann  dhellmann      8 Feb 21 06:36 os_stat_chmod_example.txt
-rw-r--r--  1 dhellmann  dhellmann   1421 Feb 19  2011 os_symlinks.py
-rw-r--r--  1 dhellmann  dhellmann   1250 Feb 19  2011 os_system_background.py
-rw-r--r--  1 dhellmann  dhellmann   1191 Feb 19  2011 os_system_example.py
-rw-r--r--  1 dhellmann  dhellmann   1214 Feb 19  2011 os_system_shell.py
-rw-r--r--  1 dhellmann  dhellmann   1499 Feb 19  2011 os_wait_example.py
-rw-r--r--  1 dhellmann  dhellmann   1555 Feb 19  2011 os_waitpid_example.py
-rw-r--r--  1 dhellmann  dhellmann   1643 Feb 19  2011 os_walk.py
```

Since the command is passed directly to the shell for processing, it can even include shell syntax such as globbing or environment variables:

```
import os

# Command with shell expansion
os.system('ls -ld $TMPDIR')
```

```
$ python -u os_system_shell.py

drwx------  10 dhellmann  dhellmann  340 Feb 21 06:36 /var/folders/5q/8gk0wq888xlggz008k8dr7180000hg/
```

Unless the command is explicitly run in the background, the call to `system()` blocks until it is complete. Standard input, output, and error from the child process are tied to the appropriate streams owned by the caller by default, but can be redirected using shell syntax.

```
import os
import time

print 'Calling...'
os.system('date; (sleep 3; date) &')

print 'Sleeping...'
time.sleep(5)
```

This is getting into shell trickery, though, and there are better ways to accomplish the same thing.

```
$ python -u os_system_background.py

Calling...
Thu Feb 21 06:36:14 EST 2013
Sleeping...
Thu Feb 21 06:36:18 EST 2013
```

15.1.11 Creating Processes with os.fork()

The POSIX functions `fork()` and `exec*()` (available under Mac OS X, Linux, and other UNIX variants) are exposed via the `os` module. Entire books have been written about reliably using these functions, so check the library or bookstore for more details than are presented here.

To create a new process as a clone of the current process, use `fork()`:

```
import os

pid = os.fork()
```

```
if pid:
    print 'Child process id:', pid
else:
    print 'I am the child'
```

The output will vary based on the state of the system each time the example is run, but it will look something like:

```
$ python -u os_fork_example.py

Child process id: 14167
I am the child
```

After the fork, there are two processes running the same code. For a program to tell which one it is in, it needs to check the return value of `fork()`. If the value is `0`, the current process is the child. If it is not `0`, the program is running in the parent process and the return value is the process id of the child process.

From the parent process, it is possible to send the child signals. This is a bit more complicated to set up, and uses the `signal` module. First, define a signal handler to be invoked when the signal is received.

```
import os
import signal
import time

def signal_usr1(signum, frame):
    "Callback invoked when a signal is received"
    pid = os.getpid()
    print 'Received USR1 in process %s' % pid
```

Then `fork()`, and in the parent pause a short amount of time before sending a `USR1` signal using `kill()`. The short pause gives the child process time to set up the signal handler.

```
print 'Forking...'
child_pid = os.fork()
if child_pid:
    print 'PARENT: Pausing before sending signal...'
    time.sleep(1)
    print 'PARENT: Signaling %s' % child_pid
    os.kill(child_pid, signal.SIGUSR1)
```

In the child, set up the signal handler and go to sleep for a while to give the parent time to send the signal:

```
else:
    print 'CHILD: Setting up signal handler'
    signal.signal(signal.SIGUSR1, signal_usr1)
    print 'CHILD: Pausing to wait for signal'
    time.sleep(5)
```

A real application, wouldn't need (or want) to call `sleep()`.

```
$ python os_kill_example.py

Forking...
PARENT: Pausing before sending signal...
PARENT: Signaling 14170
Forking...
CHILD: Setting up signal handler
CHILD: Pausing to wait for signal
Received USR1 in process 14170
```

A simple way to handle separate behavior in the child process is to check the return value of `fork()` and branch. More complex behavior may call for more code separation than a simple branch. In other cases, there may be an existing program that needs to be wrapped. For both of these situations, the `exec*()` series of functions can be used to run another program.

```
import os

child_pid = os.fork()
if child_pid:
    os.waitpid(child_pid, 0)
else:
    os.execlp('ls', 'ls', '-l', '/tmp/')
```

When a program is "execed", the code from that program replaces the code from the existing process.

```
$ python os_exec_example.py

total 320
-rw-r-----  1 root        _lp         1193 Feb 21 06:26 025c6512ef714
-rw-r--r--  1 root        wheel      70150 Feb 19 09:01 Carbon Copy Cloner-96-8F64ABE0-B932-4033-B71
-rw-r--r--  1 root        wheel      70150 Feb 19 09:01 Carbon Copy Cloner-96-F29FA27F-20E9-45F4-8FE
-rw-r--r--  1 dhellmann   wheel          0 Feb 19 09:03 CrashReportCopyLock-Doug Hellmann's iPhone
-rw-r--r--  1 dhellmann   wheel          0 Feb 19 23:52 CrashReportCopyLock-Fry
-rw-r--r--  1 dhellmann   wheel          0 Feb 19 10:02 CrashReportCopyLock-Nibbler
-rw-r--r--  1 dhellmann   wheel      12288 Feb 21 06:35 example.db
drwx------  3 dhellmann   wheel        102 Feb 19 09:00 launch-CRQRox
drwx------  3 dhellmann   wheel        102 Feb 19 15:39 launch-EId8eS
drwx------  3 dhellmann   wheel        102 Feb 19 09:00 launch-XiBNeS
drwx------  3 dhellmann   wheel        102 Feb 19 09:00 launch-m0jqKW
drwx------  3 dhellmann   wheel        102 Feb 19 09:00 launch-n4P253
drwx------  3 dhellmann   wheel        102 Feb 19 09:00 launchd-328.RnuGVc
drwx------  3 _spotlight  wheel        102 Feb 19 09:06 launchd-587.onAzLG
drwx------  2 dhellmann   wheel         68 Feb 19 15:46 ssh-DUxXnX9KUd
drwxr-xr-x  2 dhellmann   dhellmann     68 Feb 20 03:15 var_backups
```

There are many variations of `exec*()`, depending on the form in which the arguments are available, whether the path and environment of the parent process should be be copied to the child, etc. Refer to the library documentation for complete details.

For all variations, the first argument is a path or filename and the remaining arguments control how that program runs. They are either passed as command line arguments or override the process "environment" (see `os.environ` and `os.getenv`).

15.1.12 Waiting for a Child

Many computationally intensive programs use multiple processes to work around the threading limitations of Python and the Global Interpreter Lock. When starting several processes to run separate tasks, the master will need to wait for one or more of them to finish before starting new ones, to avoid overloading the server. There are a few different ways to do that using `wait()` and related functions.

When it does not matter which child process might exit first, use `wait()`. It returns as soon as any child process exits.

```
import os
import sys
import time

for i in range(3):
    print 'PARENT: Forking %s' % i
    worker_pid = os.fork()
    if not worker_pid:
        print 'WORKER %s: Starting' % i
        time.sleep(2 + i)
        print 'WORKER %s: Finishing' % i
        sys.exit(i)

for i in range(3):
    print 'PARENT: Waiting for %s' % i
    done = os.wait()
    print 'PARENT:', done
```

The return value from `wait()` is a tuple containing the process id and exit status ("a 16-bit number, whose low byte is the signal number that killed the process, and whose high byte is the exit status").

```
$ python os_wait_example.py

PARENT: Forking 0
WORKER 0: Starting
WORKER 0: Finishing
PARENT: Forking 0
PARENT: Forking 1
WORKER 1: Starting
WORKER 1: Finishing
PARENT: Forking 0
PARENT: Forking 1
PARENT: Forking 2
WORKER 2: Starting
WORKER 2: Finishing
PARENT: Forking 0
PARENT: Forking 1
PARENT: Forking 2
PARENT: Waiting for 0
PARENT: (14176, 0)
PARENT: Waiting for 1
PARENT: (14177, 256)
PARENT: Waiting for 2
PARENT: (14178, 512)
```

To wait for a specific process, use `waitpid()`.

```
import os
import sys
import time

workers = []
for i in range(3):
    print 'PARENT: Forking %s' % i
    worker_pid = os.fork()
    if not worker_pid:
        print 'WORKER %s: Starting' % i
        time.sleep(2 + i)
        print 'WORKER %s: Finishing' % i
        sys.exit(i)
    workers.append(worker_pid)

for pid in workers:
    print 'PARENT: Waiting for %s' % pid
    done = os.waitpid(pid, 0)
    print 'PARENT:', done
```

Pass the process id of the target process, and `waitpid()` blocks until that process exits.

```
$ python os_waitpid_example.py

PARENT: Forking 0
WORKER 0: Starting
WORKER 0: Finishing
PARENT: Forking 0
PARENT: Forking 1
WORKER 1: Starting
WORKER 1: Finishing
PARENT: Forking 0
PARENT: Forking 1
PARENT: Forking 2
WORKER 2: Starting
WORKER 2: Finishing
PARENT: Forking 0
PARENT: Forking 1
PARENT: Forking 2
PARENT: Waiting for 14181
PARENT: (14181, 0)
PARENT: Waiting for 14182
PARENT: (14182, 256)
PARENT: Waiting for 14183
PARENT: (14183, 512)
```

`wait3()` and `wait4()` work in a similar manner, but return more detailed information about the child process with the pid, exit status, and resource usage.

15.1.13 Spawn

As a convenience, the `spawn*()` family of functions handles the `fork()` and `exec*()` in one statement:

```
import os

os.spawnlp(os.P_WAIT, 'ls', 'ls', '-l', '/tmp/')
```

The first argument is a mode indicating whether or not to wait for the process to finish before returning. This example waits. Use `P_NOWAIT` to let the other process start, but then resume in the current process.

```
$ python os_spawn_example.py

total 320
-rw-r-----  1 root        _lp         1193 Feb 21 06:26 025c6512ef714
-rw-r--r--  1 root        wheel      70150 Feb 19 09:01 Carbon Copy Cloner-96-8F64ABE0-B932-4033-B71
-rw-r--r--  1 root        wheel      70150 Feb 19 09:01 Carbon Copy Cloner-96-F29FA27F-20E9-45F4-8FE
-rw-r--r--  1 dhellmann   wheel          0 Feb 19 09:03 CrashReportCopyLock-Doug Hellmann's iPhone
-rw-r--r--  1 dhellmann   wheel          0 Feb 19 23:52 CrashReportCopyLock-Fry
-rw-r--r--  1 dhellmann   wheel          0 Feb 19 10:02 CrashReportCopyLock-Nibbler
-rw-r--r--  1 dhellmann   wheel      12288 Feb 21 06:35 example.db
drwx------  3 dhellmann   wheel        102 Feb 19 09:00 launch-CRQRox
drwx------  3 dhellmann   wheel        102 Feb 19 15:39 launch-EId8eS
drwx------  3 dhellmann   wheel        102 Feb 19 09:00 launch-XiBNeS
drwx------  3 dhellmann   wheel        102 Feb 19 09:00 launch-m0jqKW
drwx------  3 dhellmann   wheel        102 Feb 19 09:00 launch-n4P253
```

```
drwx------  3 dhellmann   wheel        102 Feb 19 09:00 launchd-328.RnuGVc
drwx------  3 _spotlight  wheel        102 Feb 19 09:06 launchd-587.onAzLG
drwx------  2 dhellmann   wheel         68 Feb 19 15:46 ssh-DUxXnX9KUd
drwxr-xr-x  2 dhellmann   dhellmann     68 Feb 20 03:15 var_backups
```

See also:

os **(http://docs.python.org/lib/module-os.html)** Standard library documentation for this module.

subprocess The subprocess module supersedes os.popen().

multiprocessing The multiprocessing module makes working with extra processes easier than doing all of the work yourself.

tempfile The tempfile module for working with temporary files.

Unix Manual Page Introduction Includes definitions of real and effective ids, etc.

http://www.scit.wlv.ac.uk/cgi-bin/mansec?2+intro

Speaking UNIX, Part 8. Learn how UNIX multitasks.

http://www.ibm.com/developerworks/aix/library/au-speakingunix8/index.html

Unix Concepts For more discussion of stdin, stdout, and stderr.

http://www.linuxhq.com/guides/LUG/node67.html

Delve into Unix Process Creation Explains the life cycle of a UNIX process.

http://www.ibm.com/developerworks/aix/library/au-unixprocess.html

Advanced Programming in the UNIX(R) Environment (http://www.amazon.com/Programming-Environment-Addison-Wesley-P
Covers working with multiple processes, such as handling signals, closing duplicated file descriptors, etc.

File Access

15.2 time – Functions for manipulating clock time

Purpose Functions for manipulating clock time.

Available In 1.4 or earlier

The `time` module exposes C library functions for manipulating dates and times. Since it is tied to the underlying C implementation, some details (such as the start of the epoch and maximum date value supported) are platform-specific. Refer to the library documentation for complete details.

15.2.1 Wall Clock Time

One of the core functions of the `time` module is `time()`, which returns the number of seconds since the start of the epoch as a floating point value.

```
import time

print 'The time is:', time.time()
```

Although the value is always a float, actual precision is platform-dependent.

```
$ python time_time.py
The time is: 1205079300.54
```

The float representation is useful when storing or comparing dates, but not as useful for producing human readable representations. For logging or printing time `ctime()` can be more useful.

```
import time

print 'The time is      :', time.ctime()
later = time.time() + 15
print '15 secs from now :', time.ctime(later)
```

Here the second output line shows how to use `ctime()` to format a time value other than the current time.

```
$ python time_ctime.py
The time is      : Sun Mar  9 12:18:02 2008
15 secs from now : Sun Mar  9 12:18:17 2008
```

15.2.2 Processor Clock Time

While `time()` returns a wall clock time, `clock()` returns processor clock time. The values returned from `clock()` should be used for performance testing, benchmarking, etc. since they reflect the actual time used by the program, and can be more precise than the values from `time()`.

```
import hashlib
import time

# Data to use to calculate md5 checksums
data = open(__file__, 'rt').read()

for i in range(5):
    h = hashlib.sha1()
    print time.ctime(), ': %0.3f %0.3f' % (time.time(), time.clock())
    for i in range(100000):
        h.update(data)
    cksum = h.digest()
```

In this example, the formatted `ctime()` is printed along with the floating point values from `time()`, and `clock()` for each iteration through the loop. If you want to run the example on your system, you may have to add more cycles to the inner loop or work with a larger amount of data to actually see a difference.

```
$ python time_clock.py
Sun Mar  9 12:41:53 2008 : 1205080913.260 0.030
Sun Mar  9 12:41:53 2008 : 1205080913.682 0.440
Sun Mar  9 12:41:54 2008 : 1205080914.103 0.860
Sun Mar  9 12:41:54 2008 : 1205080914.518 1.270
Sun Mar  9 12:41:54 2008 : 1205080914.932 1.680
```

Typically, the processor clock doesn't tick if your program isn't doing anything.

```
import time

for i in range(6, 1, -1):
    print '%s %0.2f %0.2f' % (time.ctime(), time.time(), time.clock())
    print 'Sleeping', i
    time.sleep(i)
```

In this example, the loop does very little work by going to sleep after each iteration. The `time()` value increases even while the app is asleep, but the `clock()` value does not.

```
$ python time_clock_sleep.py
Sun Mar  9 12:46:36 2008 1205081196.20 0.02
Sleeping 6
Sun Mar  9 12:46:42 2008 1205081202.20 0.02
Sleeping 5
Sun Mar  9 12:46:47 2008 1205081207.20 0.02
Sleeping 4
Sun Mar  9 12:46:51 2008 1205081211.20 0.02
Sleeping 3
Sun Mar  9 12:46:54 2008 1205081214.21 0.02
Sleeping 2
```

Calling `sleep()` yields control from the current thread and asks it to wait for the system to wake it back up. If your program has only one thread, this effectively blocks the app and it does no work.

15.2.3 struct_time

Storing times as elapsed seconds is useful in some situations, but there are times when you need to have access to the individual fields of a date (year, month, etc.). The `time` module defines `struct_time` for holding date and time values with components broken out so they are easy to access. There are several functions that work with `struct_time` values instead of floats.

```
import time

print 'gmtime   :', time.gmtime()
print 'localtime:', time.localtime()
print 'mktime   :', time.mktime(time.localtime())

print
t = time.localtime()
print 'Day of month:', t.tm_mday
print ' Day of week:', t.tm_wday
print ' Day of year:', t.tm_yday
```

`gmtime()` returns the current time in UTC. `localtime()` returns the current time with the current time zone applied. `mktime()` takes a `struct_time` and converts it to the floating point representation.

```
$ python time_struct.py
gmtime   : (2008, 3, 9, 16, 58, 19, 6, 69, 0)
localtime: (2008, 3, 9, 12, 58, 19, 6, 69, 1)
mktime   : 1205081899.0

Day of month: 9
 Day of week: 6
 Day of year: 69
```

15.2.4 Parsing and Formatting Times

The two functions `strptime()` and `strftime()` convert between struct_time and string representations of time values. There is a long list of formatting instructions available to support input and output in different styles. The complete list is documented in the library documentation for the time module.

This example converts the current time from a string, to a `struct_time` instance, and back to a string.

```
import time

now = time.ctime()
print now
parsed = time.strptime(now)
print parsed
print time.strftime("%a %b %d %H:%M:%S %Y", parsed)
```

The output string is not exactly like the input, since the day of the month is prefixed with a zero.

```
$ python time_strptime.py
Sun Mar  9 13:01:19 2008
(2008, 3, 9, 13, 1, 19, 6, 69, -1)
Sun Mar 09 13:01:19 2008
```

15.2.5 Working with Time Zones

The functions for determining the current time depend on having the time zone set, either by your program or by using a default time zone set for the system. Changing the time zone does not change the actual time, just the way it is represented.

To change the time zone, set the environment variable `TZ`, then call `tzset()`. Using TZ, you can specify the time zone with a lot of detail, right down to the start and stop times for daylight savings time. It is usually easier to use the time zone name and let the underlying libraries derive the other information, though.

This example program changes the time zone to a few different values and shows how the changes affect other settings in the time module.

```
import time
import os

def show_zone_info():
    print '\tTZ    :', os.environ.get('TZ', '(not set)')
    print '\ttzname:', time.tzname
    print '\tZone  : %d (%d)' % (time.timezone, (time.timezone / 3600))
    print '\tDST   :', time.daylight
    print '\tTime  :', time.ctime()
    print

print 'Default :'
show_zone_info()

for zone in [ 'US/Eastern', 'US/Pacific', 'GMT', 'Europe/Amsterdam' ]:
    os.environ['TZ'] = zone
    time.tzset()
    print zone, ':'
    show_zone_info()
```

My default time zone is US/Eastern, so setting TZ to that has no effect. The other zones used change the tzname, daylight flag, and timezone offset value.

```
$ python time_timezone.py
Default :
    TZ    : (not set)
    tzname: ('EST', 'EDT')
    Zone  : 18000 (5)
    DST   : 1
    Time  : Sun Mar  9 13:06:53 2008
```

```
US/Eastern :
    TZ    : US/Eastern
    tzname: ('EST', 'EDT')
    Zone  : 18000 (5)
    DST   : 1
    Time  : Sun Mar  9 13:06:53 2008

US/Pacific :
    TZ    : US/Pacific
    tzname: ('PST', 'PDT')
    Zone  : 28800 (8)
    DST   : 1
    Time  : Sun Mar  9 10:06:53 2008

GMT :
    TZ    : GMT
    tzname: ('GMT', 'GMT')
    Zone  : 0 (0)
    DST   : 0
    Time  : Sun Mar  9 17:06:53 2008

Europe/Amsterdam :
    TZ    : Europe/Amsterdam
    tzname: ('CET', 'CEST')
    Zone  : -3600 (-1)
    DST   : 1
    Time  : Sun Mar  9 18:06:53 2008
```

See also:

time (http://docs.python.org/lib/module-time.html) Standard library documentation for this module.

`datetime` The datetime module includes other classes for doing calculations with dates and times.

`calendar` Work with higher-level date functions to produce calendars or calculate recurring events.

15.3 getopt – Command line option parsing

Purpose Command line option parsing

Available In 1.4

The getopt module is the *old-school* command line option parser that supports the conventions established by the Unix function `getopt()`. It parses an argument sequence, such as `sys.argv` and returns a sequence of (option, argument) pairs and a sequence of non-option arguments.

Supported option syntax includes:

```
-a
-bval
-b val
--noarg
--witharg=val
--witharg val
```

15.3.1 Function Arguments

The getopt function takes three arguments:

- The first argument is the sequence of arguments to be parsed. This usually comes from `sys.argv[1:]` (ignoring the program name in `sys.arg[0]`).
- The second argument is the option definition string for single character options. If one of the options requires an argument, its letter is followed by a colon.
- The third argument, if used, should be a sequence of the long-style option names. Long style options can be more than a single character, such as `--noarg` or `--witharg`. The option names in the sequence should not include the `--` prefix. If any long option requires an argument, its name should have a suffix of =.

Short and long form options can be combined in a single call.

15.3.2 Short Form Options

If a program wants to take 2 options, `-a`, and `-b` with the b option requiring an argument, the value should be `"ab:"`.

```
import getopt

print getopt.getopt(['-a', '-bval', '-c', 'val'], 'ab:c:')
```

```
$ python getopt_short.py

([('-a', ''), ('-b', 'val'), ('-c', 'val')], [])
```

15.3.3 Long Form Options

If a program wants to take 2 options, `--noarg` and `--witharg` the sequence should be `[ 'noarg', 'witharg=' ]`.

```
import getopt

print getopt.getopt([ '--noarg', '--witharg', 'val', '--witharg2=another' ],
                    '',
                    [ 'noarg', 'witharg=', 'witharg2=' ])
```

```
$ python getopt_long.py

([('--noarg', ''), ('--witharg', 'val'), ('--witharg2', 'another')], [])
```

15.3.4 Example

Below is a more complete example program which takes 5 options: `-o`, `-v`, `--output`, `--verbose`, and `--version`. The `-o`, `--output`, and `--version` options each require an argument.

```
import getopt
import sys

version = '1.0'
verbose = False
output_filename = 'default.out'
```

```
print 'ARGV      :', sys.argv[1:]

options, remainder = getopt.getopt(sys.argv[1:], 'o:v', ['output=',
                                                         'verbose',
                                                         'version=',
                                                         ])
print 'OPTIONS   :', options

for opt, arg in options:
    if opt in ('-o', '--output'):
        output_filename = arg
    elif opt in ('-v', '--verbose'):
        verbose = True
    elif opt == '--version':
        version = arg

print 'VERSION   :', version
print 'VERBOSE   :', verbose
print 'OUTPUT    :', output_filename
print 'REMAINING :', remainder
```

The program can be called in a variety of ways.

```
$ python getopt_example.py

ARGV      : []
OPTIONS   : []
VERSION   : 1.0
VERBOSE   : False
OUTPUT    : default.out
REMAINING : []
```

A single letter option can be a separate from its argument:

```
$ python getopt_example.py -o foo

ARGV      : ['-o', 'foo']
OPTIONS   : [('-o', 'foo')]
VERSION   : 1.0
VERBOSE   : False
OUTPUT    : foo
REMAINING : []
```

or combined:

```
$ python getopt_example.py -ofoo

ARGV      : ['-ofoo']
OPTIONS   : [('-o', 'foo')]
VERSION   : 1.0
VERBOSE   : False
OUTPUT    : foo
REMAINING : []
```

A long form option can similarly be separate:

```
$ python getopt_example.py --output foo

ARGV      : ['--output', 'foo']
```

```
OPTIONS   : [('--output', 'foo')]
VERSION   : 1.0
VERBOSE   : False
OUTPUT    : foo
REMAINING : []
```

or combined, with =:

```
$ python getopt_example.py --output=foo

ARGV      : ['--output=foo']
OPTIONS   : [('--output', 'foo')]
VERSION   : 1.0
VERBOSE   : False
OUTPUT    : foo
REMAINING : []
```

15.3.5 Abbreviating Long Form Options

The long form option does not have to be spelled out entirely, so long as a unique prefix is provided:

```
$ python getopt_example.py --o foo

ARGV      : ['--o', 'foo']
OPTIONS   : [('--output', 'foo')]
VERSION   : 1.0
VERBOSE   : False
OUTPUT    : foo
REMAINING : []
```

If a unique prefix is not provided, an exception is raised.

```
$ python getopt_example.py --ver 2.0

ARGV      : ['--ver', '2.0']
Traceback (most recent call last):
  File "getopt_example.py", line 44, in <module>
    'version=',
  File "/Library/Frameworks/Python.framework/Versions/2.7/lib/python2.7/getopt.py", line 88, in getop
    opts, args = do_longs(opts, args[0][2:], longopts, args[1:])
  File "/Library/Frameworks/Python.framework/Versions/2.7/lib/python2.7/getopt.py", line 152, in do_l
    has_arg, opt = long_has_args(opt, longopts)
  File "/Library/Frameworks/Python.framework/Versions/2.7/lib/python2.7/getopt.py", line 179, in long
    raise GetoptError('option --%s not a unique prefix' % opt, opt)
getopt.GetoptError: option --ver not a unique prefix
```

Option processing stops as soon as the first non-option argument is encountered.

```
$ python getopt_example.py -v not_an_option --output foo

ARGV      : ['-v', 'not_an_option', '--output', 'foo']
OPTIONS   : [('-v', '')]
VERSION   : 1.0
VERBOSE   : True
OUTPUT    : default.out
REMAINING : ['not_an_option', '--output', 'foo']
```

15.3.6 GNU-style Option Parsing

New in Python 2.3, an additional function `gnu_getopt()` was added. It allows option and non-option arguments to be mixed on the command line in any order.

```
import getopt
import sys

version = '1.0'
verbose = False
output_filename = 'default.out'

print 'ARGV      :', sys.argv[1:]

options, remainder = getopt.gnu_getopt(sys.argv[1:], 'o:v', ['output=',
                                                              'verbose',
                                                              'version=',
                                                              ])
print 'OPTIONS   :', options

for opt, arg in options:
    if opt in ('-o', '--output'):
        output_filename = arg
    elif opt in ('-v', '--verbose'):
        verbose = True
    elif opt == '--version':
        version = arg

print 'VERSION   :', version
print 'VERBOSE   :', verbose
print 'OUTPUT    :', output_filename
print 'REMAINING :', remainder
```

After changing the call in the previous example, the difference becomes clear:

```
$ python getopt_gnu.py -v not_an_option --output foo

ARGV      : ['-v', 'not_an_option', '--output', 'foo']
OPTIONS   : [('-v', ''), ('--output', 'foo')]
VERSION   : 1.0
VERBOSE   : True
OUTPUT    : foo
REMAINING : ['not_an_option']
```

15.3.7 Special Case: --

If `getopt` encounters `--` in the input arguments, it stops processing the remaining arguments as options.

```
$ python getopt_example.py -v -- --output foo

ARGV      : ['-v', '--', '--output', 'foo']
OPTIONS   : [('-v', '')]
VERSION   : 1.0
VERBOSE   : True
OUTPUT    : default.out
REMAINING : ['--output', 'foo']
```

See also:

getopt (http://docs.python.org/library/getopt.html) The standard library documentation for this module.

optparse The optparse module.

15.4 optparse – Command line option parser to replace getopt.

Purpose Command line option parser to replace getopt.

Available In 2.3

The optparse module is a modern alternative for command line option parsing that offers several features not available in getopt, including type conversion, option callbacks, and automatic help generation. There are many more features to optparse than can be covered here, but this section will introduce some of the more commonly used capabilities.

15.4.1 Creating an OptionParser

There are two phases to parsing options with optparse. First, the OptionParser instance is constructed and configured with the expected options. Then a sequence of options is fed in and processed.

```
import optparse
parser = optparse.OptionParser()
```

Usually, once the parser has been created, each option is added to the parser explicitly, with information about what to do when the option is encountered on the command line. It is also possible to pass a list of options to the OptionParser constructor, but that form is not used as frequently.

Defining Options

Options should be added one at a time using the add_option() method. Any un-named string arguments at the beginning of the argument list are treated as option names. To create aliases for an option (i.e., to have a short and long form of the same option), simply pass multiple names.

Parsing a Command Line

After all of the options are defined, the command line is parsed by passing a sequence of argument strings to parse_args(). By default, the arguments are taken from sys.argv[1:], but a list can be passed explicitly as well. The options are processed using the GNU/POSIX syntax, so option and argument values can be mixed in the sequence.

The return value from parse_args() is a two-part tuple containing an Values instance and the list of arguments to the command that were not interpreted as options. The default processing action for options is to store the value using the name given in the *dest* argument to add_option(). The Values instance returned by parse_args() holds the option values as attributes, so if an option's dest is set to "myoption", the value is accessed as options.myoption.

15.4.2 Short and Long-Form Options

Here is a simple example with three different options: a boolean option (-a), a simple string option (-b), and an integer option (-c).

```
import optparse

parser = optparse.OptionParser()
parser.add_option('-a', action="store_true", default=False)
parser.add_option('-b', action="store", dest="b")
parser.add_option('-c', action="store", dest="c", type="int")

print parser.parse_args(['-a', '-bval', '-c', '3'])
```

The options on the command line are parsed with the same rules that `getopt.gnu_getopt()` uses, so there are two ways to pass values to single character options. The example above uses both forms, `-bval` and `-c val`.

```
$ python optparse_short.py

(<Values at 0x1004cf488: {'a': True, 'c': 3, 'b': 'val'}>, [])
```

Notice that the type of the value associated with `'c'` in the output is an integer, since the `OptionParser` was told to convert the argument before storing it.

Unlike with `getopt`, "long" option names are not handled any differently by `optparse`:

```
import optparse

parser = optparse.OptionParser()
parser.add_option('--noarg', action="store_true", default=False)
parser.add_option('--witharg', action="store", dest="witharg")
parser.add_option('--witharg2', action="store", dest="witharg2", type="int")

print parser.parse_args([ '--noarg', '--witharg', 'val', '--witharg2=3' ])
```

And the results are similar:

```
$ python optparse_long.py

(<Values at 0x1004d9488: {'noarg': True, 'witharg': 'val', 'witharg2': 3}>, [])
```

15.4.3 Comparing with getopt

Since `optparse` is supposed to replace `getopt`, this example re-implements the same example program used in the section about `getopt`:

```
import optparse
import sys

print 'ARGV      :', sys.argv[1:]

parser = optparse.OptionParser()
parser.add_option('-o', '--output',
                  dest="output_filename",
                  default="default.out",
                  )
parser.add_option('-v', '--verbose',
                  dest="verbose",
                  default=False,
                  action="store_true",
                  )
parser.add_option('--version',
                  dest="version",
                  default=1.0,
                  type="float",
                  )
options, remainder = parser.parse_args()

print 'VERSION   :', options.version
print 'VERBOSE   :', options.verbose
print 'OUTPUT    :', options.output_filename
print 'REMAINING :', remainder
```

Notice how the options `-o` and `--output` are aliased by being added at the same time. Either option can be used on the command line. The short form:

```
$ python optparse_getoptcomparison.py -o output.txt

ARGV      : ['-o', 'output.txt']
VERSION   : 1.0
VERBOSE   : False
OUTPUT    : output.txt
REMAINING : []
```

or the long form:

```
$ python optparse_getoptcomparison.py --output output.txt

ARGV      : ['--output', 'output.txt']
VERSION   : 1.0
VERBOSE   : False
OUTPUT    : output.txt
REMAINING : []
```

Any unique prefix of the long option can also be used:

```
$ python optparse_getoptcomparison.py --out output.txt

ARGV      : ['--out', 'output.txt']
VERSION   : 1.0
VERBOSE   : False
OUTPUT    : output.txt
REMAINING : []
```

15.4.4 Option Values

The default processing action is to store the argument to the option. If a type is provided, the argument value is converted to that type before it is stored.

Setting Defaults

Since options are by definition optional, applications should establish default behavior when an option is not given on the command line. A default value for an individual option can be provided when the option is defined.

```
import optparse

parser = optparse.OptionParser()
parser.add_option('-o', action="store", default="default value")
```

```
options, args = parser.parse_args()

print options.o
```

```
$ python optparse_default.py

default value

$ python optparse_default.py -o "different value"

different value
```

Defaults can also be loaded after the options are defined using keyword arguments to `set_defaults()`.

```
import optparse

parser = optparse.OptionParser()
parser.add_option('-o', action="store")

parser.set_defaults(o='default value')

options, args = parser.parse_args()

print options.o
```

This form is useful when loading defaults from a configuration file or other source, instead of hard-coding them.

```
$ python optparse_set_defaults.py

default value

$ python optparse_set_defaults.py -o "different value"

different value
```

All defined options are available as attributes of the `Values` instance returned by `parse_args()` so applications do not need to check for the presence of an option before trying to use its value.

```
import optparse

parser = optparse.OptionParser()
parser.add_option('-o', action="store")

options, args = parser.parse_args()

print options.o
```

If no default value is given for an option, and the option is not specified on the command line, its value is `None`.

```
$ python optparse_no_default.py

None

$ python optparse_no_default.py -o "different value"

different value
```

Type Conversion

optparse will convert option values from strings to integers, floats, longs, and complex values. To enable the conversion, specify the *type* of the option as an argument to `add_option()`.

```
import optparse

parser = optparse.OptionParser()
parser.add_option('-i', action="store", type="int")
parser.add_option('-f', action="store", type="float")
parser.add_option('-l', action="store", type="long")
parser.add_option('-c', action="store", type="complex")

options, args = parser.parse_args()

print 'int    : %-16r %s' % (type(options.i), options.i)
print 'float  : %-16r %s' % (type(options.f), options.f)
print 'long   : %-16r %s' % (type(options.l), options.l)
print 'complex: %-16r %s' % (type(options.c), options.c)
```

If an option's value cannot be converted to the specified type, an error is printed and the program exits.

```
$ python optparse_types.py -i 1 -f 3.14 -l 1000000 -c 1+2j

int    : <type 'int'>     1
float  : <type 'float'>   3.14
long   : <type 'long'>    1000000
complex: <type 'complex'> (1+2j)

$ python optparse_types.py -i a

Usage: optparse_types.py [options]

optparse_types.py: error: option -i: invalid integer value: 'a'
```

Custom conversions can be created by subclassing the `Option` class. See the standard library documentation for complete details.

Enumerations

The `choice` type provides validation using a list of candidate strings. Set *type* to choice and provide the list of valid values using the *choices* argument to `add_option()`.

```
import optparse

parser = optparse.OptionParser()

parser.add_option('-c', type='choice', choices=['a', 'b', 'c'])

options, args = parser.parse_args()

print 'Choice:', options.c
```

Invalid inputs result in an error message that shows the allowed list of values.

```
$ python optparse_choice.py -c a

Choice: a
```

```
$ python optparse_choice.py -c b

Choice: b

$ python optparse_choice.py -c d

Usage: optparse_choice.py [options]

optparse_choice.py: error: option -c: invalid choice: 'd' (choose from
 'a', 'b', 'c')
```

15.4.5 Option Actions

Unlike getopt, which only *parses* the options, optparse is a full option *processing* library. Options can trigger different actions, specified by the action argument to `add_option()`. Supported actions include storing the argument (singly, or as part of a list), storing a constant value when the option is encountered (including special handling for true/false values for boolean switches), counting the number of times an option is seen, and calling a callback. The default action is `store`, and does not need to be specified explicitly.

Constants

When options represent a selection of fixed alternatives, such as operating modes of an application, creating separate explicit options makes it easier to document them. The `store_const` action is intended for this purpose.

```
import optparse

parser = optparse.OptionParser()
parser.add_option('--earth', action="store_const", const='earth', dest='element', default='earth')
parser.add_option('--air', action='store_const', const='air', dest='element')
parser.add_option('--water', action='store_const', const='water', dest='element')
parser.add_option('--fire', action='store_const', const='fire', dest='element')

options, args = parser.parse_args()

print options.element
```

The `store_const` action associates a constant value in the application with the option specified by the user. Several options can be configured to store different constant values to the same *dest* name, so the application only has to check a single setting.

```
$ python optparse_store_const.py

earth

$ python optparse_store_const.py --fire

fire
```

Boolean Flags

Boolean options are implemented using special actions for storing true and false constant values.

```
import optparse

parser = optparse.OptionParser()
parser.add_option('-t', action='store_true', default=False, dest='flag')
parser.add_option('-f', action='store_false', default=False, dest='flag')

options, args = parser.parse_args()

print 'Flag:', options.flag
```

True and false versions of the same flag can be created by configuring their *dest* name to the same value.

```
$ python optparse_boolean.py

Flag: False

$ python optparse_boolean.py -t

Flag: True

$ python optparse_boolean.py -f

Flag: False
```

Repeating Options

There are three ways to handle repeated options. The default is to overwrite any existing value so that the last option specified is used. The `store` action works this way.

Using the `append` action, it is possible to accumulate values as an option is repeated, creating a list of values. Append mode is useful when multiple responses are allowed, and specifying them separately is easier for the user than constructing a parsable syntax.

```
import optparse

parser = optparse.OptionParser()
parser.add_option('-o', action="append", dest='outputs', default=[])

options, args = parser.parse_args()

print options.outputs
```

The order of the values given on the command line is preserved, in case it is important for the application.

```
$ python optparse_append.py

[]

$ python optparse_append.py -o a.out

['a.out']

$ python optparse_append.py -o a.out -o b.out

['a.out', 'b.out']
```

Sometimes it is enough to know how many times an option was given, and the associated value is not needed. For example, many applications allow the user to repeat the `-v` option to increase the level of verbosity of their output.

The `count` action increments a value each time the option appears.

```
import optparse

parser = optparse.OptionParser()
parser.add_option('-v', action="count", dest='verbosity', default=1)
parser.add_option('-q', action='store_const', const=0, dest='verbosity')

options, args = parser.parse_args()

print options.verbosity
```

Since the `-v` option doesn't take an argument, it can be repeated using the syntax `-vv` as well as through separate individual options.

```
$ python optparse_count.py

1

$ python optparse_count.py -v

2

$ python optparse_count.py -v -v

3

$ python optparse_count.py -vv

3

$ python optparse_count.py -q

0
```

Callbacks

Beside saving the arguments for options directly, it is possible to define callback functions to be invoked when the option is encountered on the command line. Callbacks for options take four arguments: the `Option` instance causing the callback, the option string from the command line, any argument value associated with the option, and the `OptionParser` instance doing the parsing work.

```
import optparse

def flag_callback(option, opt_str, value, parser):
    print 'flag_callback:'
    print '\toption:', repr(option)
    print '\topt_str:', opt_str
    print '\tvalue:', value
    print '\tparser:', parser
    return

def with_callback(option, opt_str, value, parser):
    print 'with_callback:'
    print '\toption:', repr(option)
    print '\topt_str:', opt_str
    print '\tvalue:', value
    print '\tparser:', parser
    return

parser = optparse.OptionParser()
parser.add_option('--flag', action="callback", callback=flag_callback)
parser.add_option('--with',
                  action="callback",
                  callback=with_callback,
                  type="string",
                  help="Include optional feature")

parser.parse_args(['--with', 'foo', '--flag'])
```

In this example, the `--with` option is configured to take a string argument (other types such as integers and floats are support as well).

```
$ python optparse_callback.py

with_callback:
        option: <Option at 0x1004cf2d8: --with>
        opt_str: --with
        value: foo
        parser: <optparse.OptionParser instance at 0x1004675a8>
flag_callback:
        option: <Option at 0x100467830: --flag>
        opt_str: --flag
        value: None
        parser: <optparse.OptionParser instance at 0x1004675a8>
```

Callbacks can be configured to take multiple arguments using the *nargs* option.

```
import optparse

def with_callback(option, opt_str, value, parser):
    print 'with_callback:'
    print '\toption:', repr(option)
    print '\topt_str:', opt_str
    print '\tvalue:', value
    print '\tparser:', parser
    return

parser = optparse.OptionParser()
parser.add_option('--with',
                  action="callback",
                  callback=with_callback,
                  type="string",
                  nargs=2,
                  help="Include optional feature")

parser.parse_args(['--with', 'foo', 'bar'])
```

In this case, the arguments are passed to the callback function as a tuple via the value argument.

```
$ python optparse_callback_nargs.py

with_callback:
        option: <Option at 0x100467758: --with>
        opt_str: --with
        value: ('foo', 'bar')
        parser: <optparse.OptionParser instance at 0x1004674d0>
```

15.4.6 Help Messages

The `OptionParser` automatically includes a help option to all option sets, so the user can pass `--help` on the command line to see instructions for running the program. The help message includes all of the options with an indication of whether or not they take an argument. It is also possible to pass help text to `add_option()` to give a more verbose description of an option.

```
import optparse

parser = optparse.OptionParser()
parser.add_option('--no-foo', action="store_true",
                  default=False,
                  dest="foo",
                  help="Turn off foo",
                  )
parser.add_option('--with', action="store", help="Include optional feature")

parser.parse_args()
```

The options are listed in alphabetical order, with aliases included on the same line. When the option takes an argument, the `dest` name is included as an argument name in the help output. The help text is printed in the right column.

```
$ python optparse_help.py --help

Usage: optparse_help.py [options]

Options:
  -h, --help    show this help message and exit
  --no-foo      Turn off foo
  --with=WITH   Include optional feature
```

The name `WITH` printed with the option `--with` comes from the destination variable for the option. For cases where the internal variable name is descriptive enough to serve in the documentation, the *metavar* argument can be used to set a different name.

```
import optparse

parser = optparse.OptionParser()
parser.add_option('--no-foo', action="store_true",
                  default=False,
                  dest="foo",
                  help="Turn off foo",
                  )
parser.add_option('--with', action="store", help="Include optional feature",
                  metavar='feature_NAME')

parser.parse_args()
```

The value is printed exactly as it is given, without any changes to capitalization or punctuation.

```
$ python optparse_metavar.py -h

Usage: optparse_metavar.py [options]

Options:
  -h, --help            show this help message and exit
  --no-foo              Turn off foo
  --with=feature_NAME   Include optional feature
```

Organizing Options

Many applications include sets of related options. For example, **rpm** includes separate options for each of its operating modes. optparse uses *option groups* to organize options in the help output. The option values are all still saved in a single Values instance, so the namespace for option names is still flat.

```
import optparse

parser = optparse.OptionParser()

parser.add_option('-q', action='store_const', const='query', dest='mode',
                  help='Query')
parser.add_option('-i', action='store_const', const='install', dest='mode',
                  help='Install')

query_opts = optparse.OptionGroup(
    parser, 'Query Options',
    'These options control the query mode.',
    )
query_opts.add_option('-l', action='store_const', const='list', dest='query_mode',
                      help='List contents')
query_opts.add_option('-f', action='store_const', const='file', dest='query_mode',
                      help='Show owner of file')
query_opts.add_option('-a', action='store_const', const='all', dest='query_mode',
                      help='Show all packages')
parser.add_option_group(query_opts)

install_opts = optparse.OptionGroup(
    parser, 'Installation Options',
    'These options control installation.',
    )
install_opts.add_option('--hash', action='store_true', default=False,
                        help='Show hash marks as progress indication')
install_opts.add_option('--force', dest='install_force', action='store_true', default=False,
                        help='Install, regardless of depdencies or existing version')
parser.add_option_group(install_opts)

print parser.parse_args()
```

Each group has its own section title and description, and the options are displayed together.

```
$ python optparse_groups.py -h

Usage: optparse_groups.py [options]

Options:
  -h, --help  show this help message and exit
  -q          Query
  -i          Install

  Query Options:
    These options control the query mode.

    -l        List contents
    -f        Show owner of file
    -a        Show all packages

  Installation Options:
    These options control installation.
    --hash    Show hash marks as progress indication
    --force   Install, regardless of depdencies or existing version
```

Application Settings

The automatic help generation facilities support configuration settings to control several aspects of the help output. The program's *usage* string, which shows how the positional arguments are expected, can be set when the `OptionParser` is created.

```
import optparse

parser = optparse.OptionParser(usage='%prog [options] <arg1> <arg2> [<arg3>...]')
parser.add_option('-a', action="store_true", default=False)
parser.add_option('-b', action="store", dest="b")
parser.add_option('-c', action="store", dest="c", type="int")

parser.parse_args()
```

The literal value `%prog` is expanded to the name of the program at runtime, so it can reflect the full path to the script. If the script is run by **python**, instead of running directly, the script name is used.

```
$ python optparse_usage.py -h

Usage: optparse_usage.py [options] <arg1> <arg2> [<arg3>...]

Options:
  -h, --help  show this help message and exit
  -a
  -b B
  -c C
```

The program name can be changed using the *prog* argument.

```
import optparse

parser = optparse.OptionParser(usage='%prog [options] <arg1> <arg2> [<arg3>...]',
                               prog='my_program_name',
                               )
parser.add_option('-a', action="store_true", default=False)
parser.add_option('-b', action="store", dest="b")
parser.add_option('-c', action="store", dest="c", type="int")

parser.parse_args()
```

It is generally a bad idea to hard-code the program name in this way, though, because if the program is renamed the help will not reflect the change.

```
$ python optparse_prog.py -h

Usage: my_program_name [options] <arg1> <arg2> [<arg3>...]

Options:
  -h, --help  show this help message and exit
  -a
  -b B
  -c C
```

The application version can be set using the *version* argument. When a value is provided, `optparse` automatically adds a `--version` option to the parser.

```
import optparse

parser = optparse.OptionParser(usage='%prog [options] <arg1> <arg2> [<arg3>...]',
                               version='1.0',
                               )

parser.parse_args()
```

When the user runs the program with the `--version` option, `optparse` prints the version string and then exits.

```
$ python optparse_version.py -h

Usage: optparse_version.py [options] <arg1> <arg2> [<arg3>...]

Options:
  --version   show program's version number and exit
  -h, --help  show this help message and exit

$ python optparse_version.py --version

1.0
```

See also:

optparse (http://docs.python.org/lib/module-optparse.html) Standard library documentation for this module.

getopt The getopt module, replaced by optparse.

argparse Newer replacement for optparse.

15.5 argparse – Command line option and argument parsing.

Purpose Command line option and argument parsing.

Available In 2.7 and later

The `argparse` module was added to Python 2.7 as a replacement for `optparse`. The implementation of `argparse` supports features that would not have been easy to add to `optparse`, and that would have required backwards-incompatible API changes, so a new module was brought into the library instead. `optparse` is still supported, but is not likely to receive new features.

15.5.1 Comparing with optparse

The API for `argparse` is similar to the one provided by `optparse`, and in many cases `argparse` can be used as a straightforward replacement by updating the names of the classes and methods used. There are a few places where direct compatibility could not be preserved as new features were added, however.

You will have to decide whether to upgrade existing programs on a case-by-case basis. If you have written extra code to work around limitations of `optparse`, you may want to upgrade to reduce the amount of code you need to maintain. New programs should probably use argparse, if it is available on all deployment platforms.

15.5.2 Setting up a Parser

The first step when using argparse is to create a parser object and tell it what arguments to expect. The parser can then be used to process the command line arguments when your program runs.

The parser class is ArgumentParser. The constructor takes several arguments to set up the description used in the help text for the program and other global behaviors or settings.

```
import argparse
parser = argparse.ArgumentParser(description='This is a PyMOTW sample program')
```

15.5.3 Defining Arguments

argparse is a complete argument *processing* library. Arguments can trigger different actions, specified by the *action* argument to add_argument(). Supported actions include storing the argument (singly, or as part of a list), storing a constant value when the argument is encountered (including special handling for true/false values for boolean switches), counting the number of times an argument is seen, and calling a callback.

The default action is to store the argument value. In this case, if a type is provided, the value is converted to that type before it is stored. If the *dest* argument is provided, the value is saved to an attribute of that name on the Namespace object returned when the command line arguments are parsed.

15.5.4 Parsing a Command Line

Once all of the arguments are defined, you can parse the command line by passing a sequence of argument strings to parse_args(). By default, the arguments are taken from sys.argv[1:], but you can also pass your own list. The options are processed using the GNU/POSIX syntax, so option and argument values can be mixed in the sequence.

The return value from parse_args() is a Namespace containing the arguments to the command. The object holds the argument values as attributes, so if your argument dest is "myoption", you access the value as args.myoption.

15.5.5 Simple Examples

Here is a simple example with 3 different options: a boolean option (-a), a simple string option (-b), and an integer option (-c).

```
import argparse

parser = argparse.ArgumentParser(description='Short sample app')

parser.add_argument('-a', action="store_true", default=False)
parser.add_argument('-b', action="store", dest="b")
parser.add_argument('-c', action="store", dest="c", type=int)

print parser.parse_args(['-a', '-bval', '-c', '3'])
```

There are a few ways to pass values to single character options. The example above uses two different forms, -bval and -c val.

```
$ python argparse_short.py

Namespace(a=True, b='val', c=3)
```

The type of the value associated with `'c'` in the output is an integer, since the `ArgumentParser` was told to convert the argument before storing it.

"Long" option names, with more than a single character in their name, are handled in the same way.

```
import argparse

parser = argparse.ArgumentParser(description='Example with long option names')

parser.add_argument('--noarg', action="store_true", default=False)
parser.add_argument('--witharg', action="store", dest="witharg")
parser.add_argument('--witharg2', action="store", dest="witharg2", type=int)

print parser.parse_args([ '--noarg', '--witharg', 'val', '--witharg2=3' ])
```

And the results are similar:

```
$ python argparse_long.py

Namespace(noarg=True, witharg='val', witharg2=3)
```

One area in which `argparse` differs from `optparse` is the treatment of non-optional argument values. While `optparse` sticks to option parsing, `argparse` is a full command-line argument parser tool, and handles non-optional arguments as well.

```
import argparse

parser = argparse.ArgumentParser(description='Example with non-optional arguments')

parser.add_argument('count', action="store", type=int)
parser.add_argument('units', action="store")

print parser.parse_args()
```

In this example, the "count" argument is an integer and the "units" argument is saved as a string. If either is not provided on the command line, or the value given cannot be converted to the right type, an error is reported.

```
$ python argparse_arguments.py 3 inches

Namespace(count=3, units='inches')

$ python argparse_arguments.py some inches

usage: argparse_arguments.py [-h] count units
argparse_arguments.py: error: argument count: invalid int value: 'some'

$ python argparse_arguments.py

usage: argparse_arguments.py [-h] count units
argparse_arguments.py: error: too few arguments
```

Argument Actions

There are six built-in actions that can be triggered when an argument is encountered:

`store` Save the value, after optionally converting it to a different type. This is the default action taken if none is specified explicilty.

store_const Save a value defined as part of the argument specification, rather than a value that comes from the arguments being parsed. This is typically used to implement command line flags that aren't booleans.

store_true / store_false Save the appropriate boolean value. These actions are used to implement boolean switches.

append Save the value to a list. Multiple values are saved if the argument is repeated.

append_const Save a value defined in the argument specification to a list.

version Prints version details about the program and then exits.

```
import argparse

parser = argparse.ArgumentParser()

parser.add_argument('-s', action='store', dest='simple_value',
                    help='Store a simple value')

parser.add_argument('-c', action='store_const', dest='constant_value',
                    const='value-to-store',
                    help='Store a constant value')

parser.add_argument('-t', action='store_true', default=False,
                    dest='boolean_switch',
                    help='Set a switch to true')
parser.add_argument('-f', action='store_false', default=False,
                    dest='boolean_switch',
                    help='Set a switch to false')

parser.add_argument('-a', action='append', dest='collection',
                    default=[],
                    help='Add repeated values to a list',
                    )

parser.add_argument('-A', action='append_const', dest='const_collection',
                    const='value-1-to-append',
                    default=[],
                    help='Add different values to list')
parser.add_argument('-B', action='append_const', dest='const_collection',
                    const='value-2-to-append',
                    help='Add different values to list')

parser.add_argument('--version', action='version', version='%(prog)s 1.0')

results = parser.parse_args()
print 'simple_value     =', results.simple_value
print 'constant_value   =', results.constant_value
print 'boolean_switch   =', results.boolean_switch
print 'collection       =', results.collection
print 'const_collection =', results.const_collection
```

```
$ python argparse_action.py -h

usage: argparse_action.py [-h] [-s SIMPLE_VALUE] [-c] [-t] [-f]
                          [-a COLLECTION] [-A] [-B] [--version]

optional arguments:
  -h, --help       show this help message and exit
  -s SIMPLE_VALUE  Store a simple value
  -c                Store a constant value
  -t                Set a switch to true
  -f                Set a switch to false
  -a COLLECTION     Add repeated values to a list
  -A                Add different values to list
  -B                Add different values to list
  --version         show program's version number and exit

$ python argparse_action.py -s value

simple_value     = value
constant_value   = None
boolean_switch   = False
collection       = []
const_collection = []

$ python argparse_action.py -c

simple_value     = None
constant_value   = value-to-store
boolean_switch   = False
collection       = []
const_collection = []

$ python argparse_action.py -t

simple_value     = None
constant_value   = None
boolean_switch   = True
collection       = []
const_collection = []

$ python argparse_action.py -f

simple_value     = None
constant_value   = None
boolean_switch   = False
collection       = []
const_collection = []

$ python argparse_action.py -a one -a two -a three

simple_value     = None
constant_value   = None
boolean_switch   = False
collection       = ['one', 'two', 'three']
const_collection = []

$ python argparse_action.py -B -A

simple_value     = None
constant_value   = None
boolean_switch   = False
collection       = []
const_collection = ['value-2-to-append', 'value-1-to-append']

$ python argparse_action.py --version
```

```
argparse_action.py 1.0
```

Option Prefixes

The default syntax for options is based on the Unix convention of signifying command line switches using a prefix of "-". argparse supports other prefixes, so you can make your program conform to the local platform default (i.e., use "/" on Windows) or follow a different convention.

```
import argparse

parser = argparse.ArgumentParser(description='Change the option prefix characters',
                                 prefix_chars='-+/',
                                 )

parser.add_argument('-a', action="store_false", default=None,
                    help='Turn A off',
                    )
parser.add_argument('+a', action="store_true", default=None,
                    help='Turn A on',
                    )
parser.add_argument('//noarg', '++noarg', action="store_true", default=False)

print parser.parse_args()
```

Set the *prefix_chars* parameter for the `ArgumentParser` to a string containing all of the characters that should be allowed to signify options. It is important to understand that although *prefix_chars* establishes the allowed switch characters, the individual argument definitions specify the syntax for a given switch. This gives you explicit control over whether options using different prefixes are aliases (such as might be the case for platform-independent command line syntax) or alternatives (e.g., using "+" to indicate turning a switch on and "–" to turn it off). In the example above, `+a` and `-a` are separate arguments, and `//noarg` can also be given as `++noarg`, but not `--noarg`.

```
$ python argparse_prefix_chars.py -h

usage: argparse_prefix_chars.py [-h] [-a] [+a] [//noarg]

Change the option prefix characters

optional arguments:
  -h, --help        show this help message and exit
  -a                Turn A off
  +a                Turn A on
  //noarg, ++noarg

$ python argparse_prefix_chars.py +a

Namespace(a=True, noarg=False)

$ python argparse_prefix_chars.py -a

Namespace(a=False, noarg=False)

$ python argparse_prefix_chars.py //noarg

Namespace(a=None, noarg=True)

$ python argparse_prefix_chars.py ++noarg
```

```
Namespace(a=None, noarg=True)

$ python argparse_prefix_chars.py --noarg

usage: argparse_prefix_chars.py [-h] [-a] [+a] [//noarg]
argparse_prefix_chars.py: error: unrecognized arguments: --noarg
```

Sources of Arguments

In the examples so far, the list of arguments given to the parser have come from a list passed in explicitly, or were taken implicitly from *sys.argv*. Passing the list explicitly is useful when you are using `argparse` to process command line-like instructions that do not come from the command line (such as in a configuration file).

```
import argparse
from ConfigParser import ConfigParser
import shlex

parser = argparse.ArgumentParser(description='Short sample app')

parser.add_argument('-a', action="store_true", default=False)
parser.add_argument('-b', action="store", dest="b")
parser.add_argument('-c', action="store", dest="c", type=int)

config = ConfigParser()
config.read('argparse_witH_shlex.ini')
config_value = config.get('cli', 'options')
print 'Config  :', config_value

argument_list = shlex.split(config_value)
print 'Arg List:', argument_list

print 'Results :', parser.parse_args(argument_list)
```

`shlex` makes it easy to split the string stored in the configuration file.

```
$ python argparse_with_shlex.py

Config  : -a -b 2
Arg List: ['-a', '-b', '2']
Results : Namespace(a=True, b='2', c=None)
```

An alternative to processing the configuration file yourself is to tell `argparse` how to recognize an argument that specifies an input file containing a set of arguments to be processed using *fromfile_prefix_chars*.

```
import argparse
from ConfigParser import ConfigParser
import shlex

parser = argparse.ArgumentParser(description='Short sample app',
                                 fromfile_prefix_chars='@',
                                 )

parser.add_argument('-a', action="store_true", default=False)
parser.add_argument('-b', action="store", dest="b")
parser.add_argument('-c', action="store", dest="c", type=int)

print parser.parse_args(['@argparse_fromfile_prefix_chars.txt'])
```

This example stops when it finds an argument prefixed with `@`, then reads the named file to find more arguments. For example, an input file `argparse_fromfile_prefix_chars.txt` contains a series of arguments, one per line:

```
-a
-b
2
```

The output produced when processing the file is:

```
$ python argparse_fromfile_prefix_chars.py

Namespace(a=True, b='2', c=None)
```

15.5.6 Automatically Generated Options

`argparse` will automatically add options to generate help and show the version information for your application, if configured to do so.

The *add_help* argument to `ArgumentParser` controls the help-related options.

```
import argparse

parser = argparse.ArgumentParser(add_help=True)

parser.add_argument('-a', action="store_true", default=False)
parser.add_argument('-b', action="store", dest="b")
parser.add_argument('-c', action="store", dest="c", type=int)

print parser.parse_args()
```

The help options (`-h` and `--help`) are added by default, but can be disabled by setting *add_help* to false.

```
import argparse

parser = argparse.ArgumentParser(add_help=False)

parser.add_argument('-a', action="store_true", default=False)
parser.add_argument('-b', action="store", dest="b")
parser.add_argument('-c', action="store", dest="c", type=int)

print parser.parse_args()
```

Although `-h` and `--help` are defacto standard option names for requesting help, some applications or uses of `argparse` either don't need to provide help or need to use those option names for other purposes.

```
$ python argparse_with_help.py -h

usage: argparse_with_help.py [-h] [-a] [-b B] [-c C]

optional arguments:
  -h, --help  show this help message and exit
  -a
  -b B
  -c C

$ python argparse_without_help.py -h

usage: argparse_without_help.py [-a] [-b B] [-c C]
argparse_without_help.py: error: unrecognized arguments: -h
```

The version options (`-v` and `--version`) are added when *version* is set in the `ArgumentParser` constructor.

```
import argparse

parser = argparse.ArgumentParser(version='1.0')

parser.add_argument('-a', action="store_true", default=False)
parser.add_argument('-b', action="store", dest="b")
parser.add_argument('-c', action="store", dest="c", type=int)

print parser.parse_args()

print 'This is not printed'
```

Both forms of the option print the program's version string, then cause it to exit immediately.

```
$ python argparse_with_version.py -h

usage: argparse_with_version.py [-h] [-v] [-a] [-b B] [-c C]

optional arguments:
  -h, --help     show this help message and exit
  -v, --version  show program's version number and exit
  -a
  -b B
  -c C

$ python argparse_with_version.py -v

1.0

$ python argparse_with_version.py --version

1.0
```

15.5.7 Parser Organization

`argparse` includes several features for organizing your argument parsers, to make implementation easier or to improve the usability of the help output.

Sharing Parser Rules

It is common to need to implement a suite of command line programs that all take a set of arguments, and then specialize in some way. For example, if the programs all need to authenticate the user before taking any real action, they would all need to support `--user` and `--password` options. Rather than add the options explicitly to every `ArgumentParser`, you can define a "parent" parser with the shared options, and then have the parsers for the individual programs inherit from its options.

The first step is to set up the parser with the shared argument definitions. Since each subsequent user of the parent parser is going to try to add the same help options, causing an exception, we turn off automatic help generation in the base parser.

```
import argparse

parser = argparse.ArgumentParser(add_help=False)
```

```
parser.add_argument('--user', action="store")
parser.add_argument('--password', action="store")
```

Next, create another parser with *parents* set:

```
import argparse
import argparse_parent_base

parser = argparse.ArgumentParser(parents=[argparse_parent_base.parser])

parser.add_argument('--local-arg', action="store_true", default=False)

print parser.parse_args()
```

And the resulting program takes all three options:

```
$ python argparse_uses_parent.py -h

usage: argparse_uses_parent.py [-h] [--user USER] [--password PASSWORD]
                               [--local-arg]

optional arguments:
  -h, --help           show this help message and exit
  --user USER
  --password PASSWORD
  --local-arg
```

Conflicting Options

The previous example pointed out that adding two argument handlers to a parser using the same argument name causes an exception. Change the conflict resolution behavior by passing a *conflict_handler*. The two built-in handlers are `error` (the default), and `resolve`, which picks a handler based on the order they are added.

```
import argparse

parser = argparse.ArgumentParser(conflict_handler='resolve')

parser.add_argument('-a', action="store")
parser.add_argument('-b', action="store", help='Short alone')
parser.add_argument('--long-b', '-b', action="store", help='Long and short together')

print parser.parse_args(['-h'])
```

Since the last handler with a given argument name is used, in this example the stand-alone option `-b` is masked by the alias for `--long-b`.

```
$ python argparse_conflict_handler_resolve.py

usage: argparse_conflict_handler_resolve.py [-h] [-a A] [--long-b LONG_B]

optional arguments:
  -h, --help            show this help message and exit
  -a A
  --long-b LONG_B, -b LONG_B
                        Long and short together
```

Switching the order of the calls to `add_argument()` unmasks the stand-alone option:

```
import argparse

parser = argparse.ArgumentParser(conflict_handler='resolve')

parser.add_argument('-a', action="store")
parser.add_argument('--long-b', '-b', action="store", help='Long and short together')
parser.add_argument('-b', action="store", help='Short alone')

print parser.parse_args(['-h'])
```

Now both options can be used together.

```
$ python argparse_conflict_handler_resolve2.py

usage: argparse_conflict_handler_resolve2.py [-h] [-a A] [--long-b LONG_B]
                                             [-b B]

optional arguments:
  -h, --help       show this help message and exit
  -a A
  --long-b LONG_B  Long and short together
  -b B             Short alone
```

Argument Groups

argparse combines the argument definitions into "groups." By default, it uses two groups, with one for options and another for required position-based arguments.

```
import argparse

parser = argparse.ArgumentParser(description='Short sample app')

parser.add_argument('--optional', action="store_true", default=False)
parser.add_argument('positional', action="store")

print parser.parse_args()
```

The grouping is reflected in the separate "positional arguments" and "optional arguments" section of the help output:

```
$ python argparse_default_grouping.py -h

usage: argparse_default_grouping.py [-h] [--optional] positional

Short sample app

positional arguments:
  positional

optional arguments:
  -h, --help  show this help message and exit
  --optional
```

You can adjust the grouping to make it more logical in the help, so that related options or values are documented together. The shared-option example from earlier could be written using custom grouping so that the authentication options are shown together in the help.

Create the "authentication" group with `add_argument_group()` and then add each of the authentication-related options to the group, instead of the base parser.

```
import argparse

parser = argparse.ArgumentParser(add_help=False)

group = parser.add_argument_group('authentication')

group.add_argument('--user', action="store")
group.add_argument('--password', action="store")
```

The program using the group-based parent lists it in the *parents* value, just as before.

```
import argparse
import argparse_parent_with_group

parser = argparse.ArgumentParser(parents=[argparse_parent_with_group.parser])

parser.add_argument('--local-arg', action="store_true", default=False)

print parser.parse_args()
```

The help output now shows the authentication options together.

```
$ python argparse_uses_parent_with_group.py -h

usage: argparse_uses_parent_with_group.py [-h] [--user USER]
                                          [--password PASSWORD] [--local-arg]

optional arguments:
  -h, --help           show this help message and exit
  --local-arg

authentication:
  --user USER
  --password PASSWORD
```

Mutually Exclusive Options

Defining mutually exclusive options is a special case of the option grouping feature, and uses `add_mutually_exclusive_group()` instead of `add_argument_group()`.

```
import argparse

parser = argparse.ArgumentParser()

group = parser.add_mutually_exclusive_group()
group.add_argument('-a', action='store_true')
group.add_argument('-b', action='store_true')

print parser.parse_args()
```

`argparse` enforces the mutal exclusivity for you, so that only one of the options from the group can be given.

```
$ python argparse_mutually_exclusive.py -h

usage: argparse_mutually_exclusive.py [-h] [-a | -b]

optional arguments:
  -h, --help  show this help message and exit
  -a
  -b

$ python argparse_mutually_exclusive.py -a

Namespace(a=True, b=False)

$ python argparse_mutually_exclusive.py -b

Namespace(a=False, b=True)

$ python argparse_mutually_exclusive.py -a -b

usage: argparse_mutually_exclusive.py [-h] [-a | -b]
argparse_mutually_exclusive.py: error: argument -b: not allowed with argument -a
```

Nesting Parsers

The parent parser approach described above is one way to share options between related commands. An alternate approach is to combine the commands into a single program, and use subparsers to handle each portion of the command line. The result works in the way `svn`, `hg`, and other programs with multiple command line actions, or sub-commands, does.

A program to work with directories on the filesystem might define commands for creating, deleting, and listing the contents of a directory like this:

```
import argparse

parser = argparse.ArgumentParser()

subparsers = parser.add_subparsers(help='commands')

# A list command
list_parser = subparsers.add_parser('list', help='List contents')
list_parser.add_argument('dirname', action='store', help='Directory to list')

# A create command
create_parser = subparsers.add_parser('create', help='Create a directory')
create_parser.add_argument('dirname', action='store', help='New directory to create')
create_parser.add_argument('--read-only', default=False, action='store_true',
                           help='Set permissions to prevent writing to the directory',
                           )

# A delete command
delete_parser = subparsers.add_parser('delete', help='Remove a directory')
delete_parser.add_argument('dirname', action='store', help='The directory to remove')
delete_parser.add_argument('--recursive', '-r', default=False, action='store_true',
                           help='Remove the contents of the directory, too',
                           )

print parser.parse_args()
```

The help output shows the named subparsers as “commands” that can be specified on the command line as positional arguments.

```
$ python argparse_subparsers.py -h
```

```
usage: argparse_subparsers.py [-h] {list,create,delete} ...

positional arguments:
  {list,create,delete}  commands
    list                List contents
    create              Create a directory
    delete              Remove a directory

optional arguments:
  -h, --help            show this help message and exit
```

Each subparser also has its own help, describing the arguments and options for that command.

```
$ python argparse_subparsers.py create -h

usage: argparse_subparsers.py create [-h] [--read-only] dirname

positional arguments:
  dirname      New directory to create

optional arguments:
  -h, --help   show this help message and exit
  --read-only  Set permissions to prevent writing to the directory
```

And when the arguments are parsed, the `Namespace` object returned by `parse_args()` includes only the values related to the command specified.

```
$ python argparse_subparsers.py delete -r foo

Namespace(dirname='foo', recursive=True)
```

15.5.8 Advanced Argument Processing

The examples so far have shown simple boolean flags, options with string or numerical arguments, and positional arguments. `argparse` supports sophisticated argument specification for variable-length argument list, enumerations, and constant values as well.

Variable Argument Lists

You can configure a single argument defintion to consume multiple arguments on the command line being parsed. Set *nargs* to one of these flag values, based on the number of required or expected arguments:

Value	Meaning
`N`	The absolute number of arguments (e.g., `3`).
`?`	0 or 1 arguments
`*`	0 or all arguments
`+`	All, and at least one, argument

```
import argparse

parser = argparse.ArgumentParser()

parser.add_argument('--three', nargs=3)
parser.add_argument('--optional', nargs='?')
parser.add_argument('--all', nargs='*', dest='all')
parser.add_argument('--one-or-more', nargs='+')
```

```
print parser.parse_args()
```

The parser enforces the argument count instructions, and generates an accurate syntax diagram as part of the command help text.

```
$ python argparse_nargs.py -h

usage: argparse_nargs.py [-h] [--three THREE THREE THREE]
                         [--optional [OPTIONAL]] [--all [ALL [ALL ...]]]
                         [--one-or-more ONE_OR_MORE [ONE_OR_MORE ...]]

optional arguments:
  -h, --help            show this help message and exit
  --three THREE THREE THREE
  --optional [OPTIONAL]
  --all [ALL [ALL ...]]
  --one-or-more ONE_OR_MORE [ONE_OR_MORE ...]

$ python argparse_nargs.py

Namespace(all=None, one_or_more=None, optional=None, three=None)

$ python argparse_nargs.py --three

usage: argparse_nargs.py [-h] [--three THREE THREE THREE]
                         [--optional [OPTIONAL]] [--all [ALL [ALL ...]]]
                         [--one-or-more ONE_OR_MORE [ONE_OR_MORE ...]]
argparse_nargs.py: error: argument --three: expected 3 argument(s)

$ python argparse_nargs.py --three a b c

Namespace(all=None, one_or_more=None, optional=None, three=['a', 'b', 'c'])

$ python argparse_nargs.py --optional

Namespace(all=None, one_or_more=None, optional=None, three=None)

$ python argparse_nargs.py --optional with_value

Namespace(all=None, one_or_more=None, optional='with_value', three=None)

$ python argparse_nargs.py --all with multiple values

Namespace(all=['with', 'multiple', 'values'], one_or_more=None, optional=None, three=None)

$ python argparse_nargs.py --one-or-more with_value

Namespace(all=None, one_or_more=['with_value'], optional=None, three=None)

$ python argparse_nargs.py --one-or-more with multiple values

Namespace(all=None, one_or_more=['with', 'multiple', 'values'], optional=None, three=None)

$ python argparse_nargs.py --one-or-more

usage: argparse_nargs.py [-h] [--three THREE THREE THREE]
                         [--optional [OPTIONAL]] [--all [ALL [ALL ...]]]
                         [--one-or-more ONE_OR_MORE [ONE_OR_MORE ...]]
```

```
argparse_nargs.py: error: argument --one-or-more: expected at least one argument
```

Argument Types

argparse treats all argument values as strings, unless you tell it to convert the string to another type. The *type* parameter to `add_argument()` expects a converter function used by the `ArgumentParser` to transform the argument value from a string to some other type.

```
import argparse

parser = argparse.ArgumentParser()

parser.add_argument('-i', type=int)
parser.add_argument('-f', type=float)
parser.add_argument('--file', type=file)

try:
    print parser.parse_args()
except IOError, msg:
    parser.error(str(msg))
```

Any callable that takes a single string argument can be passed as *type*, including built-in types like `int()`, `float()`, and `file()`.

```
$ python argparse_type.py -i 1

Namespace(f=None, file=None, i=1)

$ python argparse_type.py -f 3.14

Namespace(f=3.14, file=None, i=None)

$ python argparse_type.py --file argparse_type.py

Namespace(f=None, file=<open file 'argparse_type.py', mode 'r' at 0x1004de270>, i=None)
```

If the type conversion fails, argparse raises an exception. *TypeError* and *ValueError* exceptions are trapped automatically and converted to a simple error message for the user. Other exceptions, such as the *IOError* in the example below where the input file does not exist, must be handled by the caller.

```
$ python argparse_type.py -i a

usage: argparse_type.py [-h] [-i I] [-f F] [--file FILE]
argparse_type.py: error: argument -i: invalid int value: 'a'

$ python argparse_type.py -f 3.14.15

usage: argparse_type.py [-h] [-i I] [-f F] [--file FILE]
argparse_type.py: error: argument -f: invalid float value: '3.14.15'

$ python argparse_type.py --file does_not_exist.txt

usage: argparse_type.py [-h] [-i I] [-f F] [--file FILE]
argparse_type.py: error: [Errno 2] No such file or directory: 'does_not_exist.txt'
```

To limit an input argument to a value within a pre-defined set, use the *choices* parameter.

```
import argparse

parser = argparse.ArgumentParser()

parser.add_argument('--mode', choices=('read-only', 'read-write'))

print parser.parse_args()
```

If the argument to `--mode` is not one of the allowed values, an error is generated and processing stops.

```
$ python argparse_choices.py -h

usage: argparse_choices.py [-h] [--mode {read-only,read-write}]

optional arguments:
  -h, --help            show this help message and exit
  --mode {read-only,read-write}

$ python argparse_choices.py --mode read-only

Namespace(mode='read-only')

$ python argparse_choices.py --mode invalid

usage: argparse_choices.py [-h] [--mode {read-only,read-write}]
argparse_choices.py: error: argument --mode: invalid choice: 'invalid'
(choose from 'read-only', 'read-write')
```

File Arguments

Although `file` objects can instantiated with a single string argument, that does not allow you to specify the access mode. `FileType` gives you a more flexible way of specifying that an argument should be a file, including the mode and buffer size.

```
import argparse

parser = argparse.ArgumentParser()

parser.add_argument('-i', metavar='in-file', type=argparse.FileType('rt'))
parser.add_argument('-o', metavar='out-file', type=argparse.FileType('wt'))

try:
    results = parser.parse_args()
    print 'Input file:', results.i
    print 'Output file:', results.o
except IOError, msg:
    parser.error(str(msg))
```

The value associated with the argument name is the open file handle. You are responsible for closing the file yourself when you are done with it.

```
$ python argparse_FileType.py -h

usage: argparse_FileType.py [-h] [-i in-file] [-o out-file]

optional arguments:
  -h, --help   show this help message and exit
  -i in-file
  -o out-file

$ python argparse_FileType.py -i argparse_FileType.py -o temporary_file.\
txt

Input file: <open file 'argparse_FileType.py', mode 'rt' at 0x1004de270>
Output file: <open file 'temporary_file.txt', mode 'wt' at 0x1004de300>

$ python argparse_FileType.py -i no_such_file.txt

usage: argparse_FileType.py [-h] [-i in-file] [-o out-file]
argparse_FileType.py: error: argument -i: can't open 'no_such_file.txt': [Errno 2] No such file or d
```

Custom Actions

In addition to the built-in actions described earlier, you can define custom actions by providing an object that implements the Action API. The object passed to `add_argument()` as *action* should take parameters describing the argument being defined (all of the same arguments given to `add_argument()`) and return a callable object that takes as parameters the *parser* processing the arguments, the *namespace* holding the parse results, the *value* of the argument being acted on, and the *option_string* that triggered the action.

A class `Action` is provided as a convenient starting point for defining new actions. The constructor handles the argument definitions, so you only need to override `__call__()` in the subclass.

```
import argparse

class CustomAction(argparse.Action):
    def __init__(self,
                 option_strings,
                 dest,
                 nargs=None,
                 const=None,
                 default=None,
                 type=None,
                 choices=None,
                 required=False,
                 help=None,
                 metavar=None):
        argparse.Action.__init__(self,
                                 option_strings=option_strings,
                                 dest=dest,
                                 nargs=nargs,
                                 const=const,
                                 default=default,
                                 type=type,
                                 choices=choices,
                                 required=required,
                                 help=help,
                                 metavar=metavar,
                                 )
        print
        print 'Initializing CustomAction'
        for name,value in sorted(locals().items()):
            if name == 'self' or value is None:
                continue
            print '  %s = %r' % (name, value)
        return

    def __call__(self, parser, namespace, values, option_string=None):
        print
        print 'Processing CustomAction for "%s"' % self.dest
        print '  parser = %s' % id(parser)
        print '  values = %r' % values
        print '  option_string = %r' % option_string

        # Do some arbitrary processing of the input values
        if isinstance(values, list):
            values = [ v.upper() for v in values ]
        else:
            values = values.upper()
        # Save the results in the namespace using the destination
        # variable given to our constructor.
        setattr(namespace, self.dest, values)

parser = argparse.ArgumentParser()

parser.add_argument('-a', action=CustomAction)
parser.add_argument('-m', nargs='*', action=CustomAction)
parser.add_argument('positional', action=CustomAction)

results = parser.parse_args(['-a', 'value', '-m' 'multi-value', 'positional-value'])
print
print results
```

The type of *values* depends on the value of *nargs*. If the argument allows multiple values, *values* will be a list even if it only contains one item.

The value of *option_string* also depends on the original argument specification. For positional, required, arguments, *option_string* is always None.

```
$ python argparse_custom_action.py


Initializing CustomAction
  dest = 'a'
  option_strings = ['-a']
  required = False

Initializing CustomAction
  dest = 'm'
  nargs = '*'
  option_strings = ['-m']
  required = False

Initializing CustomAction
  dest = 'positional'
  option_strings = []
  required = True

Processing CustomAction for "a"
  parser = 4299616464
  values = 'value'
  option_string = '-a'

Processing CustomAction for "m"
```

```
  parser = 4299616464
  values = ['multi-value']
  option_string = '-m'

Processing CustomAction for "positional"
  parser = 4299616464
  values = 'positional-value'
  option_string = None

Namespace(a='VALUE', m=['MULTI-VALUE'], positional='POSITIONAL-VALUE')
```

See also:

argparse (http://docs.python.org/library/argparse.html) The standard library documentation for this module.

original argparse (http://pypi.python.org/pypi/argparse) The PyPI page for the version of argparse from outside of the standard libary. This version is compatible with older versions of Python, and can be installed separately.

ConfigParser Read and write configuration files.

15.6 logging – Report status, error, and informational messages.

Purpose Report status, error, and informational messages.

Available In 2.3

The logging module defines a standard API for reporting errors and status information from applications and libraries. The key benefit of having the logging API provided by a standard library module is that all Python modules can participate in logging, so an application's log can include messages from third-party modules.

15.6.1 Logging in Applications

There are two perspectives for examining logging. Application developers set up the logging module, directing the messages to appropriate output channels. It is possible to log messages with different verbosity levels or to different destinations. Handlers for writing log messages to files, HTTP GET/POST locations, email via SMTP, generic sockets, or OS-specific logging mechanisms are all included, and it is possible to create custom log destination classes for special requirements not handled by any of the built-in classes.

Logging to a File

Most applications are probably going to want to log to a file. Use the `basicConfig()` function to set up the default handler so that debug messages are written to a file.

```
import logging

LOG_FILENAME = 'logging_example.out'
logging.basicConfig(filename=LOG_FILENAME,
                    level=logging.DEBUG,
                    )

logging.debug('This message should go to the log file')

f = open(LOG_FILENAME, 'rt')
try:
    body = f.read()
```

```
finally:
    f.close()

print 'FILE:'
print body
```

After running the script, the log message is written to `logging_example.out`:

```
$ python logging_file_example.py

FILE:
DEBUG:root:This message should go to the log file
```

Rotating Log Files

Running the script repeatedly causes more messages to be appended to the file. To create a new file each time the program runs, pass a `filemode` argument to `basicConfig()` with a value of `'w'`. Rather than managing the creation of files this way, though, it is simpler to use a `RotatingFileHandler`:

```
import glob
import logging
import logging.handlers

LOG_FILENAME = 'logging_rotatingfile_example.out'

# Set up a specific logger with our desired output level
my_logger = logging.getLogger('MyLogger')
my_logger.setLevel(logging.DEBUG)

# Add the log message handler to the logger
handler = logging.handlers.RotatingFileHandler(LOG_FILENAME,
                                               maxBytes=20,
                                               backupCount=5,
                                               )
my_logger.addHandler(handler)

# Log some messages
for i in range(20):
    my_logger.debug('i = %d' % i)

# See what files are created
logfiles = glob.glob('%s*' % LOG_FILENAME)
for filename in logfiles:
    print filename
```

The result should be six separate files, each with part of the log history for the application:

```
$ python logging_rotatingfile_example.py

logging_rotatingfile_example.out
logging_rotatingfile_example.out.1
logging_rotatingfile_example.out.2
logging_rotatingfile_example.out.3
logging_rotatingfile_example.out.4
logging_rotatingfile_example.out.5
```

The most current file is always `logging_rotatingfile_example.out`, and each time it reaches the size limit it is renamed with the suffix `.1`. Each of the existing backup files is renamed to increment the suffix (`.1` becomes `.2`, etc.) and the `.5` file is erased.

Note: Obviously this example sets the log length much much too small as an extreme example. Set *maxBytes* to a more appropriate value in a real program.

Verbosity Levels

Another useful feature of the `logging` API is the ability to produce different messages at different log levels. This code to be instrumented with debug messages, for example, while setting the log level down so that those debug messages are not written on a production system.

Level	Value
CRITICAL	50
ERROR	40
WARNING	30
INFO	20
DEBUG	10
UNSET	0

The logger, handler, and log message call each specify a level. The log message is only emitted if the handler and logger are configured to emit messages of that level or higher. For example, if a message is `CRITICAL`, and the logger is set to `ERROR`, the message is emitted (50 > 40). If a message is a `WARNING`, and the logger is set to produce only messages set to `ERROR`, the message is not emitted (30 < 40).

```
import logging
import sys

LEVELS = { 'debug':logging.DEBUG,
            'info':logging.INFO,
            'warning':logging.WARNING,
            'error':logging.ERROR,
            'critical':logging.CRITICAL,
            }

if len(sys.argv) > 1:
    level_name = sys.argv[1]
    level = LEVELS.get(level_name, logging.NOTSET)
    logging.basicConfig(level=level)

logging.debug('This is a debug message')
logging.info('This is an info message')
logging.warning('This is a warning message')
logging.error('This is an error message')
logging.critical('This is a critical error message')
```

Run the script with an argument like 'debug' or 'warning' to see which messages show up at different levels:

```
$ python logging_level_example.py debug

DEBUG:root:This is a debug message
INFO:root:This is an info message
WARNING:root:This is a warning message
ERROR:root:This is an error message
CRITICAL:root:This is a critical error message

$ python logging_level_example.py info
```

```
INFO:root:This is an info message
WARNING:root:This is a warning message
ERROR:root:This is an error message
CRITICAL:root:This is a critical error message
```

15.6.2 Logging in Libraries

Developers of libraries, rather than applications, should also use `logging`. For them, there is even less work to do. Simply create a logger instance for each context, using an appropriate name, and then log messages using the stanard levels. As long as a library uses the logging API with consistent naming and level selections, the application can be configured to show or hide messages from the library, as desired.

Naming Logger Instances

All of the previous log messages all have 'root' embedded in them. The `logging` module supports a hierarchy of loggers with different names. An easy way to tell where a specific log message comes from is to use a separate logger object for each module. Every new logger inherits the configuration of its parent, and log messages sent to a logger include the name of that logger. Optionally, each logger can be configured differently, so that messages from different modules are handled in different ways. Below is an example of how to log from different modules so it is easy to trace the source of the message:

```python
import logging

logging.basicConfig(level=logging.WARNING)

logger1 = logging.getLogger('package1.module1')
logger2 = logging.getLogger('package2.module2')

logger1.warning('This message comes from one module')
logger2.warning('And this message comes from another module')
```

And the output:

```
$ python logging_modules_example.py

WARNING:package1.module1:This message comes from one module
WARNING:package2.module2:And this message comes from another module
```

There are many, many, more options for configuring logging, including different log message formatting options, having messages delivered to multiple destinations, and changing the configuration of a long-running application on the fly using a socket interface. All of these options are covered in depth in the library module documentation.

See also:

logging **(http://docs.python.org/library/logging.html)** The standard library documentation for this module.

15.7 getpass – Prompt the user for a password without echoing.

Purpose Prompt the user for a value, usually a password, without echoing what they type to the console.

Available In 1.5.2

Many programs that interact with the user via the terminal need to ask the user for password values without showing what the user types on the screen. The `getpass` module provides a portable way to handle such password prompts securely.

15.7.1 Example

The `getpass()` function prints a prompt then reads input from the user until they press return. The input is passed back as a string to the caller.

```
import getpass

p = getpass.getpass()
print 'You entered:', p
```

The default prompt, if none is specified by the caller, is “`Password:`”.

```
$ python getpass_defaults.py
Password:
You entered: sekret
```

The prompt can be changed to any value your program needs.

```
import getpass

p = getpass.getpass(prompt='What is your favorite color? ')
if p.lower() == 'blue':
    print 'Right.  Off you go.'
else:
    print 'Auuuuugh!'
```

I don’t recommend such an insecure authentication scheme, but it illustrates the point.

```
$ python getpass_prompt.py
What is your favorite color?
Right.  Off you go.
$ python getpass_prompt.py
What is your favorite color?
Auuuuugh!
```

By default, `getpass()` uses stdout to print the prompt string. For a program which may produce useful output on *sys.stdout*, it is frequently better to send the prompt to another stream such as *sys.stderr*.

```
import getpass
import sys

p = getpass.getpass(stream=sys.stderr)
print 'You entered:', p
```

This way standard output can be redirected (to a pipe or file) without seeing the password prompt. The value entered by the user is still not echoed back to the screen.

```
$ python getpass_stream.py >/dev/null
Password:
```

15.7.2 Using getpass Without a Terminal

Under Unix, `getpass()` always requires a tty it can control via termios, so echo can be disabled. This means values will not be read from a non-terminal stream redirected to standard input.

```
$ echo "sekret" | python getpass_defaults.py
Traceback (most recent call last):
 File "getpass_defaults.py", line 34, in
```

```
   p = getpass.getpass()
 File "/Library/Frameworks/Python.framework/Versions/2.5/lib/python2.5/getpass.py", line 32, in unix_
   old = termios.tcgetattr(fd)     # a copy to save
termios.error: (25, 'Inappropriate ioctl for device')
```

It is up to the caller to detect when the input stream is not a tty and use an alternate method for reading in that case.

```
import getpass
import sys

if sys.stdin.isatty():
    p = getpass.getpass('Using getpass: ')
else:
    print 'Using readline'
    p = sys.stdin.readline().rstrip()

print 'Read: ', p
```

With a tty:

```
$ python ./getpass_noterminal.py
Using getpass:
Read:  sekret
```

Without a tty:

```
$ echo "sekret" | python ./getpass_noterminal.py
Using readline
Read:  sekret
```

See also:

getpass **(http://docs.python.org/library/getpass.html)** The standard library documentation for this module.

readline Interactive prompt library.

15.8 platform – Access system version information

Purpose Probe the underlying platform's hardware, operating system, and interpreter version information.

Available In 2.3 and later

Although Python is often used as a cross-platform language, it is occasionally necessary to know what sort of system a program is running on. Build tools need that information, but an application might also know that some of the libraries or external commands it uses have different interfaces on different operating systems. For example, a tool to manage the network configuration of an operating system can define a portable representation of network interfaces, aliases, IP addresses, etc. But once it actually needs to edit the configuration files, it must know more about the host so it can use the correct operating system configuration commands and files. The `platform` module includes the tools for learning about the interpreter, operating system, and hardware platform where a program is running.

Note: The example output below was generated on a MacBook Pro3,1 running OS X 10.6.4, a VMware Fusion VM running CentOS 5.5, and a Dell PC running Microsoft Windows 2008. Python was installed on the OS X and Windows systems using the pre-compiled installer from python.org. The Linux system is running an interpreter built from source locally.

15.8.1 Interpreter

There are four functions for getting information about the current Python interpreter. `python_version()` and `python_version_tuple()` return different forms of the interpreter version with major, minor, and patchlevel components. `python_compiler()` reports on the compiler used to build the interpreter. And `python_build()` gives a version string for the build of the interpreter.

```
import platform

print 'Version      :', platform.python_version()
print 'Version tuple:', platform.python_version_tuple()
print 'Compiler     :', platform.python_compiler()
print 'Build        :', platform.python_build()
```

OS X:

```
$ python platform_python.py

Version      : 2.7.2
Version tuple: ('2', '7', '2')
Compiler     : GCC 4.2.1 (Apple Inc. build 5666) (dot 3)
Build        : ('v2.7.2:8527427914a2', 'Jun 11 2011 15:22:34')
```

Linux:

```
$ python platform_python.py
Version      : 2.7.0
Version tuple: ('2', '7', '0')
Compiler     : GCC 4.1.2 20080704 (Red Hat 4.1.2-46)
Build        : ('r27', 'Aug 20 2010 11:37:51')
```

Windows:

```
C:> python.exe platform_python.py
Version      : 2.7.0
Version tuple: ['2', '7', '0']
Compiler     : MSC v.1500 64 bit (AMD64)
Build        : ('r27:82525', 'Jul  4 2010 07:43:08')
```

15.8.2 Platform

`platform()` returns string containing a general purpose platform identifier. The function accepts two optional boolean arguments. If *aliased* is True, the names in the return value are converted from a formal name to their more common form. When *terse* is true, returns a minimal value with some parts dropped.

```
import platform

print 'Normal :', platform.platform()
print 'Aliased:', platform.platform(aliased=True)
print 'Terse  :', platform.platform(terse=True)
```

OS X:

```
$ python platform_platform.py

Normal : Darwin-11.4.2-x86_64-i386-64bit
Aliased: Darwin-11.4.2-x86_64-i386-64bit
Terse  : Darwin-11.4.2
```

Linux:

```
$ python platform_platform.py
Normal : Linux-2.6.18-194.3.1.el5-i686-with-redhat-5.5-Final
Aliased: Linux-2.6.18-194.3.1.el5-i686-with-redhat-5.5-Final
Terse  : Linux-2.6.18-194.3.1.el5-i686-with-glibc2.3
```

Windows:

```
C:> python.exe platform_platform.py
Normal : Windows-2008ServerR2-6.1.7600
Aliased: Windows-2008ServerR2-6.1.7600
Terse  : Windows-2008ServerR2
```

15.8.3 Operating System and Hardware Info

More detailed information about the operating system and hardware the interpreter is running under can be retrieved as well. `uname()` returns a tuple containing the system, node, release, version, machine, and processor values. Individual values can be accessed through functions of the same names:

`system()` returns the operating system name

`node()` returns the hostname of the server, not fully qualified

`release()` returns the operating system release number

`version()` returns the more detailed system version

`machine()` gives a hardware-type identifier such as `'i386'`

`processor()` returns a real identifier for the processor, or the same value as machine() in many cases

```
import platform

print 'uname:', platform.uname()

print
print 'system   :', platform.system()
print 'node     :', platform.node()
print 'release  :', platform.release()
print 'version  :', platform.version()
print 'machine  :', platform.machine()
print 'processor:', platform.processor()
```

OS X:

```
$ python platform_os_info.py

uname: ('Darwin', 'hubert.local', '11.4.2', 'Darwin Kernel Version 11.4.2: Thu Aug 23 16:25:48 PDT 2

system   : Darwin
node     : hubert.local
release  : 11.4.2
version  : Darwin Kernel Version 11.4.2: Thu Aug 23 16:25:48 PDT 2012; root:xnu-1699.32.7~1/RELEASE_
machine  : x86_64
processor: i386
```

Linux:

```
$ python platform_os_info.py
uname: ('Linux', 'hermes.hellfly.net', '2.6.18-194.3.1.el5',
'#1 SMP Thu May 13 13:09:10 EDT 2010', 'i686', 'i686')

system   : Linux
node     : hermes.hellfly.net
release  : 2.6.18-194.3.1.el5
version  : #1 SMP Thu May 13 13:09:10 EDT 2010
machine  : i686
processor: i686
```

Windows:

```
C:> python.exe platform_os_info.py
uname: ('Windows', 'dhellmann', '2008ServerR2', '6.1.7600', 'AMD64',
'Intel64 Family 6 Model 15 Stepping 11, GenuineIntel')

system   : Windows
node     : dhellmann
release  : 2008ServerR2
version  : 6.1.7600
machine  : AMD64
processor: Intel64 Family 6 Model 15 Stepping 11, GenuineIntel
```

15.8.4 Executable Architecture

Individual program architecture information can be probed using the `architecture()` function. The first argument is the path to an executable program (defaulting to `sys.executable`, the Python interpreter). The return value is a tuple containing the bit architecture and the linkage format used.

```
import platform

print 'interpreter:', platform.architecture()
print '/bin/ls    :', platform.architecture('/bin/ls')
```

OS X:

```
$ python platform_architecture.py

interpreter: ('64bit', '')
/bin/ls    : ('64bit', '')
```

Linux:

```
$ python platform_architecture.py
interpreter: ('32bit', 'ELF')
/bin/ls    : ('32bit', 'ELF')
```

Windows:

```
C:> python.exe platform_architecture.py
interpreter  : ('64bit', 'WindowsPE')
iexplore.exe : ('64bit', '')
```

See also:

platform **(http://docs.python.org/lib/module-platform.html)** Standard library documentation for this module.

CHAPTER

SIXTEEN

OPTIONAL OPERATING SYSTEM SERVICES

16.1 threading – Manage concurrent threads

Purpose Builds on the `thread` module to more easily manage several threads of execution.

Available In 1.5.2 and later

The `threading` module builds on the low-level features of `thread` to make working with threads even easier and more *pythonic*. Using threads allows a program to run multiple operations concurrently in the same process space.

16.1.1 Thread Objects

The simplest way to use a `Thread` is to instantiate it with a target function and call `start()` to let it begin working.

```
import threading

def worker():
    """thread worker function"""
    print 'Worker'
    return

threads = []
for i in range(5):
    t = threading.Thread(target=worker)
    threads.append(t)
    t.start()
```

The output is five lines with `"Worker"` on each:

```
$ python threading_simple.py

Worker
Worker
Worker
Worker
Worker
```

It useful to be able to spawn a thread and pass it arguments to tell it what work to do. This example passes a number, which the thread then prints.

```
import threading

def worker(num):
    """thread worker function"""
    print 'Worker: %s' % num
    return

threads = []
for i in range(5):
    t = threading.Thread(target=worker, args=(i,))
    threads.append(t)
    t.start()
```

The integer argument is now included in the message printed by each thread:

```
    $ python -u threading_simpleargs.py

Worker: 0
Worker: 1
Worker: 2
Worker: 3
Worker: 4
```

16.1.2 Determining the Current Thread

Using arguments to identify or name the thread is cumbersome, and unnecessary. Each `Thread` instance has a name with a default value that can be changed as the thread is created. Naming threads is useful in server processes with multiple service threads handling different operations.

```
import threading
import time

def worker():
    print threading.currentThread().getName(), 'Starting'
    time.sleep(2)
    print threading.currentThread().getName(), 'Exiting'

def my_service():
    print threading.currentThread().getName(), 'Starting'
    time.sleep(3)
    print threading.currentThread().getName(), 'Exiting'

t = threading.Thread(name='my_service', target=my_service)
w = threading.Thread(name='worker', target=worker)
w2 = threading.Thread(target=worker) # use default name

w.start()
w2.start()
t.start()
```

The debug output includes the name of the current thread on each line. The lines with `"Thread-1"` in the thread name column correspond to the unnamed thread `w2`.

```
$ python -u threading_names.py

worker Thread-1 Starting
my_service Starting
Starting
Thread-1worker Exiting
 Exiting
my_service Exiting
```

Most programs do not use **print** to debug. The `logging` module supports embedding the thread name in every log message using the formatter code `%(threadName)s`. Including thread names in log messages makes it easier to trace those messages back to their source.

```
import logging
import threading
import time

logging.basicConfig(level=logging.DEBUG,
                    format='[%(levelname)s] (%(threadName)-10s) %(message)s',
                    )

def worker():
    logging.debug('Starting')
    time.sleep(2)
    logging.debug('Exiting')

def my_service():
    logging.debug('Starting')
    time.sleep(3)
    logging.debug('Exiting')

t = threading.Thread(name='my_service', target=my_service)
w = threading.Thread(name='worker', target=worker)
w2 = threading.Thread(target=worker) # use default name

w.start()
w2.start()
t.start()
```

`logging` is also thread-safe, so messages from different threads are kept distinct in the output.

```
$ python threading_names_log.py

[DEBUG] (worker    ) Starting
[DEBUG] (Thread-1  ) Starting
[DEBUG] (my_service) Starting
[DEBUG] (worker    ) Exiting
[DEBUG] (Thread-1  ) Exiting
[DEBUG] (my_service) Exiting
```

16.1.3 Daemon vs. Non-Daemon Threads

Up to this point, the example programs have implicitly waited to exit until all threads have completed their work. Sometimes programs spawn a thread as a *daemon* that runs without blocking the main program from exiting. Using daemon threads is useful for services where there may not be an easy way to interrupt the thread or where letting the thread die in the middle of its work does not lose or corrupt data (for example, a thread that generates "heart beats" for a service monitoring tool). To mark a thread as a daemon, call its `setDaemon()` method with a boolean argument. The default is for threads to not be daemons, so passing True turns the daemon mode on.

```
import threading
import time
import logging

logging.basicConfig(level=logging.DEBUG,
                    format='(%(threadName)-10s) %(message)s',
                    )
```

```
def daemon():
    logging.debug('Starting')
    time.sleep(2)
    logging.debug('Exiting')

d = threading.Thread(name='daemon', target=daemon)
d.setDaemon(True)

def non_daemon():
    logging.debug('Starting')
    logging.debug('Exiting')

t = threading.Thread(name='non-daemon', target=non_daemon)

d.start()
t.start()
```

Notice that the output does not include the "`Exiting`" message from the daemon thread, since all of the non-daemon threads (including the main thread) exit before the daemon thread wakes up from its two second sleep.

```
$ python threading_daemon.py

(daemon    ) Starting
(non-daemon) Starting
(non-daemon) Exiting
```

To wait until a daemon thread has completed its work, use the `join()` method.

```
import threading
import time
import logging

logging.basicConfig(level=logging.DEBUG,
                    format='(%(threadName)-10s) %(message)s',
                    )

def daemon():
    logging.debug('Starting')
    time.sleep(2)
    logging.debug('Exiting')

d = threading.Thread(name='daemon', target=daemon)
d.setDaemon(True)

def non_daemon():
    logging.debug('Starting')
    logging.debug('Exiting')

t = threading.Thread(name='non-daemon', target=non_daemon)

d.start()
t.start()

d.join()
t.join()
```

Waiting for the daemon thread to exit using `join()` means it has a chance to produce its "`Exiting`" message.

```
$ python threading_daemon_join.py

(daemon    ) Starting
(non-daemon) Starting
(non-daemon) Exiting
(daemon    ) Exiting
```

By default, `join()` blocks indefinitely. It is also possible to pass a timeout argument (a float representing the number of seconds to wait for the thread to become inactive). If the thread does not complete within the timeout period, `join()` returns anyway.

```
import threading
import time
import logging

logging.basicConfig(level=logging.DEBUG,
                    format='(%(threadName)-10s) %(message)s',
                    )

def daemon():
    logging.debug('Starting')
    time.sleep(2)
    logging.debug('Exiting')

d = threading.Thread(name='daemon', target=daemon)
d.setDaemon(True)

def non_daemon():
    logging.debug('Starting')
    logging.debug('Exiting')

t = threading.Thread(name='non-daemon', target=non_daemon)

d.start()
t.start()

d.join(1)
print 'd.isAlive()', d.isAlive()
t.join()
```

Since the timeout passed is less than the amount of time the daemon thread sleeps, the thread is still "alive" after `join()` returns.

```
$ python threading_daemon_join_timeout.py

(daemon    ) Starting
(non-daemon) Starting
(non-daemon) Exiting
d.isAlive() True
```

16.1.4 Enumerating All Threads

It is not necessary to retain an explicit handle to all of the daemon threads in order to ensure they have completed before exiting the main process. `enumerate()` returns a list of active `Thread` instances. The list includes the current thread, and since joining the current thread is not allowed (it introduces a deadlock situation), it must be skipped.

```
import random
import threading
import time
import logging

logging.basicConfig(level=logging.DEBUG,
                    format='(%(threadName)-10s) %(message)s',
                    )

def worker():
    """thread worker function"""
    t = threading.currentThread()
    pause = random.randint(1,5)
    logging.debug('sleeping %s', pause)
    time.sleep(pause)
    logging.debug('ending')
    return

for i in range(3):
    t = threading.Thread(target=worker)
    t.setDaemon(True)
    t.start()

main_thread = threading.currentThread()
for t in threading.enumerate():
    if t is main_thread:
        continue
    logging.debug('joining %s', t.getName())
    t.join()
```

Since the worker is sleeping for a random amount of time, the output from this program may vary. It should look something like this:

```
$ python threading_enumerate.py

(Thread-1  ) sleeping 3
(Thread-2  ) sleeping 2
(Thread-3  ) sleeping 5
(MainThread) joining Thread-1
(Thread-2  ) ending
(Thread-1  ) ending
(MainThread) joining Thread-3
(Thread-3  ) ending
(MainThread) joining Thread-2
```

16.1.5 Subclassing Thread

At start-up, a `Thread` does some basic initialization and then calls its `run()` method, which calls the target function passed to the constructor. To create a subclass of `Thread`, override `run()` to do whatever is necessary.

```
import threading
import logging

logging.basicConfig(level=logging.DEBUG,
                    format='(%(threadName)-10s) %(message)s',
                    )
```

```
class MyThread(threading.Thread):

    def run(self):
        logging.debug('running')
        return

for i in range(5):
    t = MyThread()
    t.start()
```

The return value of `run()` is ignored.

```
$ python threading_subclass.py

(Thread-1  ) running
(Thread-2  ) running
(Thread-3  ) running
(Thread-4  ) running
(Thread-5  ) running
```

Because the *args* and *kwargs* values passed to the `Thread` constructor are saved in private variables, they are not easily accessed from a subclass. To pass arguments to a custom thread type, redefine the constructor to save the values in an instance attribute that can be seen in the subclass.

```
import threading
import logging

logging.basicConfig(level=logging.DEBUG,
                    format='(%(threadName)-10s) %(message)s',
                    )

class MyThreadWithArgs(threading.Thread):

    def __init__(self, group=None, target=None, name=None,
                 args=(), kwargs=None, verbose=None):
        threading.Thread.__init__(self, group=group, target=target, name=name,
                                  verbose=verbose)
        self.args = args
        self.kwargs = kwargs
        return

    def run(self):
        logging.debug('running with %s and %s', self.args, self.kwargs)
        return

for i in range(5):
    t = MyThreadWithArgs(args=(i,), kwargs={'a':'A', 'b':'B'})
    t.start()
```

`MyThreadWithArgs` uses the same API as `Thread`, but another class could easily change the constructor method to take more or different arguments more directly related to the purpose of the thread, as with any other class.

```
$ python threading_subclass_args.py

(Thread-1  ) running with (0,) and {'a': 'A', 'b': 'B'}
(Thread-2  ) running with (1,) and {'a': 'A', 'b': 'B'}
(Thread-3  ) running with (2,) and {'a': 'A', 'b': 'B'}
(Thread-4  ) running with (3,) and {'a': 'A', 'b': 'B'}
(Thread-5  ) running with (4,) and {'a': 'A', 'b': 'B'}
```

16.1.6 Timer Threads

One example of a reason to subclass `Thread` is provided by `Timer`, also included in `threading`. A `Timer` starts its work after a delay, and can be canceled at any point within that delay time period.

```
import threading
import time
import logging

logging.basicConfig(level=logging.DEBUG,
                    format='(%(threadName)-10s) %(message)s',
                    )

def delayed():
    logging.debug('worker running')
    return

t1 = threading.Timer(3, delayed)
t1.setName('t1')
t2 = threading.Timer(3, delayed)
t2.setName('t2')

logging.debug('starting timers')
t1.start()
t2.start()

logging.debug('waiting before canceling %s', t2.getName())
time.sleep(2)
logging.debug('canceling %s', t2.getName())
t2.cancel()
logging.debug('done')
```

Notice that the second timer is never run, and the first timer appears to run after the rest of the main program is done. Since it is not a daemon thread, it is joined implicitly when the main thread is done.

```
$ python threading_timer.py

(MainThread) starting timers
(MainThread) waiting before canceling t2
(MainThread) canceling t2
(MainThread) done
(t1        ) worker running
```

16.1.7 Signaling Between Threads

Although the point of using multiple threads is to spin separate operations off to run concurrently, there are times when it is important to be able to synchronize the operations in two or more threads. A simple way to communicate between threads is using `Event` objects. An `Event` manages an internal flag that callers can either `set()` or `clear()`. Other threads can `wait()` for the flag to be `set()`, effectively blocking progress until allowed to continue.

```
import logging
import threading
import time

logging.basicConfig(level=logging.DEBUG,
                    format='(%(threadName)-10s) %(message)s',
                    )
```

```
def wait_for_event(e):
    """Wait for the event to be set before doing anything"""
    logging.debug('wait_for_event starting')
    event_is_set = e.wait()
    logging.debug('event set: %s', event_is_set)

def wait_for_event_timeout(e, t):
    """Wait t seconds and then timeout"""
    while not e.isSet():
        logging.debug('wait_for_event_timeout starting')
        event_is_set = e.wait(t)
        logging.debug('event set: %s', event_is_set)
        if event_is_set:
            logging.debug('processing event')
        else:
            logging.debug('doing other work')


e = threading.Event()
t1 = threading.Thread(name='block',
                      target=wait_for_event,
                      args=(e,))
t1.start()

t2 = threading.Thread(name='non-block',
                      target=wait_for_event_timeout,
                      args=(e, 2))
t2.start()

logging.debug('Waiting before calling Event.set()')
time.sleep(3)
e.set()
logging.debug('Event is set')
```

The `wait()` method takes an argument representing the number of seconds to wait for the event before timing out. It returns a boolean indicating whether or not the event is set, so the caller knows why `wait()` returned. The `isSet()` method can be used separately on the event without fear of blocking.

In this example, `wait_for_event_timeout()` checks the event status without blocking indefinitely. The `wait_for_event()` blocks on the call to `wait()`, which does not return until the event status changes.

```
$ python threading_event.py

(block     ) wait_for_event starting
(non-block ) wait_for_event_timeout starting
(MainThread) Waiting before calling Event.set()
(non-block ) event set: False
(non-block ) doing other work
(non-block ) wait_for_event_timeout starting
(MainThread) Event is set
(block     ) event set: True
(non-block ) event set: True
(non-block ) processing event
```

16.1.8 Controlling Access to Resources

In addition to synchronizing the operations of threads, it is also important to be able to control access to shared resources to prevent corruption or missed data. Python's built-in data structures (lists, dictionaries, etc.) are thread-safe as a side-effect of having atomic byte-codes for manipulating them (the GIL is not released in the middle of an update). Other data structures implemented in Python, or simpler types like integers and floats, don't have that protection. To guard against simultaneous access to an object, use a `Lock` object.

```
import logging
import random
import threading
import time

logging.basicConfig(level=logging.DEBUG,
                    format='(%(threadName)-10s) %(message)s',
                    )

class Counter(object):
    def __init__(self, start=0):
        self.lock = threading.Lock()
        self.value = start
    def increment(self):
        logging.debug('Waiting for lock')
        self.lock.acquire()
        try:
            logging.debug('Acquired lock')
            self.value = self.value + 1
        finally:
            self.lock.release()

def worker(c):
    for i in range(2):
        pause = random.random()
        logging.debug('Sleeping %0.02f', pause)
        time.sleep(pause)
        c.increment()
    logging.debug('Done')

counter = Counter()
for i in range(2):
    t = threading.Thread(target=worker, args=(counter,))
    t.start()

logging.debug('Waiting for worker threads')
main_thread = threading.currentThread()
for t in threading.enumerate():
    if t is not main_thread:
        t.join()
logging.debug('Counter: %d', counter.value)
```

In this example, the `worker()` function increments a `Counter` instance, which manages a `Lock` to prevent two threads from changing its internal state at the same time. If the `Lock` was not used, there is a possibility of missing a change to the value attribute.

```
$ python threading_lock.py

(Thread-1  ) Sleeping 0.47
(Thread-2  ) Sleeping 0.65
```

```
(MainThread) Waiting for worker threads
(Thread-1  ) Waiting for lock
(Thread-1  ) Acquired lock
(Thread-1  ) Sleeping 0.90
(Thread-2  ) Waiting for lock
(Thread-2  ) Acquired lock
(Thread-2  ) Sleeping 0.11
(Thread-2  ) Waiting for lock
(Thread-2  ) Acquired lock
(Thread-2  ) Done
(Thread-1  ) Waiting for lock
(Thread-1  ) Acquired lock
(Thread-1  ) Done
(MainThread) Counter: 4
```

To find out whether another thread has acquired the lock without holding up the current thread, pass False for the *blocking* argument to `acquire()`. In the next example, `worker()` tries to acquire the lock three separate times, and counts how many attempts it has to make to do so. In the mean time, `lock_holder()` cycles between holding and releasing the lock, with short pauses in each state used to simulate load.

```python
import logging
import threading
import time

logging.basicConfig(level=logging.DEBUG,
                    format='(%(threadName)-10s) %(message)s',
                    )

def lock_holder(lock):
    logging.debug('Starting')
    while True:
        lock.acquire()
        try:
            logging.debug('Holding')
            time.sleep(0.5)
        finally:
            logging.debug('Not holding')
            lock.release()
        time.sleep(0.5)
    return

def worker(lock):
    logging.debug('Starting')
    num_tries = 0
    num_acquires = 0
    while num_acquires < 3:
        time.sleep(0.5)
        logging.debug('Trying to acquire')
        have_it = lock.acquire(0)
        try:
            num_tries += 1
            if have_it:
                logging.debug('Iteration %d: Acquired',  num_tries)
                num_acquires += 1
            else:
                logging.debug('Iteration %d: Not acquired', num_tries)
        finally:
            if have_it:
                lock.release()
    logging.debug('Done after %d iterations', num_tries)


lock = threading.Lock()

holder = threading.Thread(target=lock_holder, args=(lock,), name='LockHolder')
holder.setDaemon(True)
holder.start()

worker = threading.Thread(target=worker, args=(lock,), name='Worker')
worker.start()
```

It takes `worker()` more than three iterations to acquire the lock three separate times.

```
$ python threading_lock_noblock.py

(LockHolder) Starting
(LockHolder) Holding
(Worker    ) Starting
(LockHolder) Not holding
(Worker    ) Trying to acquire
(Worker    ) Iteration 1: Acquired
(Worker    ) Trying to acquire
(LockHolder) Holding
(Worker    ) Iteration 2: Not acquired
(LockHolder) Not holding
(Worker    ) Trying to acquire
(Worker    ) Iteration 3: Acquired
(LockHolder) Holding
(Worker    ) Trying to acquire
(Worker    ) Iteration 4: Not acquired
(LockHolder) Not holding
(Worker    ) Trying to acquire
(Worker    ) Iteration 5: Acquired
(Worker    ) Done after 5 iterations
```

Re-entrant Locks

Normal `Lock` objects cannot be acquired more than once, even by the same thread. This can introduce undesirable side-effects if a lock is accessed by more than one function in the same call chain.

```
import threading

lock = threading.Lock()

print 'First try :', lock.acquire()
print 'Second try:', lock.acquire(0)
```

In this case, since both functions are using the same global lock, and one calls the other, the second acquisition fails and would have blocked using the default arguments to `acquire()`.

```
$ python threading_lock_reacquire.py

First try : True
Second try: False
```

In a situation where separate code from the same thread needs to "re-acquire" the lock, use an `RLock` instead.

```
import threading

lock = threading.RLock()

print 'First try :', lock.acquire()
print 'Second try:', lock.acquire(0)
```

The only change to the code from the previous example was substituting `RLock` for `Lock`.

```
$ python threading_rlock.py

First try : True
Second try: 1
```

Locks as Context Managers

Locks implement the context manager API and are compatible with the **with** statement. Using **with** removes the need to explicitly acquire and release the lock.

```
import threading
import logging

logging.basicConfig(level=logging.DEBUG,
                    format='(%(threadName)-10s) %(message)s',
                    )

def worker_with(lock):
    with lock:
        logging.debug('Lock acquired via with')

def worker_no_with(lock):
    lock.acquire()
    try:
        logging.debug('Lock acquired directly')
    finally:
        lock.release()

lock = threading.Lock()
w = threading.Thread(target=worker_with, args=(lock,))
nw = threading.Thread(target=worker_no_with, args=(lock,))

w.start()
nw.start()
```

The two functions `worker_with()` and `worker_no_with()` manage the lock in equivalent ways.

```
$ python threading_lock_with.py

(Thread-1  ) Lock acquired via with
(Thread-2  ) Lock acquired directly
```

16.1.9 Synchronizing Threads

In addition to using `Events`, another way of synchronizing threads is through using a `Condition` object. Because the `Condition` uses a `Lock`, it can be tied to a shared resource. This allows threads to wait for the resource to be updated. In this example, the `consumer()` threads `wait()` for the `Condition` to be set before continuing. The `producer()` thread is responsible for setting the condition and notifying the other threads that they can continue.

```
import logging
import threading
import time

logging.basicConfig(level=logging.DEBUG,
                    format='%(asctime)s (%(threadName)-2s) %(message)s',
                    )

def consumer(cond):
    """wait for the condition and use the resource"""
    logging.debug('Starting consumer thread')
    t = threading.currentThread()
    with cond:
        cond.wait()
        logging.debug('Resource is available to consumer')

def producer(cond):
    """set up the resource to be used by the consumer"""
    logging.debug('Starting producer thread')
    with cond:
        logging.debug('Making resource available')
        cond.notifyAll()

condition = threading.Condition()
c1 = threading.Thread(name='c1', target=consumer, args=(condition,))
c2 = threading.Thread(name='c2', target=consumer, args=(condition,))
p = threading.Thread(name='p', target=producer, args=(condition,))

c1.start()
time.sleep(2)
c2.start()
time.sleep(2)
p.start()
```

The threads use **with** to acquire the lock associated with the `Condition`. Using the `acquire()` and `release()` methods explicitly also works.

```
$ python threading_condition.py

2013-02-21 06:37:49,549 (c1) Starting consumer thread
2013-02-21 06:37:51,550 (c2) Starting consumer thread
2013-02-21 06:37:53,551 (p ) Starting producer thread
2013-02-21 06:37:53,552 (p ) Making resource available
2013-02-21 06:37:53,552 (c2) Resource is available to consumer
2013-02-21 06:37:53,553 (c1) Resource is available to consumer
```

16.1.10 Limiting Concurrent Access to Resources

Sometimes it is useful to allow more than one worker access to a resource at a time, while still limiting the overall number. For example, a connection pool might support a fixed number of simultaneous connections, or a network application might support a fixed number of concurrent downloads. A `Semaphore` is one way to manage those connections.

```
import logging
import random
import threading
import time

logging.basicConfig(level=logging.DEBUG,
                    format='%(asctime)s (%(threadName)-2s) %(message)s',
                    )

class ActivePool(object):
    def __init__(self):
        super(ActivePool, self).__init__()
        self.active = []
        self.lock = threading.Lock()
    def makeActive(self, name):
        with self.lock:
            self.active.append(name)
            logging.debug('Running: %s', self.active)
    def makeInactive(self, name):
        with self.lock:
            self.active.remove(name)
            logging.debug('Running: %s', self.active)

def worker(s, pool):
    logging.debug('Waiting to join the pool')
    with s:
        name = threading.currentThread().getName()
        pool.makeActive(name)
        time.sleep(0.1)
        pool.makeInactive(name)

pool = ActivePool()
s = threading.Semaphore(2)
for i in range(4):
    t = threading.Thread(target=worker, name=str(i), args=(s, pool))
    t.start()
```

In this example, the `ActivePool` class simply serves as a convenient way to track which threads are able to run at a given moment. A real resource pool would allocate a connection or some other value to the newly active thread, and reclaim the value when the thread is done. Here it is just used to hold the names of the active threads to show that only five are running concurrently.

```
$ python threading_semaphore.py

2013-02-21 06:37:53,629 (0 ) Waiting to join the pool
2013-02-21 06:37:53,629 (1 ) Waiting to join the pool
2013-02-21 06:37:53,629 (0 ) Running: ['0']
2013-02-21 06:37:53,629 (2 ) Waiting to join the pool
2013-02-21 06:37:53,630 (3 ) Waiting to join the pool
2013-02-21 06:37:53,630 (1 ) Running: ['0', '1']
2013-02-21 06:37:53,730 (0 ) Running: ['1']
2013-02-21 06:37:53,731 (2 ) Running: ['1', '2']
2013-02-21 06:37:53,731 (1 ) Running: ['2']
2013-02-21 06:37:53,732 (3 ) Running: ['2', '3']
2013-02-21 06:37:53,831 (2 ) Running: ['3']
2013-02-21 06:37:53,833 (3 ) Running: []
```

16.1.11 Thread-specific Data

While some resources need to be locked so multiple threads can use them, others need to be protected so that they are hidden from view in threads that do not “own” them. The `local()` function creates an object capable of hiding values from view in separate threads.

```
import random
import threading
import logging

logging.basicConfig(level=logging.DEBUG,
                    format='(%(threadName)-10s) %(message)s',
                    )

def show_value(data):
    try:
        val = data.value
    except AttributeError:
        logging.debug('No value yet')
    else:
        logging.debug('value=%s', val)


def worker(data):
    show_value(data)
    data.value = random.randint(1, 100)
    show_value(data)

local_data = threading.local()
show_value(local_data)
local_data.value = 1000
show_value(local_data)

for i in range(2):
    t = threading.Thread(target=worker, args=(local_data,))
    t.start()
```

Notice that `local_data.value` is not present for any thread until it is set in that thread.

```
$ python threading_local.py

(MainThread) No value yet
(MainThread) value=1000
(Thread-1  ) No value yet
(Thread-1  ) value=34
(Thread-2  ) No value yet
(Thread-2  ) value=7
```

To initialize the settings so all threads start with the same value, use a subclass and set the attributes in `__init__()`.

```
import random
import threading
import logging

logging.basicConfig(level=logging.DEBUG,
                    format='(%(threadName)-10s) %(message)s',
                    )
```

```
def show_value(data):
    try:
        val = data.value
    except AttributeError:
        logging.debug('No value yet')
    else:
        logging.debug('value=%s', val)

def worker(data):
    show_value(data)
    data.value = random.randint(1, 100)
    show_value(data)

class MyLocal(threading.local):
    def __init__(self, value):
        logging.debug('Initializing %r', self)
        self.value = value

local_data = MyLocal(1000)
show_value(local_data)

for i in range(2):
    t = threading.Thread(target=worker, args=(local_data,))
    t.start()
```

`__init__()` is invoked on the same object (note the `id()` value), once in each thread.

```
$ python threading_local_defaults.py

(MainThread) Initializing <__main__.MyLocal object at 0x100514390>
(MainThread) value=1000
(Thread-1  ) Initializing <__main__.MyLocal object at 0x100514390>
(Thread-1  ) value=1000
(Thread-2  ) Initializing <__main__.MyLocal object at 0x100514390>
(Thread-1  ) value=81
(Thread-2  ) value=1000
(Thread-2  ) value=54
```

See also:

threading (http://docs.python.org/lib/module-threading.html) Standard library documentation for this module.

`thread` Lower level thread API.

`Queue` Thread-safe Queue, useful for passing messages between threads.

`multiprocessing` An API for working with processes that mirrors the `threading` API.

16.2 mmap – Memory-map files

Purpose Memory-map files instead of reading the contents directly.

Available In 2.1 and later

Memory-mapping a file uses the operating system virtual memory system to access the data on the filesystem directly, instead of using normal I/O functions. Memory-mapping typically improves I/O performance because it does not involve a separate system call for each access and it does not require copying data between buffers – the memory is accessed directly.

Memory-mapped files can be treated as mutable strings or file-like objects, depending on your need. A mapped file supports the expected file API methods, such as `close()`, `flush()`, `read()`, `readline()`, `seek()`, `tell()`, and `write()`. It also supports the string API, with features such as slicing and methods like `find()`.

All of the examples use the text file `lorem.txt`, containing a bit of Lorem Ipsum. For reference, the text of the file is:

```
Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Donec
egestas, enim et consectetuer ullamcorper, lectus ligula rutrum leo, a
elementum elit tortor eu quam. Duis tincidunt nisi ut ante. Nulla
facilisi. Sed tristique eros eu libero. Pellentesque vel arcu. Vivamus
purus orci, iaculis ac, suscipit sit amet, pulvinar eu,
lacus. Praesent placerat tortor sed nisl. Nunc blandit diam egestas
dui. Pellentesque habitant morbi tristique senectus et netus et
malesuada fames ac turpis egestas. Aliquam viverra fringilla
leo. Nulla feugiat augue eleifend nulla. Vivamus mauris. Vivamus sed
mauris in nibh placerat egestas. Suspendisse potenti. Mauris massa. Ut
eget velit auctor tortor blandit sollicitudin. Suspendisse imperdiet
justo.
```

Note: There are differences in the arguments and behaviors for `mmap()` between Unix and Windows, which are not discussed below. For more details, refer to the standard library documentation.

16.2.1 Reading

Use the `mmap()` function to create a memory-mapped file. The first argument is a file descriptor, either from the `fileno()` method of a `file` object or from `os.open()`. The caller is responsible for opening the file before invoking `mmap()`, and closing it after it is no longer needed.

The second argument to `mmap()` is a size in bytes for the portion of the file to map. If the value is `0`, the entire file is mapped. If the size is larger than the current size of the file, the file is extended.

Note: You cannot create a zero-length mapping under Windows.

An optional keyword argument, *access*, is supported by both platforms. Use `ACCESS_READ` for read-only access, `ACCESS_WRITE` for write-through (assignments to the memory go directly to the file), or `ACCESS_COPY` for copy-on-write (assignments to memory are not written to the file).

```
import mmap
import contextlib

with open('lorem.txt', 'r') as f:
    with contextlib.closing(mmap.mmap(f.fileno(), 0, access=mmap.ACCESS_READ)) as m:
        print 'First 10 bytes via read :', m.read(10)
        print 'First 10 bytes via slice:', m[:10]
        print '2nd   10 bytes via read :', m.read(10)
```

The file pointer tracks the last byte accessed through a slice operation. In this example, the pointer moves ahead 10 bytes after the first read. It is then reset to the beginning of the file by the slice operation, and moved ahead 10 bytes again by the slice. After the slice operation, calling `read()` again gives the bytes 11-20 in the file.

```
$ python mmap_read.py

First 10 bytes via read : Lorem ipsu
First 10 bytes via slice: Lorem ipsu
2nd   10 bytes via read : m dolor si
```

16.2.2 Writing

To set up the memory mapped file to receive updates, start by opening it for appending with mode `'r+'` (not `'w'`) before mapping it. Then use any of the API method that change the data (`write()`, assignment to a slice, etc.).

Here's an example using the default access mode of `ACCESS_WRITE` and assigning to a slice to modify part of a line in place:

```
import mmap
import shutil
import contextlib

# Copy the example file
shutil.copyfile('lorem.txt', 'lorem_copy.txt')

word = 'consectetuer'
reversed = word[::-1]
print 'Looking for    :', word
print 'Replacing with :', reversed

with open('lorem_copy.txt', 'r+') as f:
    with contextlib.closing(mmap.mmap(f.fileno(), 0)) as m:
        print 'Before:', m.readline().rstrip()
        m.seek(0) # rewind

        loc = m.find(word)
        m[loc:loc+len(word)] = reversed
        m.flush()

        m.seek(0) # rewind
        print 'After :', m.readline().rstrip()
```

The word "consectetuer" is replaced in the middle of the first line:

```
$ python mmap_write_slice.py

Looking for    : consectetuer
Replacing with : reutetcesnoc
Before: Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Donec
After : Lorem ipsum dolor sit amet, reutetcesnoc adipiscing elit. Donec
```

ACCESS_COPY Mode

Using the access setting `ACCESS_COPY` does not write changes to the file on disk.

```
import mmap
import shutil
import contextlib

# Copy the example file
shutil.copyfile('lorem.txt', 'lorem_copy.txt')

word = 'consectetuer'
reversed = word[::-1]

with open('lorem_copy.txt', 'r+') as f:
    with contextlib.closing(mmap.mmap(f.fileno(), 0, access=mmap.ACCESS_COPY)) as m:
        print 'Memory Before:', m.readline().rstrip()
        print 'File Before  :', f.readline().rstrip()
        print

        m.seek(0) # rewind
        loc = m.find(word)
        m[loc:loc+len(word)] = reversed

        m.seek(0) # rewind
        print 'Memory After :', m.readline().rstrip()

        f.seek(0)
        print 'File After   :', f.readline().rstrip()
```

It is necessary to rewind the file handle in this example separately from the mmap handle because the internal state of the two objects is maintained separately.

```
$ python mmap_write_copy.py

Memory Before: Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Donec
File Before  : Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Donec

Memory After : Lorem ipsum dolor sit amet, reutetcesnoc adipiscing elit. Donec
File After   : Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Donec
```

16.2.3 Regular Expressions

Since a memory mapped file can act like a string, it can be used with other modules that operate on strings, such as regular expressions. This example finds all of the sentences with "nulla" in them.

```
import mmap
import re
import contextlib

pattern = re.compile(r'(\.\W+)?([^.]?nulla[^.]*?\.)',
                     re.DOTALL | re.IGNORECASE | re.MULTILINE)

with open('lorem.txt', 'r') as f:
    with contextlib.closing(mmap.mmap(f.fileno(), 0, access=mmap.ACCESS_READ)) as m:
        for match in pattern.findall(m):
            print match[1].replace('\n', ' ')
```

Because the pattern includes two groups, the return value from `findall()` is a sequence of tuples. The **print** statement pulls out the sentence match and replaces newlines with spaces so the result prints on a single line.

```
$ python mmap_regex.py

Nulla facilisi.
Nulla feugiat augue eleifend nulla.
```

See also:

mmap (http://docs.python.org/lib/module-mmap.html) Standard library documentation for this module.

`os` The os module.

`contextlib` Use the `closing()` function to create a context manager for a memory mapped file.

`re` Regular expressions.

16.3 multiprocessing – Manage processes like threads

Purpose Provides an API for managing processes.

Available In 2.6

The multiprocessing module includes a relatively simple API for dividing work up between multiple processes. It is based on the API for threading, and in some cases is a drop-in replacement. Due to the similarity, the first few examples here are modified from the threading examples. Features provided by multiprocessing but not available in threading are covered later.

16.3.1 multiprocessing Basics

The simplest way to spawn a second is to instantiate a Process object with a target function and call start() to let it begin working.

```
import multiprocessing

def worker():
    """worker function"""
    print 'Worker'
    return

if __name__ == '__main__':
    jobs = []
    for i in range(5):
        p = multiprocessing.Process(target=worker)
        jobs.append(p)
        p.start()
```

The output includes the word "Worker" printed five times, although it may not be entirely clean depending on the order of execution.

```
$ python multiprocessing_simple.py

Worker
Worker
Worker
Worker
Worker
```

It usually more useful to be able to spawn a process with arguments to tell it what work to do. Unlike with threading, to pass arguments to a multiprocessing Process the argument must be able to be serialized using pickle. This example passes each worker a number so the output is a little more interesting.

```
import multiprocessing

def worker(num):
    """thread worker function"""
    print 'Worker:', num
    return

if __name__ == '__main__':
    jobs = []
    for i in range(5):
        p = multiprocessing.Process(target=worker, args=(i,))
        jobs.append(p)
        p.start()
```

The integer argument is now included in the message printed by each worker:

```
$ python multiprocessing_simpleargs.py

Worker: 0
Worker: 1
Worker: 2
Worker: 3
Worker: 4
```

Importable Target Functions

One difference between the `threading` and `multiprocessing` examples is the extra protection for `__main__` used in the `multiprocessing` examples. Due to the way the new processes are started, the child process needs to be able to import the script containing the target function. Wrapping the main part of the application in a check for `__main__` ensures that it is not run recursively in each child as the module is imported. Another approach is to import the target function from a separate script.

For example, this main program:

```
import multiprocessing
import multiprocessing_import_worker

if __name__ == '__main__':
    jobs = []
    for i in range(5):
        p = multiprocessing.Process(target=multiprocessing_import_worker.worker)
        jobs.append(p)
        p.start()
```

uses this worker function, defined in a separate module:

```
def worker():
    """worker function"""
    print 'Worker'
    return
```

and produces output like the first example above:

```
$ python multiprocessing_import_main.py

Worker
Worker
Worker
Worker
Worker
```

Determining the Current Process

Passing arguments to identify or name the process is cumbersome, and unnecessary. Each `Process` instance has a name with a default value that can be changed as the process is created. Naming processes is useful for keeping track of them, especially in applications with multiple types of processes running simultaneously.

```
import multiprocessing
import time

def worker():
    name = multiprocessing.current_process().name
    print name, 'Starting'
    time.sleep(2)
    print name, 'Exiting'

def my_service():
    name = multiprocessing.current_process().name
    print name, 'Starting'
    time.sleep(3)
    print name, 'Exiting'

if __name__ == '__main__':
    service = multiprocessing.Process(name='my_service', target=my_service)
    worker_1 = multiprocessing.Process(name='worker 1', target=worker)
    worker_2 = multiprocessing.Process(target=worker) # use default name

    worker_1.start()
    worker_2.start()
    service.start()
```

The debug output includes the name of the current process on each line. The lines with `Process-3` in the name column correspond to the unnamed process `worker_1`.

```
$ python multiprocessing_names.py

worker 1 Starting
worker 1 Exiting
Process-3 Starting
Process-3 Exiting
my_service Starting
my_service Exiting
```

Daemon Processes

By default the main program will not exit until all of the children have exited. There are times when starting a background process that runs without blocking the main program from exiting is useful, such as in services where there may not be an easy way to interrupt the worker, or where letting it die in the middle of its work does not lose or corrupt data (for example, a task that generates "heart beats" for a service monitoring tool).

To mark a process as a daemon, set its `daemon` attribute with a boolean value. The default is for processes to not be daemons, so passing True turns the daemon mode on.

```
import multiprocessing
import time
import sys

def daemon():
    p = multiprocessing.current_process()
    print 'Starting:', p.name, p.pid
    sys.stdout.flush()
    time.sleep(2)
    print 'Exiting :', p.name, p.pid
    sys.stdout.flush()

def non_daemon():
    p = multiprocessing.current_process()
    print 'Starting:', p.name, p.pid
    sys.stdout.flush()
    print 'Exiting :', p.name, p.pid
    sys.stdout.flush()

if __name__ == '__main__':
    d = multiprocessing.Process(name='daemon', target=daemon)
    d.daemon = True

    n = multiprocessing.Process(name='non-daemon', target=non_daemon)
    n.daemon = False

    d.start()
    time.sleep(1)
    n.start()
```

The output does not include the "Exiting" message from the daemon process, since all of the non-daemon processes (including the main program) exit before the daemon process wakes up from its 2 second sleep.

```
$ python multiprocessing_daemon.py

Starting: daemon 13866
Starting: non-daemon 13867
Exiting : non-daemon 13867
```

The daemon process is terminated automatically before the main program exits, to avoid leaving orphaned processes running. You can verify this by looking for the process id value printed when you run the program, and then checking for that process with a command like `ps`.

Waiting for Processes

To wait until a process has completed its work and exited, use the `join()` method.

```
import multiprocessing
import time
import sys

def daemon():
    print 'Starting:', multiprocessing.current_process().name
    time.sleep(2)
    print 'Exiting :', multiprocessing.current_process().name

def non_daemon():
    print 'Starting:', multiprocessing.current_process().name
    print 'Exiting :', multiprocessing.current_process().name

if __name__ == '__main__':
    d = multiprocessing.Process(name='daemon', target=daemon)
    d.daemon = True

    n = multiprocessing.Process(name='non-daemon', target=non_daemon)
    n.daemon = False

    d.start()
    time.sleep(1)
    n.start()

    d.join()
    n.join()
```

Since the main process waits for the daemon to exit using `join()`, the "Exiting" message is printed this time.

```
$ python multiprocessing_daemon_join.py

Starting: non-daemon
Exiting : non-daemon
Starting: daemon
Exiting : daemon
```

By default, `join()` blocks indefinitely. It is also possible to pass a timeout argument (a float representing the number of seconds to wait for the process to become inactive). If the process does not complete within the timeout period, `join()` returns anyway.

```
import multiprocessing
import time
import sys

def daemon():
    print 'Starting:', multiprocessing.current_process().name
    time.sleep(2)
    print 'Exiting :', multiprocessing.current_process().name

def non_daemon():
    print 'Starting:', multiprocessing.current_process().name
    print 'Exiting :', multiprocessing.current_process().name

if __name__ == '__main__':
    d = multiprocessing.Process(name='daemon', target=daemon)
    d.daemon = True

    n = multiprocessing.Process(name='non-daemon', target=non_daemon)
    n.daemon = False

    d.start()
    n.start()

    d.join(1)
    print 'd.is_alive()', d.is_alive()
    n.join()
```

Since the timeout passed is less than the amount of time the daemon sleeps, the process is still "alive" after `join()` returns.

```
$ python multiprocessing_daemon_join_timeout.py

Starting: non-daemon
Exiting : non-daemon
d.is_alive() True
```

Terminating Processes

Although it is better to use the *poison pill* method of signaling to a process that it should exit (see *Passing Messages to Processes*), if a process appears hung or deadlocked it can be useful to be able to kill it forcibly. Calling `terminate()` on a process object kills the child process.

```
import multiprocessing
import time

def slow_worker():
    print 'Starting worker'
    time.sleep(0.1)
    print 'Finished worker'

if __name__ == '__main__':
    p = multiprocessing.Process(target=slow_worker)
    print 'BEFORE:', p, p.is_alive()

    p.start()
    print 'DURING:', p, p.is_alive()

    p.terminate()
    print 'TERMINATED:', p, p.is_alive()

    p.join()
    print 'JOINED:', p, p.is_alive()
```

Note: It is important to `join()` the process after terminating it in order to give the background machinery time to update the status of the object to reflect the termination.

```
$ python multiprocessing_terminate.py

BEFORE: <Process(Process-1, initial)> False
DURING: <Process(Process-1, started)> True
TERMINATED: <Process(Process-1, started)> True
JOINED: <Process(Process-1, stopped[SIGTERM])> False
```

Process Exit Status

The status code produced when the process exits can be accessed via the `exitcode` attribute.

For `exitcode` values

- `== 0` – no error was produced
- `> 0` – the process had an error, and exited with that code
- `< 0` – the process was killed with a signal of `-1 * exitcode`

```
import multiprocessing
import sys
import time

def exit_error():
    sys.exit(1)

def exit_ok():
    return

def return_value():
    return 1

def raises():
    raise RuntimeError('There was an error!')

def terminated():
    time.sleep(3)

if __name__ == '__main__':
    jobs = []
    for f in [exit_error, exit_ok, return_value, raises, terminated]:
        print 'Starting process for', f.func_name
        j = multiprocessing.Process(target=f, name=f.func_name)
        jobs.append(j)
        j.start()

    jobs[-1].terminate()

    for j in jobs:
        j.join()
        print '%s.exitcode = %s' % (j.name, j.exitcode)
```

Processes that raise an exception automatically get an `exitcode` of 1.

```
$ python multiprocessing_exitcode.py

Starting process for exit_error
Starting process for exit_ok
Starting process for return_value
Starting process for raises
Starting process for terminated
Process raises:
Traceback (most recent call last):
  File "/Library/Frameworks/Python.framework/Versions/2.7/lib/python
2.7/multiprocessing/process.py", line 258, in _bootstrap
    self.run()
  File "/Library/Frameworks/Python.framework/Versions/2.7/lib/python
2.7/multiprocessing/process.py", line 114, in run
    self._target(*self._args, **self._kwargs)
  File "multiprocessing_exitcode.py", line 24, in raises
    raise RuntimeError('There was an error!')
RuntimeError: There was an error!
exit_error.exitcode = 1
exit_ok.exitcode = 0
return_value.exitcode = 0
raises.exitcode = 1
terminated.exitcode = -15
```

Logging

When debugging concurrency issues, it can be useful to have access to the internals of the objects provided by `multiprocessing`. There is a convenient module-level function to enable logging called `log_to_stderr()`. It sets up a logger object using `logging` and adds a handler so that log messages are sent to the standard error channel.

```
import multiprocessing
import logging
import sys

def worker():
    print 'Doing some work'
    sys.stdout.flush()

if __name__ == '__main__':
    multiprocessing.log_to_stderr(logging.DEBUG)
    p = multiprocessing.Process(target=worker)
    p.start()
    p.join()
```

By default the logging level is set to `NOTSET` so no messages are produced. Pass a different level to initialize the logger to the level of detail you want.

```
$ python multiprocessing_log_to_stderr.py

[INFO/Process-1] child process calling self.run()
Doing some work
[INFO/Process-1] process shutting down
[DEBUG/Process-1] running all "atexit" finalizers with priority >= 0
[DEBUG/Process-1] running the remaining "atexit" finalizers
[INFO/Process-1] process exiting with exitcode 0
[INFO/MainProcess] process shutting down
[DEBUG/MainProcess] running all "atexit" finalizers with priority >= 0
[DEBUG/MainProcess] running the remaining "atexit" finalizers
```

To manipulate the logger directly (change its level setting or add handlers), use `get_logger()`.

```
import multiprocessing
import logging
import sys

def worker():
    print 'Doing some work'
    sys.stdout.flush()

if __name__ == '__main__':
    multiprocessing.log_to_stderr()
    logger = multiprocessing.get_logger()
    logger.setLevel(logging.INFO)
    p = multiprocessing.Process(target=worker)
    p.start()
    p.join()
```

The logger can also be configured through the `logging` configuration file API, using the name `multiprocessing`.

```
$ python multiprocessing_get_logger.py

[INFO/Process-1] child process calling self.run()
Doing some work
[INFO/Process-1] process shutting down
[INFO/Process-1] process exiting with exitcode 0
[INFO/MainProcess] process shutting down
```

Subclassing Process

Although the simplest way to start a job in a separate process is to use `Process` and pass a target function, it is also possible to use a custom subclass.

```
import multiprocessing

class Worker(multiprocessing.Process):

    def run(self):
        print 'In %s' % self.name
        return

if __name__ == '__main__':
    jobs = []
    for i in range(5):
        p = Worker()
        jobs.append(p)
        p.start()
    for j in jobs:
        j.join()
```

The derived class should override `run()` to do its work.

```
$ python multiprocessing_subclass.py

In Worker-1
In Worker-2
In Worker-3
In Worker-4
In Worker-5
```

16.3.2 Communication Between Processes

As with threads, a common use pattern for multiple processes is to divide a job up among several workers to run in parallel. Effective use of multiple processes usually requires some communication between them, so that work can be divided and results can be aggregated.

Passing Messages to Processes

A simple way to communicate between process with `multiprocessing` is to use a `Queue` to pass messages back and forth. Any pickle-able object can pass through a `Queue`.

```
import multiprocessing

class MyFancyClass(object):

    def __init__(self, name):
        self.name = name

    def do_something(self):
        proc_name = multiprocessing.current_process().name
        print 'Doing something fancy in %s for %s!' % (proc_name, self.name)


def worker(q):
    obj = q.get()
    obj.do_something()


if __name__ == '__main__':
    queue = multiprocessing.Queue()

    p = multiprocessing.Process(target=worker, args=(queue,))
    p.start()

    queue.put(MyFancyClass('Fancy Dan'))

    # Wait for the worker to finish
    queue.close()
    queue.join_thread()
    p.join()
```

This short example only passes a single message to a single worker, then the main process waits for the worker to finish.

```
$ python multiprocessing_queue.py

Doing something fancy in Process-1 for Fancy Dan!
```

A more complex example shows how to manage several workers consuming data from a `JoinableQueue` and passing results back to the parent process. The *poison pill* technique is used to stop the workers. After setting up the real tasks, the main program adds one "stop" value per worker to the job queue. When a worker encounters the special value, it breaks out of its processing loop. The main process uses the task queue's `join()` method to wait for all of the tasks to finish before processin the results.

```
import multiprocessing
import time

class Consumer(multiprocessing.Process):

    def __init__(self, task_queue, result_queue):
        multiprocessing.Process.__init__(self)
        self.task_queue = task_queue
        self.result_queue = result_queue

    def run(self):
        proc_name = self.name
        while True:
            next_task = self.task_queue.get()
            if next_task is None:
                # Poison pill means shutdown
                print '%s: Exiting' % proc_name
                self.task_queue.task_done()
                break
            print '%s: %s' % (proc_name, next_task)
            answer = next_task()
            self.task_queue.task_done()
            self.result_queue.put(answer)
        return


class Task(object):
    def __init__(self, a, b):
        self.a = a
        self.b = b
    def __call__(self):
        time.sleep(0.1) # pretend to take some time to do the work
        return '%s * %s = %s' % (self.a, self.b, self.a * self.b)
    def __str__(self):
        return '%s * %s' % (self.a, self.b)


if __name__ == '__main__':
    # Establish communication queues
    tasks = multiprocessing.JoinableQueue()
    results = multiprocessing.Queue()

    # Start consumers
    num_consumers = multiprocessing.cpu_count() * 2
    print 'Creating %d consumers' % num_consumers
    consumers = [ Consumer(tasks, results)
                  for i in xrange(num_consumers) ]
    for w in consumers:
        w.start()

    # Enqueue jobs
    num_jobs = 10
    for i in xrange(num_jobs):
        tasks.put(Task(i, i))

    # Add a poison pill for each consumer
    for i in xrange(num_consumers):
        tasks.put(None)

    # Wait for all of the tasks to finish
    tasks.join()

    # Start printing results
    while num_jobs:
        result = results.get()
        print 'Result:', result
        num_jobs -= 1
```

Although the jobs enter the queue in order, since their execution is parallelized there is no guarantee about the order they will be completed.

```
$ python -u multiprocessing_producer_consumer.py

Creating 16 consumers
Consumer-1: 0 * 0
Consumer-2: 1 * 1
Consumer-3: 2 * 2
Consumer-4: 3 * 3
Consumer-5: 4 * 4
Consumer-6: 5 * 5
Consumer-7: 6 * 6
Consumer-8: 7 * 7
Consumer-9: 8 * 8
Consumer-10: 9 * 9
Consumer-11: Exiting
Consumer-12: Exiting
Consumer-13: Exiting
Consumer-14: Exiting
Consumer-15: Exiting
Consumer-16: Exiting
Consumer-1: Exiting
```

```
Consumer-4: Exiting
Consumer-5: Exiting
Consumer-6: Exiting
Consumer-2: Exiting
Consumer-3: Exiting
Consumer-9: Exiting
Consumer-7: Exiting
Consumer-8: Exiting
Consumer-10: Exiting
Result: 0 * 0 = 0
Result: 3 * 3 = 9
Result: 8 * 8 = 64
Result: 5 * 5 = 25
Result: 4 * 4 = 16
Result: 6 * 6 = 36
Result: 7 * 7 = 49
Result: 1 * 1 = 1
Result: 2 * 2 = 4
Result: 9 * 9 = 81
```

Signaling between Processes

The `Event` class provides a simple way to communicate state information between processes. An event can be toggled between set and unset states. Users of the event object can wait for it to change from unset to set, using an optional timeout value.

```
import multiprocessing
import time

def wait_for_event(e):
    """Wait for the event to be set before doing anything"""
    print 'wait_for_event: starting'
    e.wait()
    print 'wait_for_event: e.is_set()->', e.is_set()

def wait_for_event_timeout(e, t):
    """Wait t seconds and then timeout"""
    print 'wait_for_event_timeout: starting'
    e.wait(t)
    print 'wait_for_event_timeout: e.is_set()->', e.is_set()


if __name__ == '__main__':
    e = multiprocessing.Event()
    w1 = multiprocessing.Process(name='block',
                                 target=wait_for_event,
                                 args=(e,))
    w1.start()

    w2 = multiprocessing.Process(name='non-block',
                                 target=wait_for_event_timeout,
                                 args=(e, 2))
    w2.start()

    print 'main: waiting before calling Event.set()'
    time.sleep(3)
    e.set()
    print 'main: event is set'
```

When `wait()` times out it returns without an error. The caller is responsible for checking the state of the event using `is_set()`.

```
$ python -u multiprocessing_event.py

main: waiting before calling Event.set()
wait_for_event: starting
wait_for_event_timeout: starting
wait_for_event_timeout: e.is_set()-> False
main: event is set
wait_for_event: e.is_set()-> True
```

Controlling Access to Resources

In situations when a single resource needs to be shared between multiple processes, a `Lock` can be used to avoid conflicting accesses.

```
import multiprocessing
import sys

def worker_with(lock, stream):
    with lock:
        stream.write('Lock acquired via with\n')

def worker_no_with(lock, stream):
    lock.acquire()
    try:
        stream.write('Lock acquired directly\n')
    finally:
        lock.release()

lock = multiprocessing.Lock()
w = multiprocessing.Process(target=worker_with, args=(lock, sys.stdout))
nw = multiprocessing.Process(target=worker_no_with, args=(lock, sys.stdout))

w.start()
nw.start()

w.join()
nw.join()
```

In this example, the messages printed to the console may be jumbled together if the two processes do not synchronize their access of the output stream with the lock.

```
$ python multiprocessing_lock.py

Lock acquired via with
Lock acquired directly
```

Synchronizing Operations

`Condition` objects can be used to synchronize parts of a workflow so that some run in parallel but others run sequentially, even if they are in separate processes.

```
import multiprocessing
import time

def stage_1(cond):
    """perform first stage of work, then notify stage_2 to continue"""
    name = multiprocessing.current_process().name
    print 'Starting', name
    with cond:
        print '%s done and ready for stage 2' % name
        cond.notify_all()

def stage_2(cond):
    """wait for the condition telling us stage_1 is done"""
    name = multiprocessing.current_process().name
    print 'Starting', name
    with cond:
        cond.wait()
        print '%s running' % name

if __name__ == '__main__':
    condition = multiprocessing.Condition()
    s1 = multiprocessing.Process(name='s1', target=stage_1, args=(condition,))
    s2_clients = [
        multiprocessing.Process(name='stage_2[%d]' % i, target=stage_2, args=(condition,))
        for i in range(1, 3)
        ]

    for c in s2_clients:
        c.start()
        time.sleep(1)
    s1.start()

    s1.join()
    for c in s2_clients:
        c.join()
```

In this example, two process run the second stage of a job in parallel, but only after the first stage is done.

```
$ python multiprocessing_condition.py

Starting s1
s1 done and ready for stage 2
Starting stage_2[1]
stage_2[1] running
Starting stage_2[2]
stage_2[2] running
```

Controlling Concurrent Access to Resources

Sometimes it is useful to allow more than one worker access to a resource at a time, while still limiting the overall number. For example, a connection pool might support a fixed number of simultaneous connections, or a network application might support a fixed number of concurrent downloads. A `Semaphore` is one way to manage those connections.

```
import random
import multiprocessing
import time
```

```
class ActivePool(object):
    def __init__(self):
        super(ActivePool, self).__init__()
        self.mgr = multiprocessing.Manager()
        self.active = self.mgr.list()
        self.lock = multiprocessing.Lock()
    def makeActive(self, name):
        with self.lock:
            self.active.append(name)
    def makeInactive(self, name):
        with self.lock:
            self.active.remove(name)
    def __str__(self):
        with self.lock:
            return str(self.active)

def worker(s, pool):
    name = multiprocessing.current_process().name
    with s:
        pool.makeActive(name)
        print 'Now running: %s' % str(pool)
        time.sleep(random.random())
        pool.makeInactive(name)

if __name__ == '__main__':
    pool = ActivePool()
    s = multiprocessing.Semaphore(3)
    jobs = [
        multiprocessing.Process(target=worker, name=str(i), args=(s, pool))
        for i in range(10)
        ]

    for j in jobs:
        j.start()

    for j in jobs:
        j.join()
        print 'Now running: %s' % str(pool)
```

In this example, the `ActivePool` class simply serves as a convenient way to track which processes are running at a given moment. A real resource pool would probably allocate a connection or some other value to the newly active process, and reclaim the value when the task is done. Here, the pool is just used to hold the names of the active processes to show that only three are running concurrently.

```
$ python multiprocessing_semaphore.py

Now running: ['0', '1', '2']
Now running: ['0', '1', '2']
Now running: ['0', '1', '2']
Now running: ['0', '1', '3']
Now running: ['4', '5', '6']
Now running: ['3', '4', '5']
Now running: ['1', '3', '4']
Now running: ['4', '7', '8']
Now running: ['4', '5', '7']
Now running: ['7', '8', '9']
Now running: ['1', '3', '4']
Now running: ['3', '4', '5']
Now running: ['3', '4', '5']
Now running: ['4', '5', '6']
Now running: ['7', '8', '9']
Now running: ['7', '8', '9']
Now running: ['7', '8', '9']
Now running: ['9']
Now running: ['9']
Now running: []
```

Managing Shared State

In the previous example, the list of active processes is maintained centrally in the `ActivePool` instance via a special type of list object created by a `Manager`. The `Manager` is responsible for coordinating shared information state between all of its users.

```
import multiprocessing

def worker(d, key, value):
    d[key] = value

if __name__ == '__main__':
    mgr = multiprocessing.Manager()
    d = mgr.dict()
    jobs = [ multiprocessing.Process(target=worker, args=(d, i, i*2))
             for i in range(10)
             ]
    for j in jobs:
        j.start()
    for j in jobs:
        j.join()
    print 'Results:', d
```

By creating the list through the manager, it is shared and updates are seen in all processes. Dictionaries are also supported.

```
$ python multiprocessing_manager_dict.py

Results: {0: 0, 1: 2, 2: 4, 3: 6, 4: 8, 5: 10, 6: 12, 7: 14, 8: 16, 9: 18}
```

Shared Namespaces

In addition to dictionaries and lists, a `Manager` can create a shared `Namespace`.

```
import multiprocessing

def producer(ns, event):
    ns.value = 'This is the value'
    event.set()

def consumer(ns, event):
    try:
        value = ns.value
    except Exception, err:
        print 'Before event, consumer got:', str(err)
    event.wait()
    print 'After event, consumer got:', ns.value
```

```
if __name__ == '__main__':
    mgr = multiprocessing.Manager()
    namespace = mgr.Namespace()
    event = multiprocessing.Event()
    p = multiprocessing.Process(target=producer, args=(namespace, event))
    c = multiprocessing.Process(target=consumer, args=(namespace, event))

    c.start()
    p.start()

    c.join()
    p.join()
```

Any named value added to the `Namespace` is visible to all of the clients that receive the `Namespace` instance.

```
$ python multiprocessing_namespaces.py

Before event, consumer got: 'Namespace' object has no attribute 'value'
After event, consumer got: This is the value
```

It is important to know that *updates* to the contents of mutable values in the namespace are *not* propagated automatically.

```
import multiprocessing

def producer(ns, event):
    ns.my_list.append('This is the value') # DOES NOT UPDATE GLOBAL VALUE!
    event.set()

def consumer(ns, event):
    print 'Before event, consumer got:', ns.my_list
    event.wait()
    print 'After event, consumer got:', ns.my_list

if __name__ == '__main__':
    mgr = multiprocessing.Manager()
    namespace = mgr.Namespace()
    namespace.my_list = []

    event = multiprocessing.Event()
    p = multiprocessing.Process(target=producer, args=(namespace, event))
    c = multiprocessing.Process(target=consumer, args=(namespace, event))

    c.start()
    p.start()

    c.join()
    p.join()
```

To update the list, attach it to the namespace object again.

```
$ python multiprocessing_namespaces_mutable.py

Before event, consumer got: []
After event, consumer got: []
```

Process Pools

The `Pool` class can be used to manage a fixed number of workers for simple cases where the work to be done can be broken up and distributed between workers independently. The return values from the jobs are collected and returned as a list. The pool arguments include the number of processes and a function to run when starting the task process (invoked once per child).

```
import multiprocessing

def do_calculation(data):
    return data * 2

def start_process():
    print 'Starting', multiprocessing.current_process().name

if __name__ == '__main__':
    inputs = list(range(10))
    print 'Input   :', inputs

    builtin_outputs = map(do_calculation, inputs)
    print 'Built-in:', builtin_outputs

    pool_size = multiprocessing.cpu_count() * 2
    pool = multiprocessing.Pool(processes=pool_size,
                                initializer=start_process,
                                )
    pool_outputs = pool.map(do_calculation, inputs)
    pool.close() # no more tasks
    pool.join()  # wrap up current tasks

    print 'Pool    :', pool_outputs
```

The result of the `map()` method is functionally equivalent to the built-in `map()`, except that individual tasks run in parallel. Since the pool is processing its inputs in parallel, `close()` and `join()` can be used to synchronize the main process with the task processes to ensure proper cleanup.

```
$ python multiprocessing_pool.py

Input   : [0, 1, 2, 3, 4, 5, 6, 7, 8, 9]
Built-in: [0, 2, 4, 6, 8, 10, 12, 14, 16, 18]
Starting PoolWorker-11
Starting PoolWorker-12
Starting PoolWorker-13
Starting PoolWorker-14
Starting PoolWorker-15
Starting PoolWorker-16
Starting PoolWorker-1
Starting PoolWorker-2
Starting PoolWorker-3
Starting PoolWorker-4
Starting PoolWorker-5
Starting PoolWorker-8
Starting PoolWorker-9
Starting PoolWorker-6
Starting PoolWorker-10
Starting PoolWorker-7
Pool    : [0, 2, 4, 6, 8, 10, 12, 14, 16, 18]
```

By default `Pool` creates a fixed number of worker processes and passes jobs to them until there are no more jobs.

Setting the *maxtasksperchild* parameter tells the pool to restart a worker process after it has finished a few tasks. This can be used to avoid having long-running workers consume ever more system resources.

```
import multiprocessing

def do_calculation(data):
    return data * 2

def start_process():
    print 'Starting', multiprocessing.current_process().name

if __name__ == '__main__':
    inputs = list(range(10))
    print 'Input   :', inputs

    builtin_outputs = map(do_calculation, inputs)
    print 'Built-in:', builtin_outputs

    pool_size = multiprocessing.cpu_count() * 2
    pool = multiprocessing.Pool(processes=pool_size,
                                initializer=start_process,
                                maxtasksperchild=2,
                                )
    pool_outputs = pool.map(do_calculation, inputs)
    pool.close() # no more tasks
    pool.join()  # wrap up current tasks

    print 'Pool    :', pool_outputs
```

The pool restarts the workers when they have completed their allotted tasks, even if there is no more work. In this output, eight workers are created, even though there are only 10 tasks, and each worker can complete two of them at a time.

```
$ python multiprocessing_pool_maxtasksperchild.py

Input   : [0, 1, 2, 3, 4, 5, 6, 7, 8, 9]
Built-in: [0, 2, 4, 6, 8, 10, 12, 14, 16, 18]
Starting PoolWorker-11
Starting PoolWorker-12
Starting PoolWorker-13
Starting PoolWorker-14
Starting PoolWorker-15
Starting PoolWorker-16
Starting PoolWorker-1
Starting PoolWorker-2
Starting PoolWorker-3
Starting PoolWorker-4
Starting PoolWorker-5
Starting PoolWorker-6
Starting PoolWorker-7
Starting PoolWorker-8
Starting PoolWorker-9
Starting PoolWorker-10
Pool    : [0, 2, 4, 6, 8, 10, 12, 14, 16, 18]
```

16.3.3 Implementing MapReduce with multiprocessing

The `Pool` class can be used to create a simple single-server MapReduce implementation. Although it does not give the full benefits of distributed processing, it does illustrate how easy it is to break some problems down into distributable units of work.

SimpleMapReduce

In a MapReduce-based system, input data is broken down into chunks for processing by different worker instances. Each chunk of input data is *mapped* to an intermediate state using a simple transformation. The intermediate data is then collected together and partitioned based on a key value so that all of the related values are together. Finally, the partitioned data is *reduced* to a result set.

```
import collections
import itertools
import multiprocessing

class SimpleMapReduce(object):

    def __init__(self, map_func, reduce_func, num_workers=None):
        """
        map_func

          Function to map inputs to intermediate data. Takes as
          argument one input value and returns a tuple with the key
          and a value to be reduced.

        reduce_func

          Function to reduce partitioned version of intermediate data
          to final output. Takes as argument a key as produced by
          map_func and a sequence of the values associated with that
          key.

        num_workers

          The number of workers to create in the pool. Defaults to the
          number of CPUs available on the current host.
        """
        self.map_func = map_func
        self.reduce_func = reduce_func
        self.pool = multiprocessing.Pool(num_workers)

    def partition(self, mapped_values):
        """Organize the mapped values by their key.
        Returns an unsorted sequence of tuples with a key and a sequence of values.
        """
        partitioned_data = collections.defaultdict(list)
        for key, value in mapped_values:
            partitioned_data[key].append(value)
        return partitioned_data.items()

    def __call__(self, inputs, chunksize=1):
        """Process the inputs through the map and reduce functions given.

        inputs
          An iterable containing the input data to be processed.
        chunksize=1
          The portion of the input data to hand to each worker.  This
          can be used to tune performance during the mapping phase.
        """
        map_responses = self.pool.map(self.map_func, inputs, chunksize=chunksize)
        partitioned_data = self.partition(itertools.chain(*map_responses))
        reduced_values = self.pool.map(self.reduce_func, partitioned_data)
        return reduced_values
```

Counting Words in Files

The following example script uses SimpleMapReduce to counts the “words” in the reStructuredText source for this article, ignoring some of the markup.

```
import multiprocessing
import string

from multiprocessing_mapreduce import SimpleMapReduce

def file_to_words(filename):
    """Read a file and return a sequence of (word, occurances) values.
    """
    STOP_WORDS = set([
            'a', 'an', 'and', 'are', 'as', 'be', 'by', 'for', 'if', 'in',
            'is', 'it', 'of', 'or', 'py', 'rst', 'that', 'the', 'to', 'with',
            ])
    TR = string.maketrans(string.punctuation, ' ' * len(string.punctuation))

    print multiprocessing.current_process().name, 'reading', filename
    output = []

    with open(filename, 'rt') as f:
        for line in f:
            if line.lstrip().startswith('..'): # Skip rst comment lines
                continue
            line = line.translate(TR) # Strip punctuation
            for word in line.split():
                word = word.lower()
                if word.isalpha() and word not in STOP_WORDS:
                    output.append( (word, 1) )
    return output


def count_words(item):
    """Convert the partitioned data for a word to a
    tuple containing the word and the number of occurances.
    """
    word, occurances = item
    return (word, sum(occurances))


if __name__ == '__main__':
    import operator
    import glob

    input_files = glob.glob('*.rst')
    mapper = SimpleMapReduce(file_to_words, count_words)
    word_counts = mapper(input_files)
    word_counts.sort(key=operator.itemgetter(1))
    word_counts.reverse()

    print '\nTOP 20 WORDS BY FREQUENCY\n'
    top20 = word_counts[:20]
    longest = max(len(word) for word, count in top20)
    for word, count in top20:
        print '%-*s: %5s' % (longest+1, word, count)
```

The `file_to_words()` function converts each input file to a sequence of tuples containing the word and the number 1 (representing a single occurrence) .The data is partitioned by `partition()` using the word as the key, so the partitioned data consists of a key and a sequence of 1 values representing each occurrence of the word. The partioned data is converted to a set of suples containing a word and the count for that word by `count_words()` during the reduction phase.

```
$ python multiprocessing_wordcount.py

PoolWorker-1 reading basics.rst
PoolWorker-3 reading index.rst
PoolWorker-4 reading mapreduce.rst
PoolWorker-2 reading communication.rst

TOP 20 WORDS BY FREQUENCY

process         :    80
starting        :    52
multiprocessing :    40
worker          :    37
after           :    33
poolworker      :    32
running         :    31
consumer        :    31
processes       :    30
start           :    28
exiting         :    28
python          :    28
class           :    27
literal         :    26
header          :    26
pymotw          :    26
end             :    26
daemon          :    22
now             :    21
func            :    20
```

See also:

MapReduce - Wikipedia (http://en.wikipedia.org/wiki/MapReduce) Overview of MapReduce on Wikipedia.

MapReduce: Simplified Data Processing on Large Clusters (http://labs.google.com/papers/mapreduce.html)
Google Labs presentation and paper on MapReduce.

`operator` Operator tools such as `itemgetter()`.

Special thanks to Jesse Noller for helping review this information.

See also:

multiprocessing (http://docs.python.org/library/multiprocessing.html) The standard library documentation for this module.

threading High-level API for working with threads.

16.4 readline – Interface to the GNU readline library

Purpose Provides an interface to the GNU readline library for interacting with the user at a command prompt.

Available In 1.4 and later

The readline module can be used to enhance interactive command line programs to make them easier to use. It is primarily used to provide command line text completion, or "tab completion".

Note: Because readline interacts with the console content, printing debug messages makes it difficult to see what it happening in the sample code versus what readline is doing for free. The examples below use the logging module to write debug information to a separate file. The log output is shown with each example.

16.4.1 Configuring

There are two ways to configure the underlying readline library, using a configuration file or the parse_and_bind() function. Configuration options include the keybinding to invoke completion, editing modes (vi or emacs), and many other values. Refer to the GNU readline library documentation (http://tiswww.case.edu/php/chet/readline/readline.html#SEC10) for details.

The easiest way to enable tab-completion is through a call to parse_and_bind(). Other options can be set at the same time. This example changes the editing controls to use "vi" mode instead of the default of "emacs". To edit the current input line, press ESC then use normal vi navigation keys such as j, k, l, and h.

```
import readline

readline.parse_and_bind('tab: complete')
readline.parse_and_bind('set editing-mode vi')

while True:
    line = raw_input('Prompt ("stop" to quit): ')
    if line == 'stop':
        break
    print 'ENTERED: "%s"' % line
```

The same configuration can be stored as instructions in a file read by the library with a single call. If myreadline.rc contains:

```
# Turn on tab completion
tab: complete

# Use vi editing mode instead of emacs
set editing-mode vi
```

the file can be read with read_init_file():

```
import readline

readline.read_init_file('myreadline.rc')
```

```
while True:
    line = raw_input('Prompt ("stop" to quit): ')
    if line == 'stop':
        break
    print 'ENTERED: "%s"' % line
```

16.4.2 Completing Text

As an example of how to build command line completion, we can look at a program that has a built-in set of possible commands and uses tab-completion when the user is entering instructions.

```
import readline
import logging

LOG_FILENAME = '/tmp/completer.log'
logging.basicConfig(filename=LOG_FILENAME,
                    level=logging.DEBUG,
                    )

class SimpleCompleter(object):

    def __init__(self, options):
        self.options = sorted(options)
        return

    def complete(self, text, state):
        response = None
        if state == 0:
            # This is the first time for this text, so build a match list.
            if text:
                self.matches = [s
                                for s in self.options
                                if s and s.startswith(text)]
                logging.debug('%s matches: %s', repr(text), self.matches)
            else:
                self.matches = self.options[:]
                logging.debug('(empty input) matches: %s', self.matches)

        # Return the state'th item from the match list,
        # if we have that many.
        try:
            response = self.matches[state]
        except IndexError:
            response = None
        logging.debug('complete(%s, %s) => %s',
                      repr(text), state, repr(response))
        return response

def input_loop():
    line = ''
    while line != 'stop':
        line = raw_input('Prompt ("stop" to quit): ')
        print 'Dispatch %s' % line

# Register our completer function
readline.set_completer(SimpleCompleter(['start', 'stop', 'list', 'print']).complete)
```

```
# Use the tab key for completion
readline.parse_and_bind('tab: complete')

# Prompt the user for text
input_loop()
```

The `input_loop()` function simply reads one line after another until the input value is `"stop"`. A more sophisticated program could actually parse the input line and run the command.

The `SimpleCompleter` class keeps a list of "options" that are candidates for auto-completion. The `complete()` method for an instance is designed to be registered with `readline` as the source of completions. The arguments are a "text" string to complete and a "state" value, indicating how many times the function has been called with the same text. The function is called repeatedly with the state incremented each time. It should return a string if there is a candidate for that state value or `None` if there are no more candidates. The implementation of `complete()` here looks for a set of matches when state is `0`, and then returns all of the candidate matches one at a time on subsequent calls.

When run, the initial output looks something like this:

```
$ python readline_completer.py
Prompt ("stop" to quit):
```

If you press `TAB` twice, a list of options are printed.

```
$ python readline_completer.py
Prompt ("stop" to quit):
list   print  start  stop
Prompt ("stop" to quit):
```

The log file shows that `complete()` was called with two separate sequences of state values.

```
$ tail -f /tmp/completer.log
DEBUG:root:(empty input) matches: ['list', 'print', 'start', 'stop']
DEBUG:root:complete('', 0) => 'list'
DEBUG:root:complete('', 1) => 'print'
DEBUG:root:complete('', 2) => 'start'
DEBUG:root:complete('', 3) => 'stop'
DEBUG:root:complete('', 4) => None
DEBUG:root:(empty input) matches: ['list', 'print', 'start', 'stop']
DEBUG:root:complete('', 0) => 'list'
DEBUG:root:complete('', 1) => 'print'
DEBUG:root:complete('', 2) => 'start'
DEBUG:root:complete('', 3) => 'stop'
DEBUG:root:complete('', 4) => None
```

The first sequence is from the first TAB key-press. The completion algorithm asks for all candidates but does not expand the empty input line. Then on the second TAB, the list of candidates is recalculated so it can be printed for the user.

If next we type "`l`" and press TAB again, the screen shows:

```
Prompt ("stop" to quit): list
```

and the log reflects the different arguments to `complete()`:

```
DEBUG:root:'l' matches: ['list']
DEBUG:root:complete('l', 0) => 'list'
DEBUG:root:complete('l', 1) => None
```

Pressing RETURN now causes `raw_input()` to return the value, and the `while` loop cycles.

```
Dispatch list
Prompt ("stop" to quit):
```

There are two possible completions for a command beginning with "s". Typing "s", then pressing TAB finds that "start" and "stop" are candidates, but only partially completes the text on the screen by adding a "t".

The log file shows:

```
DEBUG:root:'s' matches: ['start', 'stop']
DEBUG:root:complete('s', 0) => 'start'
DEBUG:root:complete('s', 1) => 'stop'
DEBUG:root:complete('s', 2) => None
```

and the screen:

```
Prompt ("stop" to quit): st
```

Warning: If your completer function raises an exception, it is ignored silently and readline assumes there are no matching completions.

16.4.3 Accessing the Completion Buffer

The completion algorithm above is simplistic because it only looks the text argument passed to the function, but does not use any more of readline's internal state. It is also possible to use readline functions to manipulate the text of the input buffer.

```
import readline
import logging

LOG_FILENAME = '/tmp/completer.log'
logging.basicConfig(filename=LOG_FILENAME,
                    level=logging.DEBUG,
                    )

class BufferAwareCompleter(object):

    def __init__(self, options):
        self.options = options
        self.current_candidates = []
        return

    def complete(self, text, state):
        response = None
        if state == 0:
            # This is the first time for this text, so build a match list.

            origline = readline.get_line_buffer()
            begin = readline.get_begidx()
            end = readline.get_endidx()
            being_completed = origline[begin:end]
            words = origline.split()

            logging.debug('origline=%s', repr(origline))
            logging.debug('begin=%s', begin)
            logging.debug('end=%s', end)
            logging.debug('being_completed=%s', being_completed)
            logging.debug('words=%s', words)
            if not words:
                self.current_candidates = sorted(self.options.keys())
            else:
                try:
                    if begin == 0:
                        # first word
                        candidates = self.options.keys()
                    else:
                        # later word
                        first = words[0]
                        candidates = self.options[first]

                    if being_completed:
                        # match options with portion of input
                        # being completed
                        self.current_candidates = [ w for w in candidates
                                                    if w.startswith(being_completed) ]
                    else:
                        # matching empty string so use all candidates
                        self.current_candidates = candidates

                    logging.debug('candidates=%s', self.current_candidates)

                except (KeyError, IndexError), err:
                    logging.error('completion error: %s', err)
                    self.current_candidates = []

        try:
            response = self.current_candidates[state]
        except IndexError:
            response = None
        logging.debug('complete(%s, %s) => %s', repr(text), state, response)
        return response


def input_loop():
    line = ''
    while line != 'stop':
        line = raw_input('Prompt ("stop" to quit): ')
        print 'Dispatch %s' % line

# Register our completer function
readline.set_completer(BufferAwareCompleter(
    {'list':['files', 'directories'],
     'print':['byname', 'bysize'],
     'stop':[],
    }).complete)

# Use the tab key for completion
readline.parse_and_bind('tab: complete')

# Prompt the user for text
input_loop()
```

In this example, commands with sub-options are are being completed. The `complete()` method needs to look at the position of the completion within the input buffer to determine whether it is part of the first word or a later word. If the target is the first word, the keys of the options dictionary are used as candidates. If it is not the first word, then the first word is used to find candidates from the options dictionary.

There are three top-level commands, two of which have subcommands:

- list
  - files
  - directories
- print
  - byname
  - bysize
- stop

Following the same sequence of actions as before, pressing TAB twice gives us the three top-level commands:

```
$ python readline_buffer.py
Prompt ("stop" to quit):
list   print  stop
Prompt ("stop" to quit):
```

and in the log:

```
DEBUG:root:origline=''
DEBUG:root:begin=0
DEBUG:root:end=0
DEBUG:root:being_completed=
DEBUG:root:words=[]
DEBUG:root:complete('', 0) => list
DEBUG:root:complete('', 1) => print
DEBUG:root:complete('', 2) => stop
DEBUG:root:complete('', 3) => None
DEBUG:root:origline=''
DEBUG:root:begin=0
DEBUG:root:end=0
DEBUG:root:being_completed=
DEBUG:root:words=[]
DEBUG:root:complete('', 0) => list
DEBUG:root:complete('', 1) => print
DEBUG:root:complete('', 2) => stop
DEBUG:root:complete('', 3) => None
```

If the first word is `"list "` (with a space after the word), the candidates for completion are different:

```
Prompt ("stop" to quit): list
directories  files
```

The log shows that the text being completed is *not* the full line, but the portion after

```
DEBUG:root:origline='list '
DEBUG:root:begin=5
DEBUG:root:end=5
DEBUG:root:being_completed=
DEBUG:root:words=['list']
DEBUG:root:candidates=['files', 'directories']
DEBUG:root:complete('', 0) => files
DEBUG:root:complete('', 1) => directories
DEBUG:root:complete('', 2) => None
DEBUG:root:origline='list '
DEBUG:root:begin=5
DEBUG:root:end=5
```

```
DEBUG:root:being_completed=
DEBUG:root:words=['list']
DEBUG:root:candidates=['files', 'directories']
DEBUG:root:complete('', 0) => files
DEBUG:root:complete('', 1) => directories
DEBUG:root:complete('', 2) => None
```

16.4.4 Input History

readline tracks the input history automatically. There are two different sets of functions for working with the history. The history for the current session can be accessed with `get_current_history_length()` and `get_history_item()`. That same history can be saved to a file to be reloaded later using `write_history_file()` and `read_history_file()`. By default the entire history is saved but the maximum length of the file can be set with `set_history_length()`. A length of -1 means no limit.

```python
import readline
import logging
import os

LOG_FILENAME = '/tmp/completer.log'
HISTORY_FILENAME = '/tmp/completer.hist'

logging.basicConfig(filename=LOG_FILENAME,
                    level=logging.DEBUG,
                    )

def get_history_items():
    return [ readline.get_history_item(i)
             for i in xrange(1, readline.get_current_history_length() + 1)
             ]

class HistoryCompleter(object):

    def __init__(self):
        self.matches = []
        return

    def complete(self, text, state):
        response = None
        if state == 0:
            history_values = get_history_items()
            logging.debug('history: %s', history_values)
            if text:
                self.matches = sorted(h
                                      for h in history_values
                                      if h and h.startswith(text))
            else:
                self.matches = []
            logging.debug('matches: %s', self.matches)
        try:
            response = self.matches[state]
        except IndexError:
            response = None
        logging.debug('complete(%s, %s) => %s',
                      repr(text), state, repr(response))
        return response
```

```
def input_loop():
    if os.path.exists(HISTORY_FILENAME):
        readline.read_history_file(HISTORY_FILENAME)
    print 'Max history file length:', readline.get_history_length()
    print 'Startup history:', get_history_items()
    try:
        while True:
            line = raw_input('Prompt ("stop" to quit): ')
            if line == 'stop':
                break
            if line:
                print 'Adding "%s" to the history' % line
    finally:
        print 'Final history:', get_history_items()
        readline.write_history_file(HISTORY_FILENAME)

# Register our completer function
readline.set_completer(HistoryCompleter().complete)

# Use the tab key for completion
readline.parse_and_bind('tab: complete')

# Prompt the user for text
input_loop()
```

The **HistoryCompleter** remembers everything you type and uses those values when completing subsequent inputs.

```
$ python readline_history.py
Max history file length: -1
Startup history: []
Prompt ("stop" to quit): foo
Adding "foo" to the history
Prompt ("stop" to quit): bar
Adding "bar" to the history
Prompt ("stop" to quit): blah
Adding "blah" to the history
Prompt ("stop" to quit): b
bar   blah
Prompt ("stop" to quit): b
Prompt ("stop" to quit): stop
Final history: ['foo', 'bar', 'blah', 'stop']
```

The log shows this output when the "b" is followed by two TABs.

```
DEBUG:root:history: ['foo', 'bar', 'blah']
DEBUG:root:matches: ['bar', 'blah']
DEBUG:root:complete('b', 0) => 'bar'
DEBUG:root:complete('b', 1) => 'blah'
DEBUG:root:complete('b', 2) => None
DEBUG:root:history: ['foo', 'bar', 'blah']
DEBUG:root:matches: ['bar', 'blah']
DEBUG:root:complete('b', 0) => 'bar'
DEBUG:root:complete('b', 1) => 'blah'
DEBUG:root:complete('b', 2) => None
```

When the script is run the second time, all of the history is read from the file.

```
$ python readline_history.py
Max history file length: -1
Startup history: ['foo', 'bar', 'blah', 'stop']
Prompt ("stop" to quit):
```

There are functions for removing individual history items and clearing the entire history, as well.

16.4.5 Hooks

There are several hooks available for triggering actions as part of the interaction sequence. The *startup* hook is invoked immediately before printing the prompt, and the *pre-input* hook is run after the prompt, but before reading text from the user.

```
import readline

def startup_hook():
    readline.insert_text('from startup_hook')

def pre_input_hook():
    readline.insert_text(' from pre_input_hook')
    readline.redisplay()

readline.set_startup_hook(startup_hook)
readline.set_pre_input_hook(pre_input_hook)
readline.parse_and_bind('tab: complete')

while True:
    line = raw_input('Prompt ("stop" to quit): ')
    if line == 'stop':
        break
    print 'ENTERED: "%s"' % line
```

Either hook is a potentially good place to use `insert_text()` to modify the input buffer.

```
$ python readline_hooks.py
Prompt ("stop" to quit): from startup_hook from pre_input_hook
```

If the buffer is modified inside the pre-input hook, you need to call `redisplay()` to update the screen.

See also:

readline (http://docs.python.org/library/readline.html) The standard library documentation for this module.

GNU readline (http://tiswww.case.edu/php/chet/readline/readline.html) Documentation for the GNU readline library.

readline init file format (http://tiswww.case.edu/php/chet/readline/readline.html#SEC10) The initialization and configuration file format.

effbot: The readline module (http://sandbox.effbot.org/librarybook/readline.htm) Effbot's guide to the readline module.

pyreadline (https://launchpad.net/pyreadline) pyreadline, developed as a Python-based replacement for readline to be used in iPython (http://ipython.scipy.org/).

cmd The `cmd` module uses `readline` extensively to implement tab-completion in the command interface. Some of the examples here were adapted from the code in `cmd`.

rlcompleter `rlcompleter` uses `readline` to add tab-completion to the interactive Python interpreter.

16.5 rlcompleter – Adds tab-completion to the interactive interpreter

Purpose Adds tab-completion to the interactive interpreter

Available In 1.5 and later

`rlcompleter` adds tab-completion for Python symbols to the interactive interpreter. Importing the module causes it to configure a completer function for `readline`. The only other step required is to configure the tab key to trigger the completer. All of this can be done in a PYTHONSTARTUP (http://docs.python.org/using/cmdline.html#envvar-PYTHONSTARTUP) file so that it runs each time the interactive interpreter starts.

For example, create a file `~/.pythonrc` containing:

```
try:
    import readline
except ImportError:
    # Silently ignore missing readline module
    pass
else:
    import rlcompleter
    readline.parse_and_bind("tab: complete")
```

Then set `PYTHONSTARTUP` to `"~/.pythonrc"`. When you start the interactive interpreter, tab completion for names from the contents of modules or attributes of objects is activated.

See also:

rlcompleter (http://docs.python.org/library/rlcompleter.html) The standard library documentation for this module.

`readline` The readline module.

CHAPTER

SEVENTEEN

UNIX-SPECIFIC SERVICES

17.1 commands – Run external shell commands

Purpose The commands module contains utility functions for working with shell command output under Unix.

Available In 1.4

Warning: This module is made obsolete by the subprocess module.

There are 3 functions in the commands module for working with external commands. The functions are shell-aware and return the output or status code from the command.

17.1.1 getstatusoutput()

The function getstatusoutput() runs a command via the shell and returns the exit code and the text output (stdout and stderr combined). The exit codes are the same as for the C function wait() or os.wait(). The code is a 16-bit number. The low byte contains the signal number that killed the process. When the signal is zero, the high byte is the exit status of the program. If a core file was produced, the high bit of the low byte is set.

```
from commands import *

def run_command(cmd):
    print 'Running: "%s"' % cmd
    status, text = getstatusoutput(cmd)
    exit_code = status >> 8 # high byte
    signal_num = status % 256 # low byte
    print 'Status: x%04x' % status
    print 'Signal: x%02x (%d)' % (signal_num, signal_num)
    print 'Exit  : x%02x (%d)' % (exit_code, exit_code)
    print 'Core? : %s' % bool(signal_num & (1 << 8)) # high bit
    print 'Output:'
    print text
    print

run_command('ls -l *.py')
run_command('ls -l *.notthere')
run_command('./dumpscore')
run_command('echo "WAITING TO BE KILLED"; read input')
```

This example runs two commands that exit normally, a third meant to generate a core dump, and a fourth that blocks waiting to be killed from another shell. (Don't simply use Ctrl-C as the interpreter will intercept that signal. Use ps and grep in another window to find the read process and send it a signal with kill.)

```
$ python commands_getstatusoutput.py
Running: "ls -l *.py"
Status: x0000
Signal: x00 (0)
Exit  : x00 (0)
Core? : False
Output:
-rw-r--r--  1 dhellmann  dhellmann  1140 Mar 12  2009 __init__.py
-rw-r--r--  1 dhellmann  dhellmann  1297 Mar 12  2009 commands_getoutput.py
-rw-r--r--@ 1 dhellmann  dhellmann  1355 Mar 12  2009 commands_getstatus.py
-rw-r--r--@ 1 dhellmann  dhellmann  1739 Nov 26 12:52 commands_getstatusoutput.py

Running: "ls -l *.notthere"
Status: x0100
Signal: x00 (0)
Exit  : x01 (1)
Core? : False
Output:
ls: *.notthere: No such file or directory

Running: "./dumpscore"
Status: x8600
Signal: x00 (0)
Exit  : x86 (134)
Core? : False
Output:
sh: line 1: 47021 Abort trap              (core dumped) ./dumpscore

Running: "echo "WAITING TO BE KILLED"; read input"
Status: x0001
Signal: x01 (1)
Exit  : x00 (0)
Core? : False
Output:
WAITING TO BE KILLED
```

In this example, I used `kill -HUP $PID` to kill the reading process from a separate shell window, so the signal is reported as `1`.

17.1.2 getoutput()

If the exit code is not useful for your application, you can use getoutput() to receive only the text output from the command.

```python
from commands import *

text = getoutput('ls -l *.py')
print 'ls -l *.py:'
print text

print

text = getoutput('ls -l *.notthere')
print 'ls -l *.py:'
print text
```

```
$ python commands_getoutput.py
ls -l *.py:
-rw-r--r--   1 dhellman  dhellman  1191 Oct 21 09:41 __init__.py
-rw-r--r--   1 dhellman  dhellman  1321 Oct 21 09:48 commands_getoutput.py
-rw-r--r--   1 dhellman  dhellman  1265 Oct 21 09:50 commands_getstatus.py
-rw-r--r--   1 dhellman  dhellman  1626 Oct 21 10:10 commands_getstatusoutput.py

ls -l *.py:
ls: *.notthere: No such file or directory
```

17.1.3 getstatus()

Contrary to what you might expect, getstatus() does not run a command and return the status code. Instead, it's argument is a filename which is combined with "ls -ld" to build a command to be run by getoutput(). The text output of the command is returned.

```
from commands import *

status = getstatus('commands_getstatus.py')
print 'commands_getstatus.py:', status
status = getstatus('notthere.py')
print 'notthere.py:', status
status = getstatus('$filename')
print '$filename:', status
```

As you notice from the output, the $ character in the argument to the last call is escaped so the environment variable name is not expanded.

```
$ python commands_getstatus.py
commands_getstatus.py: -rw-r--r--   1 dhellman  dhellman  1387 Oct 21 10:19 commands_getstatus.py
notthere.py: ls: notthere.py: No such file or directory
$filename: ls: $filename: No such file or directory
```

See also:

commands **(http://docs.python.org/library/commands.html)** The standard library documentation for this module.

`signal` Defines constants for signals such as HUP (1).

17.2 grp – Unix Group Database

Purpose Read group data from Unix group database.

Available In 1.4 and later

The grp module can be used to read information about Unix groups from the group database (usually `/etc/group`). The read-only interface returns tuple-like objects with named attributes for the standard fields of a group record.

Index	Attribute	Meaning
0	gr_name	Name
1	gr_passwd	Password, if any (encrypted)
2	gr_gid	Numerical id (integer)
3	gr_mem	Names of group members

The name and password values are both strings, the GID is an integer, and the members are reported as a list of strings.

17.2.1 Querying All Groups

Suppose you need to print a report of all of the “real” groups on a system, including their members (for our purposes, “real” is defined as having a name not starting with “_”). To load the entire password database, you would use `getgrall()`. The return value is a list with an undefined order, so you probably want to sort it before printing the report.

```
import grp
import operator

# Load all of the user data, sorted by username
all_groups = grp.getgrall()
interesting_groups = sorted((g
                             for g in all_groups
                             if not g.gr_name.startswith('_')),
                            key=operator.attrgetter('gr_name'))

# Find the longest length for the name
name_length = max(len(g.gr_name) for g in interesting_groups) + 1

# Print report headers
fmt = '%-*s %4s %10s %s'
print fmt % (name_length, 'Name',
             'GID',
             'Password',
             'Members')
print '-' * name_length, '----', '-' * 10, '-' * 30

# Print the data
for g in interesting_groups:
    print fmt % (name_length, g.gr_name,
                 g.gr_gid,
                 g.gr_passwd,
                 ', '.join(g.gr_mem))
```

```
$ python grp_getgrall.py

Name                                      GID   Password Members
----------------------------------------- ---- ---------- ------------------------------
accessibility                               90          *
accessibility                               90          *
admin                                       80          * root, dhellmann
admin                                       80          * root
authedusers                                 50          *
authedusers                                 50          *
bin                                          7          *
bin                                          7          *
certusers                                   29          * root, _jabber, _postfix, _cyrus, _calendar,
certusers                                   29          * root, _jabber, _postfix, _cyrus, _calendar,
com.apple.access_screensharing             401            dhellmann
com.apple.access_screensharing-disabled    101            dhellmann
com.apple.access_ssh                       102            dhellmann
consoleusers                                53          *
consoleusers                                53          *
daemon                                       1          * root
daemon                                       1          * root
dhellmann                                  501
dialer                                      68          *
dialer                                    68          *
everyone                                  12          *
everyone                                  12          *
group                                     16          *
group                                     16          *
interactusers                             51          *
interactusers                             51          *
kmem                                       2          * root
kmem                                       2          * root
localaccounts                             61          *
localaccounts                             61          *
mail                                       6          * _teamsserver
mail                                       6          * _teamsserver
netaccounts                               62          *
netaccounts                               62          *
netusers                                  52          *
netusers                                  52          *
network                                   69          *
network                                   69          *
nobody                                  4294967294          *
nobody                                  4294967294          *
nogroup                                 4294967295          *
nogroup                                 4294967295          *
operator                                   5          * root
operator                                   5          * root
owner                                     10          *
owner                                     10          *
procmod                                    9          * root
procmod                                    9          * root
procview                                   8          * root
procview                                   8          * root
racemi                                   500            dhellmann
smmsp                                    103          *
staff                                     20          * root
staff                                     20          * root
sys                                        3          * root
sys                                        3          * root
tty                                        4          * root
tty                                        4          * root
utmp                                      45          *
utmp                                      45          *
wheel                                      0          * root
wheel                                      0          * root
```

17.2.2 Group Memberships for a User

Another common task might be to print a list of all the groups for a given user:

```
import grp

username = 'dhellmann'
groups = [g.gr_name for g in grp.getgrall() if username in g.gr_mem]
print username, 'belongs to:', ', '.join(groups)
```

```
$ python grp_groups_for_user.py

dhellmann belongs to: _lpadmin, admin, com.apple.access_screensharing-disabled, com.apple.access_scre
```

17.2.3 Finding a Group By Name

As with `pwd`, it is also possible to query for information about a specific group, either by name or numeric id.

```
import grp

name = 'admin'
info = grp.getgrnam(name)
print 'Name    :', info.gr_name
print 'GID     :', info.gr_gid
print 'Password:', info.gr_passwd
print 'Members :', ', '.join(info.gr_mem)
```

```
$ python grp_getgrnam.py

Name    : admin
GID     : 80
Password: *
Members : root, dhellmann
```

17.2.4 Finding a Group by ID

To identify the group running the current process, combine `getgrgid()` with `os.getgid()`.

```
import grp
import os

gid = os.getgid()
group_info = grp.getgrgid(gid)
print 'Currently running with GID=%s name=%s' % (gid, group_info.gr_name)
```

```
$ python grp_getgrgid_process.py

Currently running with GID=501 name=dhellmann
```

And to get the group name based on the permissions on a file, look up the group returned by `os.stat()`.

```
import grp
import os
import sys

filename = 'grp_getgrgid_fileowner.py'
stat_info = os.stat(filename)
owner = grp.getgrgid(stat_info.st_gid).gr_name

print '%s is owned by %s (%s)' % (filename, owner, stat_info.st_gid)
```

```
$ python grp_getgrgid_fileowner.py

grp_getgrgid_fileowner.py is owned by dhellmann (501)
```

See also:

grp (http://docs.python.org/library/grp.html) The standard library documentation for this module.

`pwd` Read user data from the password database.

`spwd` Read user data from the shadow password database.

17.3 pipes – Unix shell command pipeline templates

Purpose Create repeatable Unix shell command pipelines.

Available In Python 1.4

The `pipes` module implements a class to create arbitrarily complex Unix command pipelines. Inputs and outputs of the commands can be chained together as with the shell `|` operator, even if the individual commands need to write to or read from files instead of stdin/stdout.

17.3.1 Passing Standard I/O Through a Pipe

A very simple example, passing standard input through a pipe and receiving the results in a file looks like this:

```python
import pipes
import tempfile

# Establish a very simple pipeline using stdio
p = pipes.Template()
p.append('cat -', '--')
p.debug(True)

# Pass some text through the pipeline,
# saving the output to a temporary file.
t = tempfile.NamedTemporaryFile(mode='r')
f = p.open(t.name, 'w')
try:
    f.write('Some text')
finally:
    f.close()

# Rewind and read the text written
# to the temporary file
t.seek(0)
print t.read()
t.close()
```

The pipeline Template is created and then a single command, `cat -` is added. The command reads standard input and writes it to standard output, without modification. The second argument to `append()` encodes the input and output sources for the command in two characters (input, then output). Using `-` means the command uses standard I/O. Using `f` means the command needs to read from a file (as may be the case with an image processing pipeline).

The `debug()` method toggles debugging output on and off. When debugging is enabled, the commands being run are printed and the shell is given `set -x` so it runs verbosely.

After the pipeline is set up, a NamedTemporaryFile is created to give the pipeline somewhere to write its output. A file must always be specified as argument to `open()`, whether reading or writing.

```
$ python pipes_simple_write.py

+ cat -
cat - >/var/folders/5q/8gk0wq888xlggz008k8dr7180000hg/T/tmpLXAYxI
Some text
```

Reading from a pipeline works basically the same way, with a few changes to the arguments. For our example, we need to set up the contents of the input file before opening the pipline. Then we can pass that filename as input to `open()`.

```
import pipes
import tempfile

# Establish a very simple pipeline using stdio
p = pipes.Template()
p.append('cat -', '--')
p.debug(True)

# Establish an input file
t = tempfile.NamedTemporaryFile(mode='w')
t.write('Some text')
t.flush()

# Pass some text through the pipeline,
# saving the output to a temporary file.
f = p.open(t.name, 'r')
try:
    contents = f.read()
finally:
    f.close()

print contents
```

We can read the results from the pipeline directly.

```
$ python pipes_simple_read.py

+ cat -
cat - </var/folders/5q/8gk0wq888xlggz008k8dr7180000hg/T/tmpeqkbXa
Some text
```

17.3.2 Using Files Instead of Streams

Some commands need to work on files on the filesystem instead of input streams. Commands that process a large amount of data might perform better in this mode, since they will not block on the next command reading their output. Anything that works on non-stream-based data requires this capability as well (e.g., databases or other binary file manipulation tools). To support this mode of operation, `append()` lets you specify a *kind* of `f`, and the pipeline code will create the needed temporary files. The filenames are passed to the shell as `$IN` and `$OUT`, so those variable names need to appear in your command string.

```
import pipes
import tempfile

p = pipes.Template()
p.append('cat $IN > $OUT', 'ff')
p.debug(True)

t = tempfile.NamedTemporaryFile('r')
f = p.open(t.name, 'w')
try:
    f.write('Some text')
finally:
    f.close()

t.seek(0)
print t.read()
t.close()
```

As you see, several intermediate temporary files are created to hold the input and output of the step.

```
$ python pipes_file_kind.py

+ trap 'rm -f /var/folders/5q/8gk0wq888xlggz008k8dr7180000hg/T/tmpMlX74D; exit' 1 2 3 13 14 15
+ cat
+ IN=/var/folders/5q/8gk0wq888xlggz008k8dr7180000hg/T/tmpMlX74D
+ OUT=/var/folders/5q/8gk0wq888xlggz008k8dr7180000hg/T/tmp4mLFvP
+ cat /var/folders/5q/8gk0wq888xlggz008k8dr7180000hg/T/tmpMlX74D
+ rm -f /var/folders/5q/8gk0wq888xlggz008k8dr7180000hg/T/tmpMlX74D
trap 'rm -f /var/folders/5q/8gk0wq888xlggz008k8dr7180000hg/T/tmpMlX74D; exit' 1 2 3 13 14 15
cat >/var/folders/5q/8gk0wq888xlggz008k8dr7180000hg/T/tmpMlX74D
IN=/var/folders/5q/8gk0wq888xlggz008k8dr7180000hg/T/tmpMlX74D; OUT=/var/folders/5q/8gk0wq888xlggz008
rm -f /var/folders/5q/8gk0wq888xlggz008k8dr7180000hg/T/tmpMlX74D
Some text
```

And the input and output *kind* values can be mixed, so that different steps of the pipeline use files or standard I/O as needed.

```python
import pipes
import tempfile

p = pipes.Template()
p.append('cat $IN', 'f-')
p.append('cat - > $OUT', '-f')
p.debug(True)

t = tempfile.NamedTemporaryFile('r')
f = p.open(t.name, 'w')
try:
    f.write('Some text')
finally:
    f.close()

t.seek(0)
print t.read()
t.close()
```

The trap statements visible in the output here ensure that the temporary files created by the pipeline are cleaned up even if a task fails in the middle or the shell is killed.

```
$ python pipes_mixed_kinds.py

+ trap 'rm -f /var/folders/5q/8gk0wq888xlggz008k8dr7180000hg/T/tmpWSCqXa; exit' 1 2 3 13 14 15
+ cat
+ IN=/var/folders/5q/8gk0wq888xlggz008k8dr7180000hg/T/tmpWSCqXa
+ cat /var/folders/5q/8gk0wq888xlggz008k8dr7180000hg/T/tmpWSCqXa
+ OUT=/var/folders/5q/8gk0wq888xlggz008k8dr7180000hg/T/tmpvccJBL
+ cat -
+ rm -f /var/folders/5q/8gk0wq888xlggz008k8dr7180000hg/T/tmpWSCqXa
trap 'rm -f /var/folders/5q/8gk0wq888xlggz008k8dr7180000hg/T/tmpWSCqXa; exit' 1 2 3 13 14 15
cat >/var/folders/5q/8gk0wq888xlggz008k8dr7180000hg/T/tmpWSCqXa
IN=/var/folders/5q/8gk0wq888xlggz008k8dr7180000hg/T/tmpWSCqXa; cat $IN |
{ OUT=/var/folders/5q/8gk0wq888xlggz008k8dr7180000hg/T/tmpvccJBL; cat - > $OUT; }
rm -f /var/folders/5q/8gk0wq888xlggz008k8dr7180000hg/T/tmpWSCqXa
Some text
```

17.3.3 A More Complex Example

All of the examples up to this point have been fairly trivial. They were constructed to illustrate how to use `pipes.Template()` without depending on deep knowledge of shell scripting in general. This example is more complex, and shows how several commands can be combined to manipulate data before bringing it into Python.

My virtualenvwrapper (http://www.doughellmann.com/projects/virtualenvwrapper/) script includes a shell function for listing all of the virtual environments you have created. The function is used for tab-completion and can be called directly to list the environments, in case you forget a name. The heart of that function is a small pipeline that looks in `$WORKON_HOME` for directories that look like virtual environments (i.e., they have an `activate` script). That pipeline is:

```
(cd "$WORKON_HOME"; for f in */bin/activate; do echo $f; done) \
    | sed 's|^\./||' \
    | sed 's|/bin/activate||' \
    | sort
```

Implemented using `pipes`, the pipeline looks like:

```
import pipes
import pprint
import tempfile

p = pipes.Template()
p.append('cd "$WORKON_HOME"; for f in */bin/activate; do echo $f; done', '--')
p.append(r"sed 's|^\./||'", '--')
p.append("sed 's|/bin/activate||'", '--')
p.append('sort', '--')

t = tempfile.NamedTemporaryFile('r')

f = p.open(t.name, 'r')
try:
    sandboxes = [ l.strip() for l in f.readlines() ]
finally:
    f.close()

print 'SANDBOXES:'
pprint.pprint(sandboxes)
```

Since each sandbox name is written to a separate line, parsing the output is easy:

```
$ python pipes_multistep.py

SANDBOXES:
['AstronomyPictureOfTheDay',
 'aspell',
 'athensdocket',
 'backups',
 'bartender',
 'billsapp',
 'bpython',
 'cliff',
 'commandlineapp',
 'csvcat',
 'd765e36b407a6270',
 'dh-akanda',
 'dh-betauser-creator',
 'dh-ceilometer',
 'dh-ceilometerclient',
 'dh-keystone',
 'dh-openstackclient',
 'dictprofilearticle',
 'distutils2',
 'docket',
 'docket-pyparsing',
 'dotfiles',
 'dreamhost',
 'dreamhost-lunch-and-learn',
 'emacs_tools',
 'extensions',
 'feedcache',
 'fuzzy',
 'git_tools',
 'hidden_stdlib',
 'ical2org',
 'mytweets',
 'ndn-billing-usage',
 'ndn-datamodels-python',
 'ndn-dhc-dude',
 'ndn-ndn',
 'nose-testconfig',
 'openstack',
 'personal',
 'phonetic-hashing',
 'pinboard_tools',
 'psfblog',
 'psfboard',
 'pyatl',
 'pyatl-readlines',
 'pycon2012',
 'pycon2013-plugins',
 'pycon2013-sphinx',
 'pydotorg',
 'pymotw',
 'pymotw-book',
 'pymotw-ja',
 'python-dev',
 'pywebdav',
 'racemi',
 'racemi_status',
 'reporting_server',
 'rst2blogger',
 'rst2marsedit',
 'sobell-book',
 'sphinxcontrib-bitbucket',
 'sphinxcontrib-fulltoc',
 'sphinxcontrib-spelling',
 'sphinxcontrib-sqltable',
 'stevedore',
 'summerfield-book',
 'svnautobackup',
 'virtualenvwrapper',
 'website',
 'wsme',
 'zenofpy']
```

17.3.4 Passing Files Through Pipelines

If the input to your pipeline already exists in a file on disk, there's no need to read it into Python simply to pass it to the pipeline. You can use the `copy()` method to pass the file directly through the pipeline and create an output file for reading.

```
import pipes
import tempfile

p = pipes.Template()
p.debug(True)
p.append('grep -n tortor $IN', 'f-')

t = tempfile.NamedTemporaryFile('r')

p.copy('lorem.txt', t.name)

t.seek(0)
print t.read()
t.close()
```

```
$ python pipes_copy.py

+ IN=lorem.txt
+ grep -n tortor lorem.txt
IN=lorem.txt; grep -n tortor $IN >/var/folders/5q/8gk0wq888xlggz008k8dr7180000hg/T/tmpjlfxq6
3:elementum elit tortor eu quam. Duis tincidunt nisi ut ante. Nulla
6:lacus. Praesent placerat tortor sed nisl. Nunc blandit diam egestas
11:eget velit auctor tortor blandit sollicitudin. Suspendisse imperdiet
```

17.3.5 Cloning Templates

Once you have a pipeline template, you may want to use it multiple times or create variants without re-constructing the entire object. The `clone()` method makes both of these operations easy. This example constructs a simple word-counter pipeline, then prepends commands to a couple of clones to make it look for different words.

```
import pipes
import tempfile

count_word_substring = pipes.Template()
#count_word_substring.debug(True)
count_word_substring.append('grep -f - /usr/share/dict/words', '--')
count_word_substring.append('wc -l', '--')

count_py = count_word_substring.clone()
count_py.prepend('echo "py"', '--')
f = count_py.open('/dev/null', 'r')
try:
    print '  "py": %5s' % f.read().strip()
finally:
    f.close()

count_perl = count_word_substring.clone()
count_perl.prepend('echo "perl"', '--')
f = count_perl.open('/dev/null', 'r')
try:
    print '"perl": %5s' % f.read().strip()
```

```
finally:
    f.close()
```

By prepending a custom command to each clone, we can create separate pipelines that perform the same basic function with small variations.

```
$ python pipes_clone.py

  "py":  1381
"perl":    71
```

See also:

pipes **(http://docs.python.org/library/pipes.html)** The standard library documentation for this module.

`tempfile` The tempfile module includes classes for managing temporary files.

`subprocess` The subprocess module also supports chaining the inputs and outputs of processes together.

17.4 pwd – Unix Password Database

Purpose Read user data from Unix password database.

Available In 1.4 and later

The pwd module can be used to read user information from the Unix password database (usually `/etc/passwd`). The read-only interface returns tuple-like objects with named attributes for the standard fields of a password record.

Index	Attribute	Meaning
0	pw_name	The user's login name
1	pw_passwd	Encrypted password (optional)
2	pw_uid	User id (integer)
3	pw_gid	Group id (integer)
4	pw_gecos	Comment/full name
5	pw_dir	Home directory
6	pw_shell	Application started on login, usually a command interpreter

17.4.1 Querying All Users

Suppose you need to print a report of all of the "real" users on a system, including their home directories (for our purposes, "real" is defined as having a name not starting with "_"). To load the entire password database, you would use `getpwall()`. The return value is a list with an undefined order, so you will need to sort it before printing the report.

```
import pwd
import operator

# Load all of the user data, sorted by username
all_user_data = pwd.getpwall()
interesting_users = sorted((u
                            for u in all_user_data
                            if not u.pw_name.startswith('_')),
                            key=operator.attrgetter('pw_name'))

# Find the longest lengths for a few fields
username_length = max(len(u.pw_name) for u in interesting_users) + 1
```

```
home_length = max(len(u.pw_dir) for u in interesting_users) + 1

# Print report headers
fmt = '%-*s %4s %-*s %s'
print fmt % (username_length, 'User',
             'UID',
             home_length, 'Home Dir',
             'Description')
print '-' * username_length, '----', '-' * home_length, '-' * 30

# Print the data
for u in interesting_users:
    print fmt % (username_length, u.pw_name,
                 u.pw_uid,
                 home_length, u.pw_dir,
                 u.pw_gecos)
```

Most of the example code above deals with formatting the results nicely. The `for` loop at the end shows how to access fields from the records by name.

```
$ python pwd_getpwall.py

User        UID Home Dir                 Description
---------- ---- ------------------------ ------------------------------
daemon        1 /var/root                System Services
daemon        1 /var/root                System Services
dhellmann   527 /Users/dhellmann         Doug Hellmann
nobody     4294967294 /var/empty               Unprivileged User
nobody     4294967294 /var/empty               Unprivileged User
postgres    528 /Library/PostgreSQL/9.0  PostgreSQL
root          0 /var/root                System Administrator
root          0 /var/root                System Administrator
```

17.4.2 Querying User By Name

If you need information about one user, it is not necessary to read the entire password database. Using `getpwnam()`, you can retrieve the information about a user by name.

```
import pwd
import sys

username = sys.argv[1]
user_info = pwd.getpwnam(username)

print 'Username:', user_info.pw_name
print 'Password:', user_info.pw_passwd
print 'Comment :', user_info.pw_gecos
print 'UID/GID :', user_info.pw_uid, '/', user_info.pw_gid
print 'Home    :', user_info.pw_dir
print 'Shell   :', user_info.pw_shell
```

The passwords on my system are stored outside of the main user database in a shadow file, so the password field, when set, is reported as all `*`.

```
$ python pwd_getpwnam.py dhellmann

Username: dhellmann
```

```
Password: ********
Comment : Doug Hellmann
UID/GID : 527 / 501
Home    : /Users/dhellmann
Shell   : /bin/bash

$ python pwd_getpwnam.py nobody

Username: nobody
Password: *
Comment : Unprivileged User
UID/GID : 4294967294 / 4294967294
Home    : /var/empty
Shell   : /usr/bin/false
```

17.4.3 Querying User By UID

It is also possible to look up a user by their numerical user id. This is useful to find the owner of a file:

```
import pwd
import os
import sys

filename = 'pwd_getpwuid_fileowner.py'
stat_info = os.stat(filename)
owner = pwd.getpwuid(stat_info.st_uid).pw_name

print '%s is owned by %s (%s)' % (filename, owner, stat_info.st_uid)
```

```
$ python pwd_getpwuid_fileowner.py

pwd_getpwuid_fileowner.py is owned by dhellmann (527)
```

The numeric user id is can also be used to find information about the user currently running a process:

```
import pwd
import os

uid = os.getuid()
user_info = pwd.getpwuid(uid)
print 'Currently running with UID=%s username=%s' % (uid, user_info.pw_name)
```

```
$ python pwd_getpwuid_process.py

Currently running with UID=527 username=dhellmann
```

See also:

pwd **(http://docs.python.org/library/pwd.html)** The standard library documentation for this module.

spwd Secure password database access for systems using shadow passwords.

grp The grp module reads Unix group information.

17.5 resource – System resource management

Purpose Manage the system resource limits for a Unix program.

Available In 1.5.2

The functions in `resource` probe the current system resources consumed by a process, and place limits on them to control how much load a program can impose on a system.

17.5.1 Current Usage

Use `getrusage()` to probe the resources used by the current process and/or its children. The return value is a data structure containing several resource metrics based on the current state of the system.

Note: Not all of the resource values gathered are displayed here. Refer to the stdlib docs (http://docs.python.org/library/resource.html#resource.getrusage) for a more complete list.

```
import resource
import time

usage = resource.getrusage(resource.RUSAGE_SELF)

for name, desc in [
    ('ru_utime', 'User time'),
    ('ru_stime', 'System time'),
    ('ru_maxrss', 'Max. Resident Set Size'),
    ('ru_ixrss', 'Shared Memory Size'),
    ('ru_idrss', 'Unshared Memory Size'),
    ('ru_isrss', 'Stack Size'),
    ('ru_inblock', 'Block inputs'),
    ('ru_oublock', 'Block outputs'),
    ]:
    print '%-25s (%-10s) = %s' % (desc, name, getattr(usage, name))
```

Because the test program is extremely simple, it does not use very many resources:

```
$ python resource_getrusage.py

User time                  (ru_utime  ) = 0.010192
System time                (ru_stime  ) = 0.005743
Max. Resident Set Size     (ru_maxrss ) = 3891200
Shared Memory Size         (ru_ixrss  ) = 0
Unshared Memory Size       (ru_idrss  ) = 0
Stack Size                 (ru_isrss  ) = 0
Block inputs               (ru_inblock) = 0
Block outputs              (ru_oublock) = 0
```

17.5.2 Resource Limits

Separate from the current actual usage, it is possible to check the *limits* imposed on the application, and then change them.

```
import resource

for name, desc in [
    ('RLIMIT_CORE', 'core file size'),
    ('RLIMIT_CPU',  'CPU time'),
    ('RLIMIT_FSIZE', 'file size'),
    ('RLIMIT_DATA', 'heap size'),
    ('RLIMIT_STACK', 'stack size'),
    ('RLIMIT_RSS', 'resident set size'),
    ('RLIMIT_NPROC', 'number of processes'),
    ('RLIMIT_NOFILE', 'number of open files'),
    ('RLIMIT_MEMLOCK', 'lockable memory address'),
    ]:
    limit_num = getattr(resource, name)
    soft, hard = resource.getrlimit(limit_num)
    print 'Maximum %-25s (%-15s) : %20s %20s' % (desc, name, soft, hard)
```

The return value for each limit is a tuple containing the *soft* limit imposed by the current configuration and the *hard* limit imposed by the operating system.

```
$ python resource_getrlimit.py

Maximum core file size            (RLIMIT_CORE    ) :                    0  9223372036854775807
Maximum CPU time                  (RLIMIT_CPU     ) :  9223372036854775807  9223372036854775807
Maximum file size                 (RLIMIT_FSIZE   ) :  9223372036854775807  9223372036854775807
Maximum heap size                 (RLIMIT_DATA    ) :  9223372036854775807  9223372036854775807
Maximum stack size                (RLIMIT_STACK   ) :              8388608             67104768
Maximum resident set size         (RLIMIT_RSS     ) :  9223372036854775807  9223372036854775807
Maximum number of processes       (RLIMIT_NPROC   ) :                  709                 1064
Maximum number of open files      (RLIMIT_NOFILE  ) :                 2560  9223372036854775807
Maximum lockable memory address   (RLIMIT_MEMLOCK ) :  9223372036854775807  9223372036854775807
```

The limits can be changed with `setrlimit()`. For example, to control the number of files a process can open the `RLIMIT_NOFILE` value can be set to use a smaller soft limit value.

```
import resource
import os

soft, hard = resource.getrlimit(resource.RLIMIT_NOFILE)
print 'Soft limit starts as  :', soft

resource.setrlimit(resource.RLIMIT_NOFILE, (4, hard))

soft, hard = resource.getrlimit(resource.RLIMIT_NOFILE)
print 'Soft limit changed to :', soft

random = open('/dev/random', 'r')
print 'random has fd =', random.fileno()
try:
    null = open('/dev/null', 'w')
except IOError, err:
    print err
else:
    print 'null has fd =', null.fileno()
```

```
$ python resource_setrlimit_nofile.py

Soft limit starts as  : 2560
Soft limit changed to : 4
random has fd = 3
[Errno 24] Too many open files: '/dev/null'
```

It can also be useful to limit the amount of CPU time a process should consume, to avoid eating up too much time. When the process runs past the allotted amount of time, it it sent a `SIGXCPU` signal.

```
import resource
import sys
import signal
import time

# Set up a signal handler to notify us
# when we run out of time.
def time_expired(n, stack):
    print 'EXPIRED :', time.ctime()
    raise SystemExit('(time ran out)')

signal.signal(signal.SIGXCPU, time_expired)

# Adjust the CPU time limit
soft, hard = resource.getrlimit(resource.RLIMIT_CPU)
print 'Soft limit starts as  :', soft

resource.setrlimit(resource.RLIMIT_CPU, (1, hard))

soft, hard = resource.getrlimit(resource.RLIMIT_CPU)
print 'Soft limit changed to :', soft
print

# Consume some CPU time in a pointless exercise
print 'Starting:', time.ctime()
for i in range(200000):
    for i in range(200000):
        v = i * i

# We should never make it this far
print 'Exiting :', time.ctime()
```

Normally the signal handler should flush all open files and close them, but in this case it just prints a message and exits.

```
$ python resource_setrlimit_cpu.py

Soft limit starts as  : 9223372036854775807
Soft limit changed to : 1

Starting: Thu Feb 21 06:36:32 2013
EXPIRED : Thu Feb 21 06:36:33 2013
(time ran out)
```

See also:

resource (http://docs.python.org/library/resource.html) The standard library documentation for this module.

`signal` For details on registering signal handlers.

CHAPTER

EIGHTEEN

INTERPROCESS COMMUNICATION AND NETWORKING

18.1 asynchat – Asynchronous protocol handler

Purpose Asynchronous network communication protocol handler

Available In 1.5.2 and later

The asynchat module builds on asyncore to make it easier to implement protocols based on passing messages back and forth between server and client. The async_chat class is an asyncore.dispatcher subclass that receives data and looks for a message terminator. Your subclass only needs to specify what to do when data comes in and how to respond once the terminator is found. Outgoing data is queued for transmission via FIFO objects managed by async_chat.

18.1.1 Message Terminators

Incoming messages are broken up based on *terminators*, controlled for each instance via set_terminator(). There are three possible configurations:

1. If a string argument is passed to set_terminator(), the message is considered complete when that string appears in the input data.
2. If a numeric argument is passed, the message is considered complete when that many bytes have been read.
3. If None is passed, message termination is not managed by async_chat.

The EchoServer example below uses both a simple string terminator and a message length terminator, depending on the context of the incoming data. The HTTP request handler example in the standard library documentation offers another example of how to change the terminator based on the context to differentiate between HTTP headers and the HTTP POST request body.

18.1.2 Server and Handler

To make it easier to understand how asynchat is different from asyncore, the examples here duplicate the functionality of the EchoServer example from the asyncore discussion. The same pieces are needed: a server object to accept connections, handler objects to deal with communication with each client, and client objects to initiate the conversation.

The EchoServer needed to work with asynchat is essentially the same as the one created for the asyncore example, with fewer logging calls because they are less interesting this time around:

```
import asyncore
import logging
import socket
```

```
from asynchat_echo_handler import EchoHandler

class EchoServer(asyncore.dispatcher):
    """Receives connections and establishes handlers for each client.
    """

    def __init__(self, address):
        asyncore.dispatcher.__init__(self)
        self.create_socket(socket.AF_INET, socket.SOCK_STREAM)
        self.bind(address)
        self.address = self.socket.getsockname()
        self.listen(1)
        return

    def handle_accept(self):
        # Called when a client connects to our socket
        client_info = self.accept()
        EchoHandler(sock=client_info[0])
        # We only want to deal with one client at a time,
        # so close as soon as we set up the handler.
        # Normally you would not do this and the server
        # would run forever or until it received instructions
        # to stop.
        self.handle_close()
        return

    def handle_close(self):
        self.close()
```

The `EchoHandler` is based on `asynchat.async_chat` instead of the `asyncore.dispatcher` this time around. It operates at a slightly higher level of abstraction, so reading and writing are handled automatically. The buffer needs to know four things:

- what to do with incoming data (by overriding `handle_incoming_data()`)
- how to recognize the end of an incoming message (via `set_terminator()`)
- what to do when a complete message is received (in `found_terminator()`)
- what data to send (using `push()`)

The example application has two operating modes. It is either waiting for a command of the form `ECHO length\n`, or waiting for the data to be echoed. The mode is toggled back and forth by setting an instance variable *process_data* to the method to be invoked when the terminator is found and then changing the terminator as appropriate.

```
import asynchat
import logging


class EchoHandler(asynchat.async_chat):
    """Handles echoing messages from a single client.
    """

    # Artificially reduce buffer sizes to illustrate
    # sending and receiving partial messages.
    ac_in_buffer_size = 64
    ac_out_buffer_size = 64

    def __init__(self, sock):
        self.received_data = []
        self.logger = logging.getLogger('EchoHandler')
        asynchat.async_chat.__init__(self, sock)
        # Start looking for the ECHO command
        self.process_data = self._process_command
        self.set_terminator('\n')
        return

    def collect_incoming_data(self, data):
        """Read an incoming message from the client and put it into our outgoing queue."""
        self.logger.debug('collect_incoming_data() -> (%d bytes)\n"""%s"""', len(data), data)
        self.received_data.append(data)

    def found_terminator(self):
        """The end of a command or message has been seen."""
        self.logger.debug('found_terminator()')
        self.process_data()

    def _process_command(self):
        """We have the full ECHO command"""
        command = ''.join(self.received_data)
        self.logger.debug('_process_command() "%s"', command)
        command_verb, command_arg = command.strip().split(' ')
        expected_data_len = int(command_arg)
        self.set_terminator(expected_data_len)
        self.process_data = self._process_message
        self.received_data = []

    def _process_message(self):
        """We have read the entire message to be sent back to the client"""
        to_echo = ''.join(self.received_data)
        self.logger.debug('_process_message() echoing\n"""%s"""', to_echo)
        self.push(to_echo)
        # Disconnect after sending the entire response
        # since we only want to do one thing at a time
        self.close_when_done()
```

Once the complete command is found, the handler switches to message-processing mode and waits for the complete set of text to be received. When all of the data is available, it is pushed onto the outgoing channel and set up the handler to be closed once the data is sent.

18.1.3 Client

The client works in much the same way as the handler. As with the `asyncore` implementation, the message to be sent is an argument to the client's constructor. When the socket connection is established, `handle_connect()` is called so the client can send the command and message data.

The command is pushed directly, but a special "producer" class is used for the message text. The producer is polled for chunks of data to send out over the network. When the producer returns an empty string, it is assumed to be empty and writing stops.

The client expects just the message data in response, so it sets an integer terminator and collects data in a list until the entire message has been received.

```
import asynchat
import logging
import socket
```

```
class EchoClient(asynchat.async_chat):
    """Sends messages to the server and receives responses.
    """

    # Artificially reduce buffer sizes to illustrate
    # sending and receiving partial messages.
    ac_in_buffer_size = 64
    ac_out_buffer_size = 64

    def __init__(self, host, port, message):
        self.message = message
        self.received_data = []
        self.logger = logging.getLogger('EchoClient')
        asynchat.async_chat.__init__(self)
        self.create_socket(socket.AF_INET, socket.SOCK_STREAM)
        self.logger.debug('connecting to %s', (host, port))
        self.connect((host, port))
        return

    def handle_connect(self):
        self.logger.debug('handle_connect()')
        # Send the command
        self.push('ECHO %d\n' % len(self.message))
        # Send the data
        self.push_with_producer(EchoProducer(self.message, buffer_size=self.ac_out_buffer_size))
        # We expect the data to come back as-is,
        # so set a length-based terminator
        self.set_terminator(len(self.message))

    def collect_incoming_data(self, data):
        """Read an incoming message from the client and put it into our outgoing queue."""
        self.logger.debug('collect_incoming_data() -> (%d)\n"""%s"""', len(data), data)
        self.received_data.append(data)

    def found_terminator(self):
        self.logger.debug('found_terminator()')
        received_message = ''.join(self.received_data)
        if received_message == self.message:
            self.logger.debug('RECEIVED COPY OF MESSAGE')
        else:
            self.logger.debug('ERROR IN TRANSMISSION')
            self.logger.debug('EXPECTED "%s"', self.message)
            self.logger.debug('RECEIVED "%s"', received_message)
        return

class EchoProducer(asynchat.simple_producer):

    logger = logging.getLogger('EchoProducer')

    def more(self):
        response = asynchat.simple_producer.more(self)
        self.logger.debug('more() -> (%s bytes)\n"""%s"""', len(response), response)
        return response
```

18.1.4 Putting It All Together

The main program for this example sets up the client and server in the same `asyncore` main loop.

```
import asyncore
import logging
import socket

from asynchat_echo_server import EchoServer
from asynchat_echo_client import EchoClient

logging.basicConfig(level=logging.DEBUG,
                    format='%(name)s: %(message)s',
                    )

address = ('localhost', 0) # let the kernel give us a port
server = EchoServer(address)
ip, port = server.address # find out what port we were given

message_data = open('lorem.txt', 'r').read()
client = EchoClient(ip, port, message=message_data)

asyncore.loop()
```

Normally you would have them in separate processes, but this makes it easier to show the combined output.

```
$ python asynchat_echo_main.py

EchoClient: connecting to ('127.0.0.1', 56193)
EchoClient: handle_connect()
EchoProducer: more() -> (64 bytes)
"""Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Donec
"""
EchoHandler: collect_incoming_data() -> (8 bytes)
"""ECHO 166"""
EchoHandler: found_terminator()
EchoHandler: _process_command() "ECHO 166"
EchoHandler: collect_incoming_data() -> (55 bytes)
"""Lorem ipsum dolor sit amet, consectetuer adipiscing eli"""
EchoProducer: more() -> (64 bytes)
"""egestas, enim et consectetuer ullamcorper, lectus ligula rutrum """
EchoHandler: collect_incoming_data() -> (64 bytes)
"""t. Donec
egestas, enim et consectetuer ullamcorper, lectus ligul"""
EchoProducer: more() -> (38 bytes)
"""leo, a
elementum elit tortor eu quam.
"""
EchoHandler: collect_incoming_data() -> (47 bytes)
"""a rutrum leo, a
elementum elit tortor eu quam.
"""
EchoHandler: found_terminator()
EchoHandler: _process_message() echoing
"""Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Donec
egestas, enim et consectetuer ullamcorper, lectus ligula rutrum leo, a
elementum elit tortor eu quam.
"""
EchoProducer: more() -> (0 bytes)
```

```
""""""
EchoClient: collect_incoming_data() -> (64)
"""Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Donec
"""
EchoClient: collect_incoming_data() -> (64)
"""egestas, enim et consectetuer ullamcorper, lectus ligula rutrum """
EchoClient: collect_incoming_data() -> (38)
"""leo, a
elementum elit tortor eu quam.
"""
EchoClient: found_terminator()
EchoClient: RECEIVED COPY OF MESSAGE
```

See also:

asyncchat **(http://docs.python.org/library/asynchat.html)** The standard library documentation for this module.

`asyncore` The asyncore module implements an lower-level asynchronous I/O event loop.

18.2 asyncore – Asynchronous I/O handler

Purpose Asynchronous I/O handler

Available In 1.5.2 and later

The asyncore module includes tools for working with I/O objects such as sockets so they can be managed asynchronously (instead of, for example, using threads). The main class provided is `dispatcher`, a wrapper around a socket that provides hooks for handling events like connecting, reading, and writing when invoked from the main loop function, `loop()`.

18.2.1 Clients

To create an asyncore-based client, subclass `dispatcher` and provide implementations for creating the socket, reading, and writing. Let's examine this HTTP client, based on the one from the standard library documentation.

```python
import asyncore
import logging
import socket
from cStringIO import StringIO
import urlparse

class HttpClient(asyncore.dispatcher):

    def __init__(self, url):
        self.url = url
        self.logger = logging.getLogger(self.url)
        self.parsed_url = urlparse.urlparse(url)
        asyncore.dispatcher.__init__(self)
        self.write_buffer = 'GET %s HTTP/1.0\r\n\r\n' % self.url
        self.read_buffer = StringIO()
        self.create_socket(socket.AF_INET, socket.SOCK_STREAM)
        address = (self.parsed_url.netloc, 80)
        self.logger.debug('connecting to %s', address)
        self.connect(address)

    def handle_connect(self):
        self.logger.debug('handle_connect()')

    def handle_close(self):
        self.logger.debug('handle_close()')
        self.close()

    def writable(self):
        is_writable = (len(self.write_buffer) > 0)
        if is_writable:
            self.logger.debug('writable() -> %s', is_writable)
        return is_writable

    def readable(self):
        self.logger.debug('readable() -> True')
        return True

    def handle_write(self):
        sent = self.send(self.write_buffer)
        self.logger.debug('handle_write() -> "%s"', self.write_buffer[:sent])
        self.write_buffer = self.write_buffer[sent:]

    def handle_read(self):
        data = self.recv(8192)
        self.logger.debug('handle_read() -> %d bytes', len(data))
        self.read_buffer.write(data)

if __name__ == '__main__':
    logging.basicConfig(level=logging.DEBUG,
                        format='%(name)s: %(message)s',
                        )

    clients = [
        HttpClient('http://www.python.org/'),
        HttpClient('http://www.doughellmann.com/PyMOTW/contents.html'),
        ]

    logging.debug('LOOP STARTING')

    asyncore.loop()

    logging.debug('LOOP DONE')

    for c in clients:
        response_body = c.read_buffer.getvalue()
        print c.url, 'got', len(response_body), 'bytes'
```

First, the socket is created in `__init__()` using the base class method `create_socket()`. Alternative implementations of the method may be provided, but in this case we want a TCP/IP socket so the base class version is sufficient.

The `handle_connect()` hook is present simply to illustrate when it is called. Other types of clients that need to do some sort of hand-shaking or protocol negotiation should do the work in `handle_connect()`.

`handle_close()` is similarly presented for the purposes of showing when the method is called. The base class version closes the socket correctly, so if you don't need to do extra cleanup on close you can leave the method out.

The asyncore loop uses `writable()` and its sibling method `readable()` to decide what actions to take with each dispatcher. Actual use of poll() or select() on the sockets or file descriptors managed by each dispatcher is handled inside the `asyncore` code, so you don't need to do that yourself. Simply indicate whether the dispatcher cares at all about reading or writing. In the case of this HTTP client, `writable()` returns True as long as there is data from the request to send to the server. `readable()` always returns True because we want to read all of the data.

Each time through the loop when `writable()` responds positively, `handle_write()` is invoked. In this version, the HTTP request string that was built in `__init__()` is sent to the server and the write buffer is reduced by the amount successfully sent.

Similarly, when `readable()` responds positively and there is data to read, `handle_read()` is invoked.

The example below the `__main__` test configures logging for debugging then creates two clients to download two separate web pages. Creating the clients registers them in a "map" kept internally by asyncore. The downloading occurs as the loop iterates over the clients. When the client reads 0 bytes from a socket that seems readable, the condition is interpreted as a closed connection and `handle_close()` is called.

One example of how this client app may run is:

```
$ python asyncore_http_client.py

http://www.python.org/: connecting to ('www.python.org', 80)
http://www.doughellmann.com/PyMOTW/contents.html: connecting to ('www.doughellmann.com', 80)
root: LOOP STARTING
http://www.python.org/: readable() -> True
http://www.python.org/: writable() -> True
http://www.doughellmann.com/PyMOTW/contents.html: readable() -> True
http://www.doughellmann.com/PyMOTW/contents.html: writable() -> True
http://www.python.org/: handle_connect()
http://www.python.org/: handle_write() -> "GET http://www.python.org/ HTTP/1.0

"
http://www.python.org/: readable() -> True
http://www.doughellmann.com/PyMOTW/contents.html: readable() -> True
http://www.doughellmann.com/PyMOTW/contents.html: writable() -> True
http://www.doughellmann.com/PyMOTW/contents.html: handle_connect()
http://www.doughellmann.com/PyMOTW/contents.html: handle_write() -> "GET http://www.doughellmann.com

"
http://www.python.org/: readable() -> True
http://www.doughellmann.com/PyMOTW/contents.html: readable() -> True
http://www.python.org/: handle_read() -> 2896 bytes
http://www.python.org/: readable() -> True
http://www.doughellmann.com/PyMOTW/contents.html: readable() -> True
http://www.python.org/: handle_read() -> 1448 bytes
http://www.python.org/: readable() -> True
http://www.doughellmann.com/PyMOTW/contents.html: readable() -> True
http://www.python.org/: handle_read() -> 1448 bytes
http://www.python.org/: readable() -> True
http://www.doughellmann.com/PyMOTW/contents.html: readable() -> True
http://www.python.org/: handle_read() -> 1448 bytes
http://www.python.org/: readable() -> True
http://www.doughellmann.com/PyMOTW/contents.html: readable() -> True
http://www.python.org/: handle_read() -> 1448 bytes
http://www.python.org/: readable() -> True
http://www.doughellmann.com/PyMOTW/contents.html: readable() -> True
http://www.python.org/: handle_read() -> 1448 bytes
http://www.python.org/: readable() -> True
http://www.doughellmann.com/PyMOTW/contents.html: readable() -> True
http://www.python.org/: handle_read() -> 1448 bytes
http://www.python.org/: readable() -> True
http://www.doughellmann.com/PyMOTW/contents.html: readable() -> True
http://www.python.org/: handle_read() -> 1448 bytes
```

```
http://www.python.org/: readable() -> True
http://www.doughellmann.com/PyMOTW/contents.html: readable() -> True
http://www.python.org/: handle_read() -> 1448 bytes
http://www.python.org/: readable() -> True
http://www.doughellmann.com/PyMOTW/contents.html: readable() -> True
http://www.python.org/: handle_read() -> 1448 bytes
http://www.python.org/: readable() -> True
http://www.doughellmann.com/PyMOTW/contents.html: readable() -> True
http://www.python.org/: handle_read() -> 1448 bytes
http://www.python.org/: readable() -> True
http://www.doughellmann.com/PyMOTW/contents.html: readable() -> True
http://www.python.org/: handle_read() -> 1448 bytes
http://www.python.org/: readable() -> True
http://www.doughellmann.com/PyMOTW/contents.html: readable() -> True
http://www.python.org/: handle_read() -> 1448 bytes
http://www.python.org/: readable() -> True
http://www.doughellmann.com/PyMOTW/contents.html: readable() -> True
http://www.python.org/: handle_read() -> 1432 bytes
http://www.python.org/: readable() -> True
http://www.doughellmann.com/PyMOTW/contents.html: readable() -> True
http://www.python.org/: handle_close()
http://www.python.org/: handle_read() -> 0 bytes
http://www.doughellmann.com/PyMOTW/contents.html: readable() -> True
http://www.doughellmann.com/PyMOTW/contents.html: handle_read() -> 481 bytes
http://www.doughellmann.com/PyMOTW/contents.html: readable() -> True
http://www.doughellmann.com/PyMOTW/contents.html: handle_close()
http://www.doughellmann.com/PyMOTW/contents.html: handle_read() -> 0 bytes
root: LOOP DONE
http://www.python.org/ got 21704 bytes
http://www.doughellmann.com/PyMOTW/contents.html got 481 bytes
```

18.2.2 Servers

The example below illustrates using asyncore on the server by re-implementing the EchoServer from the `SocketServer` examples. There are three classes: `EchoServer` receives incoming connections from clients and creates `EchoHandler` instances to deal with each. The `EchoClient` is an asyncore dispatcher similar to the HttpClient defined above.

```python
import asyncore
import logging

class EchoServer(asyncore.dispatcher):
    """Receives connections and establishes handlers for each client.
    """

    def __init__(self, address):
        self.logger = logging.getLogger('EchoServer')
        asyncore.dispatcher.__init__(self)
        self.create_socket(socket.AF_INET, socket.SOCK_STREAM)
        self.bind(address)
        self.address = self.socket.getsockname()
        self.logger.debug('binding to %s', self.address)
        self.listen(1)
        return

    def handle_accept(self):
        # Called when a client connects to our socket
        client_info = self.accept()
        self.logger.debug('handle_accept() -> %s', client_info[1])
        EchoHandler(sock=client_info[0])
        # We only want to deal with one client at a time,
        # so close as soon as we set up the handler.
        # Normally you would not do this and the server
        # would run forever or until it received instructions
        # to stop.
        self.handle_close()
        return

    def handle_close(self):
        self.logger.debug('handle_close()')
        self.close()
        return

class EchoHandler(asyncore.dispatcher):
    """Handles echoing messages from a single client.
    """

    def __init__(self, sock, chunk_size=256):
        self.chunk_size = chunk_size
        self.logger = logging.getLogger('EchoHandler%s' % str(sock.getsockname()))
        asyncore.dispatcher.__init__(self, sock=sock)
        self.data_to_write = []
        return

    def writable(self):
        """We want to write if we have received data."""
        response = bool(self.data_to_write)
        self.logger.debug('writable() -> %s', response)
        return response

    def handle_write(self):
        """Write as much as possible of the most recent message we have received."""
        data = self.data_to_write.pop()
        sent = self.send(data[:self.chunk_size])
        if sent < len(data):
            remaining = data[sent:]
            self.data.to_write.append(remaining)
        self.logger.debug('handle_write() -> (%d) "%s"', sent, data[:sent])
        if not self.writable():
            self.handle_close()

    def handle_read(self):
        """Read an incoming message from the client and put it into our outgoing queue."""
        data = self.recv(self.chunk_size)
        self.logger.debug('handle_read() -> (%d) "%s"', len(data), data)
        self.data_to_write.insert(0, data)

    def handle_close(self):
        self.logger.debug('handle_close()')
        self.close()


class EchoClient(asyncore.dispatcher):
    """Sends messages to the server and receives responses.
    """
    def __init__(self, host, port, message, chunk_size=512):
        self.message = message
        self.to_send = message
        self.received_data = []
        self.chunk_size = chunk_size
        self.logger = logging.getLogger('EchoClient')
        asyncore.dispatcher.__init__(self)
        self.create_socket(socket.AF_INET, socket.SOCK_STREAM)
        self.logger.debug('connecting to %s', (host, port))
        self.connect((host, port))
        return

    def handle_connect(self):
        self.logger.debug('handle_connect()')

    def handle_close(self):
        self.logger.debug('handle_close()')
        self.close()
        received_message = ''.join(self.received_data)
        if received_message == self.message:
            self.logger.debug('RECEIVED COPY OF MESSAGE')
        else:
            self.logger.debug('ERROR IN TRANSMISSION')
            self.logger.debug('EXPECTED "%s"', self.message)
            self.logger.debug('RECEIVED "%s"', received_message)
        return

    def writable(self):
        self.logger.debug('writable() -> %s', bool(self.to_send))
        return bool(self.to_send)

    def handle_write(self):
        sent = self.send(self.to_send[:self.chunk_size])
        self.logger.debug('handle_write() -> (%d) "%s"', sent, self.to_send[:sent])
        self.to_send = self.to_send[sent:]

    def handle_read(self):
        data = self.recv(self.chunk_size)
        self.logger.debug('handle_read() -> (%d) "%s"', len(data), data)
        self.received_data.append(data)


if __name__ == '__main__':
    import socket

    logging.basicConfig(level=logging.DEBUG,
                        format='%(name)s: %(message)s',
                        )

    address = ('localhost', 0) # let the kernel give us a port
    server = EchoServer(address)
    ip, port = server.address # find out what port we were given

    client = EchoClient(ip, port, message=open('lorem.txt', 'r').read())

    asyncore.loop()
```

The EchoServer and EchoHandler are defined in separate classes because they do different things. When EchoServer accepts a connection, a new socket is established. Rather than try to dispatch to individual clients within EchoServer, an EchoHandler is created to take advantage of the socket map maintained by asyncore.

```
$ python asyncore_echo_server.py

EchoServer: binding to ('127.0.0.1', 56199)
EchoClient: connecting to ('127.0.0.1', 56199)
EchoClient: writable() -> True
EchoServer: handle_accept() -> ('127.0.0.1', 56200)
EchoServer: handle_close()
EchoClient: handle_connect()
EchoClient: handle_write() -> (512) "Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Donec
egestas, enim et consectetuer ullamcorper, lectus ligula rutrum leo, a
elementum elit tortor eu quam. Duis tincidunt nisi ut ante. Nulla
facilisi. Sed tristique eros eu libero. Pellentesque vel arcu. Vivamus
purus orci, iaculis ac, suscipit sit amet, pulvinar eu,
lacus. Praesent placerat tortor sed nisl. Nunc blandit diam egestas
dui. Pellentesque habitant morbi tristique senectus et netus et
malesuada fames ac turpis egestas. Aliquam viverra f"
EchoClient: writable() -> True
EchoHandler('127.0.0.1', 56199): writable() -> False
EchoHandler('127.0.0.1', 56199): handle_read() -> (256) "Lorem ipsum dolor sit amet, consectetuer adi
egestas, enim et consectetuer ullamcorper, lectus ligula rutrum leo, a
elementum elit tortor eu quam. Duis tincidunt nisi ut ante. Nulla
facilisi. Sed tristique eros eu libero. Pellentesque ve"
EchoClient: handle_write() -> (225) "ringilla
leo. Nulla feugiat augue eleifend nulla. Vivamus mauris. Vivamus sed
mauris in nibh placerat egestas. Suspendisse potenti. Mauris massa. Ut
eget velit auctor tortor blandit sollicitudin. Suspendisse imperdiet
justo.
"
EchoClient: writable() -> False
EchoHandler('127.0.0.1', 56199): writable() -> True
EchoHandler('127.0.0.1', 56199): handle_read() -> (256) "l arcu. Vivamus
purus orci, iaculis ac, suscipit sit amet, pulvinar eu,
lacus. Praesent placerat tortor sed nisl. Nunc blandit diam egestas
dui. Pellentesque habitant morbi tristique senectus et netus et
malesuada fames ac turpis egestas. Aliquam viverra f"
EchoHandler('127.0.0.1', 56199): handle_write() -> (256) "Lorem ipsum dolor sit amet, consectetuer ac
egestas, enim et consectetuer ullamcorper, lectus ligula rutrum leo, a
elementum elit tortor eu quam. Duis tincidunt nisi ut ante. Nulla
facilisi. Sed tristique eros eu libero. Pellentesque ve"
EchoHandler('127.0.0.1', 56199): writable() -> True
EchoClient: writable() -> False
EchoHandler('127.0.0.1', 56199): writable() -> True
EchoClient: handle_read() -> (256) "Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Donec
egestas, enim et consectetuer ullamcorper, lectus ligula rutrum leo, a
elementum elit tortor eu quam. Duis tincidunt nisi ut ante. Nulla
facilisi. Sed tristique eros eu libero. Pellentesque ve"
EchoHandler('127.0.0.1', 56199): handle_read() -> (225) "ringilla
leo. Nulla feugiat augue eleifend nulla. Vivamus mauris. Vivamus sed
mauris in nibh placerat egestas. Suspendisse potenti. Mauris massa. Ut
eget velit auctor tortor blandit sollicitudin. Suspendisse imperdiet
justo.
"
EchoHandler('127.0.0.1', 56199): handle_write() -> (256) "l arcu. Vivamus
purus orci, iaculis ac, suscipit sit amet, pulvinar eu,
lacus. Praesent placerat tortor sed nisl. Nunc blandit diam egestas
dui. Pellentesque habitant morbi tristique senectus et netus et
```

```
malesuada fames ac turpis egestas. Aliquam viverra f"
EchoHandler('127.0.0.1', 56199): writable() -> True
EchoClient: writable() -> False
EchoHandler('127.0.0.1', 56199): writable() -> True
EchoClient: handle_read() -> (256) "l arcu. Vivamus
purus orci, iaculis ac, suscipit sit amet, pulvinar eu,
lacus. Praesent placerat tortor sed nisl. Nunc blandit diam egestas
dui. Pellentesque habitant morbi tristique senectus et netus et
malesuada fames ac turpis egestas. Aliquam viverra f"
EchoHandler('127.0.0.1', 56199): handle_write() -> (225) "ringilla
leo. Nulla feugiat augue eleifend nulla. Vivamus mauris. Vivamus sed
mauris in nibh placerat egestas. Suspendisse potenti. Mauris massa. Ut
eget velit auctor tortor blandit sollicitudin. Suspendisse imperdiet
justo.
"
EchoHandler('127.0.0.1', 56199): writable() -> False
EchoHandler('127.0.0.1', 56199): handle_close()
EchoClient: writable() -> False
EchoClient: handle_read() -> (225) "ringilla
leo. Nulla feugiat augue eleifend nulla. Vivamus mauris. Vivamus sed
mauris in nibh placerat egestas. Suspendisse potenti. Mauris massa. Ut
eget velit auctor tortor blandit sollicitudin. Suspendisse imperdiet
justo.
"
EchoClient: writable() -> False
EchoClient: handle_close()
EchoClient: RECEIVED COPY OF MESSAGE
EchoClient: handle_read() -> (0) ""
```

In this example the server, handler, and client objects are all being maintained in the same socket map by asyncore in a single process. To separate the server from the client, simply instantiate them from separate scripts and run `asyncore.loop()` in both. When a dispatcher is closed, it is removed from the map maintained by asyncore and the loop exits when the map is empty.

18.2.3 Working with Other Event Loops

It is sometimes necessary to integrate the asyncore event loop with an event loop from the parent application. For example, a GUI application would not want the UI to block until all asynchronous transfers are handled – that would defeat the purpose of making them asynchronous. To make this sort of integration easy, `asyncore.loop()` accepts arguments to set a timeout and to limit the number of times the loop is run. We can see their effect on the client by re-using HttpClient from the first example.

```python
import asyncore
import logging

from asyncore_http_client import HttpClient

logging.basicConfig(level=logging.DEBUG,
                    format='%(name)s: %(message)s',
                    )

clients = [
    HttpClient('http://www.doughellmann.com/PyMOTW/contents.html'),
    HttpClient('http://www.python.org/'),
    ]

loop_counter = 0
```

```
while asyncore.socket_map:
    loop_counter += 1
    logging.debug('loop_counter=%s', loop_counter)
    asyncore.loop(timeout=1, count=1)
```

Here we see that the client is only asked to read or data once per call into `asyncore.loop()`. Instead of our own `while` loop, we could call `asyncore.loop()` like this from a GUI toolkit idle handler or other mechanism for doing a small amount of work when the UI is not busy with other event handlers.

```
$ python asyncore_loop.py

http://www.doughellmann.com/PyMOTW/contents.html: connecting to ('www.doughellmann.com', 80)
http://www.python.org/: connecting to ('www.python.org', 80)
root: loop_counter=1
http://www.doughellmann.com/PyMOTW/contents.html: readable() -> True
http://www.doughellmann.com/PyMOTW/contents.html: writable() -> True
http://www.python.org/: readable() -> True
http://www.python.org/: writable() -> True
http://www.doughellmann.com/PyMOTW/contents.html: handle_connect()
http://www.doughellmann.com/PyMOTW/contents.html: handle_write() -> "GET http://www.doughellmann.com/

"
root: loop_counter=2
http://www.doughellmann.com/PyMOTW/contents.html: readable() -> True
http://www.python.org/: readable() -> True
http://www.python.org/: writable() -> True
http://www.python.org/: handle_connect()
http://www.python.org/: handle_write() -> "GET http://www.python.org/ HTTP/1.0

"
root: loop_counter=3
http://www.doughellmann.com/PyMOTW/contents.html: readable() -> True
http://www.python.org/: readable() -> True
http://www.python.org/: handle_read() -> 2896 bytes
root: loop_counter=4
http://www.doughellmann.com/PyMOTW/contents.html: readable() -> True
http://www.python.org/: readable() -> True
http://www.python.org/: handle_read() -> 1448 bytes
root: loop_counter=5
http://www.doughellmann.com/PyMOTW/contents.html: readable() -> True
http://www.python.org/: readable() -> True
http://www.python.org/: handle_read() -> 1448 bytes
root: loop_counter=6
http://www.doughellmann.com/PyMOTW/contents.html: readable() -> True
http://www.python.org/: readable() -> True
http://www.python.org/: handle_read() -> 1448 bytes
root: loop_counter=7
http://www.doughellmann.com/PyMOTW/contents.html: readable() -> True
http://www.python.org/: readable() -> True
http://www.python.org/: handle_read() -> 1448 bytes
root: loop_counter=8
http://www.doughellmann.com/PyMOTW/contents.html: readable() -> True
http://www.python.org/: readable() -> True
http://www.python.org/: handle_read() -> 1448 bytes
root: loop_counter=9
http://www.doughellmann.com/PyMOTW/contents.html: readable() -> True
http://www.python.org/: readable() -> True
http://www.python.org/: handle_read() -> 1448 bytes
```

```
root: loop_counter=10
http://www.doughellmann.com/PyMOTW/contents.html: readable() -> True
http://www.python.org/: readable() -> True
http://www.python.org/: handle_read() -> 1448 bytes
root: loop_counter=11
http://www.doughellmann.com/PyMOTW/contents.html: readable() -> True
http://www.python.org/: readable() -> True
http://www.python.org/: handle_read() -> 1448 bytes
root: loop_counter=12
http://www.doughellmann.com/PyMOTW/contents.html: readable() -> True
http://www.python.org/: readable() -> True
http://www.python.org/: handle_read() -> 1448 bytes
root: loop_counter=13
http://www.doughellmann.com/PyMOTW/contents.html: readable() -> True
http://www.python.org/: readable() -> True
http://www.python.org/: handle_read() -> 1448 bytes
root: loop_counter=14
http://www.doughellmann.com/PyMOTW/contents.html: readable() -> True
http://www.python.org/: readable() -> True
http://www.python.org/: handle_read() -> 1448 bytes
root: loop_counter=15
http://www.doughellmann.com/PyMOTW/contents.html: readable() -> True
http://www.python.org/: readable() -> True
http://www.python.org/: handle_read() -> 1448 bytes
root: loop_counter=16
http://www.doughellmann.com/PyMOTW/contents.html: readable() -> True
http://www.python.org/: readable() -> True
http://www.python.org/: handle_read() -> 1432 bytes
root: loop_counter=17
http://www.doughellmann.com/PyMOTW/contents.html: readable() -> True
http://www.python.org/: readable() -> True
http://www.python.org/: handle_close()
http://www.python.org/: handle_read() -> 0 bytes
root: loop_counter=18
http://www.doughellmann.com/PyMOTW/contents.html: readable() -> True
root: loop_counter=19
http://www.doughellmann.com/PyMOTW/contents.html: readable() -> True
http://www.doughellmann.com/PyMOTW/contents.html: handle_read() -> 481 bytes
root: loop_counter=20
http://www.doughellmann.com/PyMOTW/contents.html: readable() -> True
http://www.doughellmann.com/PyMOTW/contents.html: handle_close()
http://www.doughellmann.com/PyMOTW/contents.html: handle_read() -> 0 bytes
```

18.2.4 Working with Files

Normally you would want to use asyncore with sockets, but there are times when it is useful to read files asynchronously, too (to use files when testing network servers without requiring the network setup, or to read or write large data files in parts). For these situations, asyncore provides the `file_dispatcher` and `file_wrapper` classes.

```python
import asyncore
import os

class FileReader(asyncore.file_dispatcher):

    def writable(self):
        return False
    def handle_read(self):
        data = self.recv(256)
        print 'READ: (%d) "%s"' % (len(data), data)

    def handle_expt(self):
        # Ignore events that look like out of band data
        pass

    def handle_close(self):
        self.close()

lorem_fd = os.open('lorem.txt', os.O_RDONLY)
reader = FileReader(lorem_fd)
asyncore.loop()
```

This example was tested under Python 2.5.2, so I am using `os.open()` to get a file descriptor for the file. For Python 2.6 and later, `file_dispatcher` automatically converts anything with a `fileno()` method to a file descriptor.

```
$ python asyncore_file_dispatcher.py

READ: (256) "Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Donec
egestas, enim et consectetuer ullamcorper, lectus ligula rutrum leo, a
elementum elit tortor eu quam. Duis tincidunt nisi ut ante. Nulla
facilisi. Sed tristique eros eu libero. Pellentesque ve"
READ: (256) "l arcu. Vivamus
purus orci, iaculis ac, suscipit sit amet, pulvinar eu,
lacus. Praesent placerat tortor sed nisl. Nunc blandit diam egestas
dui. Pellentesque habitant morbi tristique senectus et netus et
malesuada fames ac turpis egestas. Aliquam viverra f"
READ: (225) "ringilla
leo. Nulla feugiat augue eleifend nulla. Vivamus mauris. Vivamus sed
mauris in nibh placerat egestas. Suspendisse potenti. Mauris massa. Ut
eget velit auctor tortor blandit sollicitudin. Suspendisse imperdiet
justo.
"
READ: (0) ""
```

See also:

asyncore (http://docs.python.org/library/asyncore.html) The standard library documentation for this module.

`asynchat` The asynchat module builds on asyncore to make it easier to create clients and servers communicate by passing messages back and forth using a set protocol.

`SocketServer` The SocketServer module article includes another example of the EchoServer with threading and forking variants.

18.3 signal – Receive notification of asynchronous system events

Purpose Receive notification of asynchronous system events

Available In 1.4 and later

Note: Programming with Unix signal handlers is a non-trivial endeavor. This is an introduction, and does not include all of the details you may need to use signals successfully on every platform. There is some degree of standardization across versions of Unix, but there is also some variation, so consult documentation for your OS if you run into trouble.

Signals are an operating system feature that provide a means of notifying your program of an event, and having it handled asynchronously. They can be generated by the system itself, or sent from one process to another. Since signals interrupt the regular flow of your program, it is possible that some operations (especially I/O) may produce error if a signal is received in the middle.

Signals are identified by integers and are defined in the operating system C headers. Python exposes the signals appropriate for the platform as symbols in the `signal` module. For the examples below, I will use `SIGINT` and `SIGUSR1`. Both are typically defined for all Unix and Unix-like systems.

18.3.1 Receiving Signals

As with other forms of event-based programming, signals are received by establishing a callback function, called a *signal handler*, that is invoked when the signal occurs. The arguments to your signal handler are the signal number and the stack frame from the point in your program that was interrupted by the signal.

```
import signal
import os
import time

def receive_signal(signum, stack):
    print 'Received:', signum

signal.signal(signal.SIGUSR1, receive_signal)
signal.signal(signal.SIGUSR2, receive_signal)

print 'My PID is:', os.getpid()

while True:
    print 'Waiting...'
    time.sleep(3)
```

This relatively simple example script loops indefinitely, pausing for a few seconds each time. When a signal comes in, the sleep call is interrupted and the signal handler `receive_signal()` prints the signal number. When the signal handler returns, the loop continues.

To send signals to the running program, I use the command line program kill. To produce the output below, I ran `signal_signal.py` in one window, then `kill -USR1 $pid`, `kill -USR2 $pid`, and `kill -INT $pid` in another.

```
$ python signal_signal.py
My PID is: 71387
Waiting...
Waiting...
Waiting...
Received: 30
Waiting...
Waiting...
Received: 31
Waiting...
Waiting...
Traceback (most recent call last):
  File "signal_signal.py", line 25, in <module>
    time.sleep(3)
KeyboardInterrupt
```

18.3.2 getsignal()

To see what signal handlers are registered for a signal, use `getsignal()`. Pass the signal number as argument. The return value is the registered handler, or one of the special values `signal.SIG_IGN` (if the signal is being ignored), `signal.SIG_DFL` (if the default behavior is being used), or `None` (if the existing signal handler was registered from C, rather than Python).

```
import signal

def alarm_received(n, stack):
    return

signal.signal(signal.SIGALRM, alarm_received)

signals_to_names = {}
for n in dir(signal):
    if n.startswith('SIG') and not n.startswith('SIG_'):
        signals_to_names[getattr(signal, n)] = n

for s, name in sorted(signals_to_names.items()):
    handler = signal.getsignal(s)
    if handler is signal.SIG_DFL:
        handler = 'SIG_DFL'
    elif handler is signal.SIG_IGN:
        handler = 'SIG_IGN'
    print '%-10s (%2d):' % (name, s), handler
```

Again, since each OS may have different signals defined, the output you see from running this on other systems may vary. This is from OS X:

```
$ python signal_getsignal.py
SIGHUP     ( 1): SIG_DFL
SIGINT     ( 2): &lt;built-in function default_int_handler&gt;
SIGQUIT    ( 3): SIG_DFL
SIGILL     ( 4): SIG_DFL
SIGTRAP    ( 5): SIG_DFL
SIGIOT     ( 6): SIG_DFL
SIGEMT     ( 7): SIG_DFL
SIGFPE     ( 8): SIG_DFL
SIGKILL    ( 9): None
SIGBUS     (10): SIG_DFL
SIGSEGV    (11): SIG_DFL
SIGSYS     (12): SIG_DFL
SIGPIPE    (13): SIG_IGN
SIGALRM    (14): &lt;function alarm_received at 0x7c3f0&gt;
SIGTERM    (15): SIG_DFL
SIGURG     (16): SIG_DFL
SIGSTOP    (17): None
SIGTSTP    (18): SIG_DFL
SIGCONT    (19): SIG_DFL
SIGCHLD    (20): SIG_DFL
SIGTTIN    (21): SIG_DFL
SIGTTOU    (22): SIG_DFL
SIGIO      (23): SIG_DFL
SIGXCPU    (24): SIG_DFL
SIGXFSZ    (25): SIG_IGN
SIGVTALRM  (26): SIG_DFL
SIGPROF    (27): SIG_DFL
SIGWINCH   (28): SIG_DFL
```

```
SIGINFO     (29): SIG_DFL
SIGUSR1     (30): SIG_DFL
SIGUSR2     (31): SIG_DFL
```

18.3.3 Sending Signals

The function for sending signals is `os.kill()`. Its use is covered in the section on the `os` module, *Creating Processes with os.fork()*.

18.3.4 Alarms

Alarms are a special sort of signal, where your program asks the OS to notify it after some period of time has elapsed. As the standard module documentation for os (http://docs.python.org/lib/node545.html) points out, this is useful for avoiding blocking indefinitely on an I/O operation or other system call.

```python
import signal
import time

def receive_alarm(signum, stack):
    print 'Alarm :', time.ctime()

# Call receive_alarm in 2 seconds
signal.signal(signal.SIGALRM, receive_alarm)
signal.alarm(2)

print 'Before:', time.ctime()
time.sleep(4)
print 'After :', time.ctime()
```

In this example, the call to `sleep()` does not last the full 4 seconds.

```
$ python signal_alarm.py
Before: Sun Aug 17 10:51:09 2008
Alarm : Sun Aug 17 10:51:11 2008
After : Sun Aug 17 10:51:11 2008
```

18.3.5 Ignoring Signals

To ignore a signal, register `SIG_IGN` as the handler. This script replaces the default handler for `SIGINT` with `SIG_IGN`, and registers a handler for `SIGUSR1`. Then it uses `signal.pause()` to wait for a signal to be received.

```python
import signal
import os
import time

def do_exit(sig, stack):
    raise SystemExit('Exiting')

signal.signal(signal.SIGINT, signal.SIG_IGN)
signal.signal(signal.SIGUSR1, do_exit)

print 'My PID:', os.getpid()

signal.pause()
```

Normally `SIGINT` (the signal sent by the shell to your program when you hit Ctrl-C) raises a *KeyboardInterrupt*. In this example, we ignore `SIGINT` and raise *SystemExit* when we see `SIGUSR1`. Each `^C` represents an attempt to use Ctrl-C to kill the script from the terminal. Using `kill -USR1 72598` from another terminal eventually causes the script to exit.

```
$ python signal_ignore.py
My PID: 72598
^C^C^C^CExiting
```

18.3.6 Signals and Threads

Signals and threads don't generally mix well because only the main thread of a process will receive signals. The following example sets up a signal handler, waits for the signal in one thread, and sends the signal from another.

```
import signal
import threading
import os
import time

def signal_handler(num, stack):
    print 'Received signal %d in %s' % (num, threading.currentThread())

signal.signal(signal.SIGUSR1, signal_handler)

def wait_for_signal():
    print 'Waiting for signal in', threading.currentThread()
    signal.pause()
    print 'Done waiting'

# Start a thread that will not receive the signal
receiver = threading.Thread(target=wait_for_signal, name='receiver')
receiver.start()
time.sleep(0.1)

def send_signal():
    print 'Sending signal in', threading.currentThread()
    os.kill(os.getpid(), signal.SIGUSR1)

sender = threading.Thread(target=send_signal, name='sender')
sender.start()
sender.join()

# Wait for the thread to see the signal (not going to happen!)
print 'Waiting for', receiver
signal.alarm(2)
receiver.join()
```

Notice that the signal handlers were all registered in the main thread. This is a requirement of the signal module implementation for Python, regardless of underlying platform support for mixing threads and signals. Although the receiver thread calls `signal.pause()`, it does not receive the signal. The `signal.alarm(2)` call near the end of the example prevents an infinite block, since the receiver thread will never exit.

```
$ python signal_threads.py
Waiting for signal in <Thread(receiver, started)>
Sending signal in <Thread(sender, started)>
Received signal 30 in <_MainThread(MainThread, started)>
```

```
Waiting for <Thread(receiver, started)>
Alarm clock
```

Although alarms can be set in threads, they are also received by the main thread.

```
import signal
import time
import threading

def signal_handler(num, stack):
    print time.ctime(), 'Alarm in', threading.currentThread()

signal.signal(signal.SIGALRM, signal_handler)

def use_alarm():
    print time.ctime(), 'Setting alarm in', threading.currentThread()
    signal.alarm(1)
    print time.ctime(), 'Sleeping in', threading.currentThread()
    time.sleep(3)
    print time.ctime(), 'Done with sleep'

# Start a thread that will not receive the signal
alarm_thread = threading.Thread(target=use_alarm, name='alarm_thread')
alarm_thread.start()
time.sleep(0.1)

# Wait for the thread to see the signal (not going to happen!)
print time.ctime(), 'Waiting for', alarm_thread
alarm_thread.join()

print time.ctime(), 'Exiting normally'
```

Notice that the alarm does not abort the `sleep()` call in `use_alarm()`.

```
$ python signal_threads_alarm.py
Sun Aug 17 12:06:00 2008 Setting alarm in <Thread(alarm_thread, started)>
Sun Aug 17 12:06:00 2008 Sleeping in <Thread(alarm_thread, started)>
Sun Aug 17 12:06:00 2008 Waiting for <Thread(alarm_thread, started)>;
Sun Aug 17 12:06:03 2008 Done with sleep
Sun Aug 17 12:06:03 2008 Alarm in <_MainThread(MainThread, started)>
Sun Aug 17 12:06:03 2008 Exiting normally
```

See also:

signal (http://docs.python.org/lib/module-signal.html) Standard library documentation for this module.

Creating Processes with os.fork() The `kill()` function can be used to send signals between processes.

18.4 subprocess – Work with additional processes

Purpose Spawn and communicate with additional processes.

Available In 2.4 and later

The `subprocess` module provides a consistent interface to creating and working with additional processes. It offers a higher-level interface than some of the other available modules, and is intended to replace functions such as `os.system()`, `os.spawn*()`, `os.popen*()`, `popen2.*()` and `commands.*()`. To make it easier to compare subprocess with those other modules, many of the examples here re-create the ones used for os and popen.

The subprocess module defines one class, Popen and a few wrapper functions that use that class. The constructor for Popen takes arguments to set up the new process so the parent can communicate with it via pipes. It provides all of the functionality of the other modules and functions it replaces, and more. The API is consistent for all uses, and many of the extra steps of overhead needed (such as closing extra file descriptors and ensuring the pipes are closed) are "built in" instead of being handled by the application code separately.

Note: The API is roughly the same, but the underlying implementation is slightly different between Unix and Windows. All of the examples shown here were tested on Mac OS X. Behavior on a non-Unix OS will vary.

18.4.1 Running External Command

To run an external command without interacting with it, such as one would do with *os.system()*, Use the `call()` function.

```
import subprocess

# Simple command
subprocess.call(['ls', '-1'], shell=True)
```

The command line arguments are passed as a list of strings, which avoids the need for escaping quotes or other special characters that might be interpreted by the shell.

```
$ python subprocess_os_system.py

__init__.py
index.rst
interaction.py
repeater.py
signal_child.py
signal_parent.py
subprocess_check_call.py
subprocess_check_output.py
subprocess_check_output_error.py
subprocess_check_output_error_trap_output.py
subprocess_os_system.py
subprocess_pipes.py
subprocess_popen2.py
subprocess_popen3.py
subprocess_popen4.py
subprocess_popen_read.py
subprocess_popen_write.py
subprocess_shell_variables.py
subprocess_signal_parent_shell.py
subprocess_signal_setsid.py
```

Setting the *shell* argument to a true value causes subprocess to spawn an intermediate shell process, and tell it to run the command. The default is to run the command directly.

```
import subprocess

# Command with shell expansion
subprocess.call('echo $HOME', shell=True)
```

Using an intermediate shell means that variables, glob patterns, and other special shell features in the command string are processed before the command is run.

```
$ python subprocess_shell_variables.py

/Users/dhellmann
```

Error Handling

The return value from `call()` is the exit code of the program. The caller is responsible for interpreting it to detect errors. The `check_call()` function works like `call()` except that the exit code is checked, and if it indicates an error happened then a `CalledProcessError` exception is raised.

```
import subprocess

subprocess.check_call(['false'])
```

The **false** command always exits with a non-zero status code, which `check_call()` interprets as an error.

```
$ python subprocess_check_call.py

Traceback (most recent call last):
  File "subprocess_check_call.py", line 11, in <module>
    subprocess.check_call(['false'])
  File "/Library/Frameworks/Python.framework/Versions/2.7/lib/python2.
7/subprocess.py", line 511, in check_call
    raise CalledProcessError(retcode, cmd)
subprocess.CalledProcessError: Command '['false']' returned non-zero e
xit status 1
```

Capturing Output

The standard input and output channels for the process started by `call()` are bound to the parent's input and output. That means the calling programm cannot capture the output of the command. Use `check_output()` to capture the output for later processing.

```
import subprocess

output = subprocess.check_output(['ls', '-1'])
print 'Have %d bytes in output' % len(output)
print output
```

The `ls -1` command runs successfully, so the text it prints to standard output is captured and returned.

```
$ python subprocess_check_output.py

Have 462 bytes in output
__init__.py
index.rst
interaction.py
repeater.py
signal_child.py
signal_parent.py
subprocess_check_call.py
subprocess_check_output.py
subprocess_check_output_error.py
subprocess_check_output_error_trap_output.py
```

```
subprocess_os_system.py
subprocess_pipes.py
subprocess_popen2.py
subprocess_popen3.py
subprocess_popen4.py
subprocess_popen_read.py
subprocess_popen_write.py
subprocess_shell_variables.py
subprocess_signal_parent_shell.py
subprocess_signal_setsid.py
```

This script runs a series of commands in a subshell. Messages are sent to standard output and standard error before the commands exit with an error code.

```
import subprocess

output = subprocess.check_output(
    'echo to stdout; echo to stderr 1>&2; exit 1',
    shell=True,
    )
print 'Have %d bytes in output' % len(output)
print output
```

The message to standard error is printed to the console, but the message to standard output is hidden.

```
$ python subprocess_check_output_error.py

to stderr
Traceback (most recent call last):
  File "subprocess_check_output_error.py", line 14, in <module>
    shell=True,
  File "/Library/Frameworks/Python.framework/Versions/2.7/lib/python2.
7/subprocess.py", line 544, in check_output
    raise CalledProcessError(retcode, cmd, output=output)
subprocess.CalledProcessError: Command 'echo to stdout; echo to stderr
 1>&2; exit 1' returned non-zero exit status 1
```

To prevent error messages from commands run through `check_output()` from being written to the console, set the *stderr* parameter to the constant `STDOUT`.

```
import subprocess

output = subprocess.check_output(
    'echo to stdout; echo to stderr 1>&2; exit 1',
    shell=True,
    stderr=subprocess.STDOUT,
    )
print 'Have %d bytes in output' % len(output)
print output
```

Now the error and standard output channels are merged together so if the command prints error messages, they are captured and not sent to the console.

```
$ python subprocess_check_output_error_trap_output.py

Traceback (most recent call last):
  File "subprocess_check_output_error_trap_output.py", line 15, in <mo
dule>
    stderr=subprocess.STDOUT,
  File "/Library/Frameworks/Python.framework/Versions/2.7/lib/python2.
7/subprocess.py", line 544, in check_output
    raise CalledProcessError(retcode, cmd, output=output)
subprocess.CalledProcessError: Command 'echo to stdout; echo to stderr
 1>&2; exit 1' returned non-zero exit status 1
```

18.4.2 Working with Pipes Directly

By passing different arguments for *stdin*, *stdout*, and *stderr* it is possible to mimic the variations of `os.popen()`.

popen

To run a process and read all of its output, set the *stdout* value to `PIPE` and call `communicate()`.

```
import subprocess

print '\nread:'
proc = subprocess.Popen(['echo', '"to stdout"'],
                        stdout=subprocess.PIPE,
                        )
stdout_value = proc.communicate()[0]
print '\tstdout:', repr(stdout_value)
```

This is similar to the way `popen()` works, except that the reading is managed internally by the `Popen` instance.

```
$ python subprocess_popen_read.py


read:
        stdout: '"to stdout"\n'
```

To set up a pipe to allow the calling program to write data to it, set *stdin* to `PIPE`.

```
import subprocess

print '\nwrite:'
proc = subprocess.Popen(['cat', '-'],
                        stdin=subprocess.PIPE,
                        )
proc.communicate('\tstdin: to stdin\n')
```

To send data to the standard input channel of the process one time, pass the data to `communicate()`. This is similar to using `popen()` with mode `'w'`.

```
$ python -u subprocess_popen_write.py


write:
        stdin: to stdin
```

popen2

To set up the `Popen` instance for reading and writing, use a combination of the previous techniques.

```
import subprocess

print '\npopen2:'

proc = subprocess.Popen(['cat', '-'],
                        stdin=subprocess.PIPE,
                        stdout=subprocess.PIPE,
                        )
stdout_value = proc.communicate('through stdin to stdout')[0]
print '\tpass through:', repr(stdout_value)
```

This sets up the pipe to mimic `popen2()`.

```
$ python -u subprocess_popen2.py


popen2:
        pass through: 'through stdin to stdout'
```

popen3

It is also possible watch both of the streams for stdout and stderr, as with `popen3()`.

```
import subprocess

print '\npopen3:'
proc = subprocess.Popen('cat -; echo "to stderr" 1>&2',
                        shell=True,
                        stdin=subprocess.PIPE,
                        stdout=subprocess.PIPE,
                        stderr=subprocess.PIPE,
                        )
stdout_value, stderr_value = proc.communicate('through stdin to stdout')
print '\tpass through:', repr(stdout_value)
print '\tstderr      :', repr(stderr_value)
```

Reading from stderr works the same as with stdout. Passing `PIPE` tells `Popen` to attach to the channel, and `communicate()` reads all of the data from it before returning.

```
$ python -u subprocess_popen3.py


popen3:
        pass through: 'through stdin to stdout'
        stderr      : 'to stderr\n'
```

popen4

To direct the error output from the process to its standard output channel, use `STDOUT` for *stderr* instead of `PIPE`.

```
import subprocess

print '\npopen4:'
proc = subprocess.Popen('cat -; echo "to stderr" 1>&2',
                        shell=True,
                        stdin=subprocess.PIPE,
                        stdout=subprocess.PIPE,
                        stderr=subprocess.STDOUT,
                        )
stdout_value, stderr_value = proc.communicate('through stdin to stdout\n')
print '\tcombined output:', repr(stdout_value)
print '\tstderr value   :', repr(stderr_value)
```

Combining the output in this way is similar to how `popen4()` works.

```
$ python -u subprocess_popen4.py


popen4:
        combined output: 'through stdin to stdout\nto stderr\n'
        stderr value   : None
```

18.4.3 Connecting Segments of a Pipe

Multiple commands can be connected into a *pipeline*, similar to the way the Unix shell works, by creating separate `Popen` instances and chaining their inputs and outputs together. The `stdout` attribute of one `Popen` instance is used as the *stdin* argument for the next in the pipeline, instead of the constant `PIPE`. The output is read from the `stdout` handle for the final command in the pipeline.

```
import subprocess

cat = subprocess.Popen(['cat', 'index.rst'],
                        stdout=subprocess.PIPE,
                        )

grep = subprocess.Popen(['grep', '.. include::'],
                        stdin=cat.stdout,
                        stdout=subprocess.PIPE,
                        )

cut = subprocess.Popen(['cut', '-f', '3', '-d:'],
                        stdin=grep.stdout,
                        stdout=subprocess.PIPE,
                        )

end_of_pipe = cut.stdout

print 'Included files:'
for line in end_of_pipe:
    print '\t', line.strip()
```

This example reproduces the command line `cat index.rst | grep ".. include" | cut -f 3 -d:`, which reads the reStructuredText source file for this section and finds all of the lines that include other files, then prints only the filenames.

```
$ python -u subprocess_pipes.py

Included files:
        subprocess_os_system.py
        subprocess_shell_variables.py
        subprocess_check_call.py
        subprocess_check_output.py
        subprocess_check_output_error.py
```

```
subprocess_check_output_error_trap_output.py
subprocess_popen_read.py
subprocess_popen_write.py
subprocess_popen2.py
subprocess_popen3.py
subprocess_popen4.py
subprocess_pipes.py
repeater.py
interaction.py
signal_child.py
signal_parent.py
subprocess_signal_parent_shell.py
subprocess_signal_setsid.py
```

18.4.4 Interacting with Another Command

All of the above examples assume a limited amount of interaction. The `communicate()` method reads all of the output and waits for child process to exit before returning. It is also possible to write to and read from the individual pipe handles used by the `Popen` instance. A simple echo program that reads from standard input and writes to standard output illustrates this:

```
import sys

sys.stderr.write('repeater.py: starting\n')
sys.stderr.flush()

while True:
    next_line = sys.stdin.readline()
    if not next_line:
        break
    sys.stdout.write(next_line)
    sys.stdout.flush()

sys.stderr.write('repeater.py: exiting\n')
sys.stderr.flush()
```

The script, `repeater.py`, writes to stderr when it starts and stops. That information can be used to show the lifetime of the child process.

The next interaction example uses the stdin and stdout file handles owned by the `Popen` instance in different ways. In the first example, a sequence of 10 numbers are written to stdin of the process, and after each write the next line of output is read back. In the second example, the same 10 numbers are written but the output is read all at once using `communicate()`.

```
import subprocess

print 'One line at a time:'
proc = subprocess.Popen('python repeater.py',
                        shell=True,
                        stdin=subprocess.PIPE,
                        stdout=subprocess.PIPE,
                        )
for i in range(10):
    proc.stdin.write('%d\n' % i)
    output = proc.stdout.readline()
    print output.rstrip()
remainder = proc.communicate()[0]
```

```
print remainder

print
print 'All output at once:'
proc = subprocess.Popen('python repeater.py',
                        shell=True,
                        stdin=subprocess.PIPE,
                        stdout=subprocess.PIPE,
                        )
for i in range(10):
    proc.stdin.write('%d\n' % i)

output = proc.communicate()[0]
print output
```

The "`repeater.py:  exiting`" lines come at different points in the output for each loop style.

```
$ python -u interaction.py

One line at a time:
repeater.py: starting
0
1
2
3
4
5
6
7
8
9
repeater.py: exiting


All output at once:
repeater.py: starting
repeater.py: exiting
0
1
2
3
4
5
6
7
8
9
```

18.4.5 Signaling Between Processes

The `os` examples include a demonstration of *signaling between processes using os.fork() and os.kill()*. Since each `Popen` instance provides a *pid* attribute with the process id of the child process, it is possible to do something similar with `subprocess`. For example, using this script for the child process to be executed by the parent process

```
import os
import signal
import time
import sys

pid = os.getpid()
received = False

def signal_usr1(signum, frame):
    "Callback invoked when a signal is received"
    global received
    received = True
    print 'CHILD %6s: Received USR1' % pid
    sys.stdout.flush()

print 'CHILD %6s: Setting up signal handler' % pid
sys.stdout.flush()
signal.signal(signal.SIGUSR1, signal_usr1)
print 'CHILD %6s: Pausing to wait for signal' % pid
sys.stdout.flush()
time.sleep(3)

if not received:
    print 'CHILD %6s: Never received signal' % pid
```

combined with this parent process

```
import os
import signal
import subprocess
import time
import sys

proc = subprocess.Popen(['python', 'signal_child.py'])
print 'PARENT      : Pausing before sending signal...'
sys.stdout.flush()
time.sleep(1)
print 'PARENT      : Signaling child'
sys.stdout.flush()
os.kill(proc.pid, signal.SIGUSR1)
```

the output is:

```
$ python signal_parent.py

PARENT      : Pausing before sending signal...
CHILD  14756: Setting up signal handler
CHILD  14756: Pausing to wait for signal
PARENT      : Signaling child
CHILD  14756: Received USR1
```

Process Groups / Sessions

Because of the way the process tree works under Unix, if the process created by `Popen` spawns sub-processes, those children will not receive any signals sent to the parent. That means, for example, it will be difficult to cause them to terminate by sending `SIGINT` or `SIGTERM`.

```
import os
import signal
import subprocess
import tempfile
import time
import sys

script = '''#!/bin/sh
echo "Shell script in process $$"
set -x
python signal_child.py
'''
script_file = tempfile.NamedTemporaryFile('wt')
script_file.write(script)
script_file.flush()

proc = subprocess.Popen(['sh', script_file.name], close_fds=True)
print 'PARENT      : Pausing before sending signal to child %s...' % proc.pid
sys.stdout.flush()
time.sleep(1)
print 'PARENT      : Signaling child %s' % proc.pid
sys.stdout.flush()
os.kill(proc.pid, signal.SIGUSR1)
time.sleep(3)
```

The pid used to send the signal does not match the pid of the child of the shell script waiting for the signal because in this example, there are three separate processes interacting:

1. `subprocess_signal_parent_shell.py`
2. The Unix shell process running the script created by the main python program.
3. `signal_child.py`

```
$ python subprocess_signal_parent_shell.py

PARENT      : Pausing before sending signal to child 14759...
Shell script in process 14759
+ python signal_child.py
CHILD  14760: Setting up signal handler
CHILD  14760: Pausing to wait for signal
PARENT      : Signaling child 14759
CHILD  14760: Never received signal
```

The solution to this problem is to use a *process group* to associate the children so they can be signaled together. The process group is created with `os.setsid()`, setting the "session id" to the process id of the current process. All child processes inherit the session id, and since it should only be set set in the shell created by `Popen` and its descendants, `os.setsid()` should not be called in the parent process. Instead, the function is passed to `Popen` as the *preexec_fn* argument so it is run after the `fork()` inside the new process, before it uses `exec()` to run the shell.

```
import os
import signal
import subprocess
import tempfile
import time
import sys

script = '''#!/bin/sh
echo "Shell script in process $$"
set -x
python signal_child.py
'''
```

```
script_file = tempfile.NamedTemporaryFile('wt')
script_file.write(script)
script_file.flush()

proc = subprocess.Popen(['sh', script_file.name],
                        close_fds=True,
                        preexec_fn=os.setsid,
                        )
print 'PARENT      : Pausing before sending signal to child %s...' % proc.pid
sys.stdout.flush()
time.sleep(1)
print 'PARENT      : Signaling process group %s' % proc.pid
sys.stdout.flush()
os.killpg(proc.pid, signal.SIGUSR1)
time.sleep(3)
```

The sequence of events is:

1. The parent program instantiates `Popen`.
2. The `Popen` instance forks a new process.
3. The new process runs `os.setsid()`.
4. The new process runs `exec()` to start the shell.
5. The shell runs the shell script.
6. The shell script forks again and that process execs Python.
7. Python runs `signal_child.py`.
8. The parent program signals the process group using the pid of the shell.
9. The shell and Python processes receive the signal. The shell ignores it. Python invokes the signal handler.

To signal the entire process group, use `os.killpg()` with the pid value from the `Popen` instance.

```
$ python subprocess_signal_setsid.py

PARENT      : Pausing before sending signal to child 14763...
Shell script in process 14763
+ python signal_child.py
CHILD  14764: Setting up signal handler
CHILD  14764: Pausing to wait for signal
PARENT      : Signaling process group 14763
CHILD  14764: Received USR1
```

See also:

subprocess (http://docs.python.org/lib/module-subprocess.html) Standard library documentation for this module.

os Although many are deprecated, the functions for working with processes found in the os module are still widely used in existing code.

UNIX SIgnals and Process Groups (http://www.frostbytes.com/ jimf/papers/signals/signals.html) A good description of UNIX signaling and how process groups work.

Advanced Programming in the UNIX(R) Environment (http://www.amazon.com/Programming-Environment-Addison-Wesley-I
Covers working with multiple processes, such as handling signals, closing duplicated file descriptors, etc.

pipes Unix shell command pipeline templates in the standard library.

CHAPTER

NINETEEN

INTERNET PROTOCOLS AND SUPPORT

19.1 BaseHTTPServer – base classes for implementing web servers

Purpose BaseHTTPServer includes classes that can form the basis of a web server.

Available In 1.4 and later

BaseHTTPServer uses classes from SocketServer to create base classes for making HTTP servers. HTTPServer can be used directly, but the BaseHTTPRequestHandler is intended to be extended to handle each protocol method (GET, POST, etc.).

19.1.1 HTTP GET

To add support for an HTTP method in your request handler class, implement the method do_METHOD(), replacing *METHOD* with the name of the HTTP method. For example, do_GET(), do_POST(), etc. For consistency, the method takes no arguments. All of the parameters for the request are parsed by BaseHTTPRequestHandler and stored as instance attributes of the request instance.

This example request handler illustrates how to return a response to the client and some of the local attributes which can be useful in building the response:

```
from BaseHTTPServer import BaseHTTPRequestHandler
import urlparse

class GetHandler(BaseHTTPRequestHandler):

    def do_GET(self):
        parsed_path = urlparse.urlparse(self.path)
        message_parts = [
                'CLIENT VALUES:',
                'client_address=%s (%s)' % (self.client_address,
                                            self.address_string()),
                'command=%s' % self.command,
                'path=%s' % self.path,
                'real path=%s' % parsed_path.path,
                'query=%s' % parsed_path.query,
                'request_version=%s' % self.request_version,
                '',
                'SERVER VALUES:',
                'server_version=%s' % self.server_version,
                'sys_version=%s' % self.sys_version,
                'protocol_version=%s' % self.protocol_version,
                '',
                'HEADERS RECEIVED:',
                ]
        for name, value in sorted(self.headers.items()):
            message_parts.append('%s=%s' % (name, value.rstrip()))
        message_parts.append('')
        message = '\r\n'.join(message_parts)
        self.send_response(200)
        self.end_headers()
        self.wfile.write(message)
        return

if __name__ == '__main__':
    from BaseHTTPServer import HTTPServer
    server = HTTPServer(('localhost', 8080), GetHandler)
    print 'Starting server, use <Ctrl-C> to stop'
    server.serve_forever()
```

The message text is assembled and then written to `wfile`, the file handle wrapping the response socket. Each response needs a response code, set via `send_response()`. If an error code is used (404, 501, etc.), an appropriate default error message is included in the header, or a message can be passed with the error code.

To run the request handler in a server, pass it to the constructor of HTTPServer, as in the `__main__` processing portion of the sample script.

Then start the server:

```
$ python BaseHTTPServer_GET.py
Starting server, use <Ctrl-C> to stop
```

In a separate terminal, use **curl** to access it:

```
$ curl -i http://localhost:8080/?foo=barHTTP/1.0 200 OK
Server: BaseHTTP/0.3 Python/2.5.1
Date: Sun, 09 Dec 2007 16:00:34 GMT

CLIENT VALUES:
client_address=('127.0.0.1', 51275) (localhost)
command=GET
path=/?foo=bar
real path=/
query=foo=bar
request_version=HTTP/1.1

SERVER VALUES:
server_version=BaseHTTP/0.3
sys_version=Python/2.5.1
protocol_version=HTTP/1.0
```

19.1.2 HTTP POST

Supporting POST requests is a little more work, because the base class does not parse the form data for us. The `cgi` module provides the `FieldStorage` class which knows how to parse the form, if it is given the correct inputs.

```
from BaseHTTPServer import BaseHTTPRequestHandler
import cgi

class PostHandler(BaseHTTPRequestHandler):

    def do_POST(self):
        # Parse the form data posted
        form = cgi.FieldStorage(
            fp=self.rfile,
            headers=self.headers,
            environ={'REQUEST_METHOD':'POST',
                     'CONTENT_TYPE':self.headers['Content-Type'],
                     })

        # Begin the response
        self.send_response(200)
        self.end_headers()
        self.wfile.write('Client: %s\n' % str(self.client_address))
        self.wfile.write('User-agent: %s\n' % str(self.headers['user-agent']))
        self.wfile.write('Path: %s\n' % self.path)
        self.wfile.write('Form data:\n')

        # Echo back information about what was posted in the form
        for field in form.keys():
            field_item = form[field]
            if field_item.filename:
                # The field contains an uploaded file
                file_data = field_item.file.read()
                file_len = len(file_data)
                del file_data
                self.wfile.write('\tUploaded %s as "%s" (%d bytes)\n' % \
                        (field, field_item.filename, file_len))
            else:
                # Regular form value
                self.wfile.write('\t%s=%s\n' % (field, form[field].value))
        return

if __name__ == '__main__':
    from BaseHTTPServer import HTTPServer
    server = HTTPServer(('localhost', 8080), PostHandler)
    print 'Starting server, use <Ctrl-C> to stop'
    server.serve_forever()
```

curl can include form data in the message it posts to the server. The last argument, `-F datafile=@BaseHTTPServer_GET.py`, posts the contents of the file `BaseHTTPServer_GET.py` to illustrate reading file data from the form.

```
$ curl http://localhost:8080/ -F name=dhellmann -F foo=bar -F  datafile=@BaseHTTPServer_GET.py
Client: ('127.0.0.1', 51128)
Path: /
Form data:
        name=dhellmann
        foo=bar
        Uploaded datafile (2222 bytes)
```

19.1.3 Threading and Forking

`HTTPServer` is a simple subclass of `SocketServer.TCPServer`, and does not use multiple threads or processes to handle requests. To add threading or forking, create a new class using the appropriate mix-in from `SocketServer`.

```
from BaseHTTPServer import HTTPServer, BaseHTTPRequestHandler
from SocketServer import ThreadingMixIn
```

```
import threading

class Handler(BaseHTTPRequestHandler):

    def do_GET(self):
        self.send_response(200)
        self.end_headers()
        message =  threading.currentThread().getName()
        self.wfile.write(message)
        self.wfile.write('\n')
        return

class ThreadedHTTPServer(ThreadingMixIn, HTTPServer):
    """Handle requests in a separate thread."""

if __name__ == '__main__':
    server = ThreadedHTTPServer(('localhost', 8080), Handler)
    print 'Starting server, use <Ctrl-C> to stop'
    server.serve_forever()
```

Each time a request comes in, a new thread or process is created to handle it:

```
$ curl http://localhost:8080/
Thread-1
$ curl http://localhost:8080/
Thread-2
$ curl http://localhost:8080/
Thread-3
```

Swapping `ForkingMixIn` for `ThreadingMixIn` above would achieve similar results, using separate processes instead of threads.

19.1.4 Handling Errors

Error handling is made easy with `send_error()`. Simply pass the appropriate error code and an optional error message, and the entire response (with headers, status code, and body) is generated automatically.

```
from BaseHTTPServer import BaseHTTPRequestHandler

class ErrorHandler(BaseHTTPRequestHandler):

    def do_GET(self):
        self.send_error(404)
        return

if __name__ == '__main__':
    from BaseHTTPServer import HTTPServer
    server = HTTPServer(('localhost', 8080), ErrorHandler)
    print 'Starting server, use <Ctrl-C> to stop'
    server.serve_forever()
```

In this case, a 404 error is always returned.

```
$ curl -i http://localhost:8080/
HTTP/1.0 404 Not Found
Server: BaseHTTP/0.3 Python/2.5.1
Date: Sun, 09 Dec 2007 15:49:44 GMT
Content-Type: text/html
```

```
Connection: close

<head>
<title>Error response</title>
</head>
<body>
<h1>Error response</h1>
<p>Error code 404.
<p>Message: Not Found.
<p>Error code explanation: 404 = Nothing matches the given URI.
</body>
```

19.1.5 Setting Headers

The `send_header` method adds header data to the HTTP response. It takes two arguments, the name of the header and the value.

```
from BaseHTTPServer import BaseHTTPRequestHandler
import urlparse
import time

class GetHandler(BaseHTTPRequestHandler):

    def do_GET(self):
        self.send_response(200)
        self.send_header('Last-Modified', self.date_time_string(time.time()))
        self.end_headers()
        self.wfile.write('Response body\n')
        return

if __name__ == '__main__':
    from BaseHTTPServer import HTTPServer
    server = HTTPServer(('localhost', 8080), GetHandler)
    print 'Starting server, use <Ctrl-C> to stop'
    server.serve_forever()
```

This example sets the `Last-Modified` header to the current timestamp formatted according to **RFC 2822** (http://tools.ietf.org/html/rfc2822.html).

```
$ curl -i http://localhost:8080/
HTTP/1.0 200 OK
Server: BaseHTTP/0.3 Python/2.7
Date: Sun, 10 Oct 2010 13:58:32 GMT
Last-Modified: Sun, 10 Oct 2010 13:58:32 -0000

Response body
```

See also:

BaseHTTPServer (http://docs.python.org/library/basehttpserver.html) The standard library documentation for this module.

`SocketServer` The SocketServer module provides the base class which handles the raw socket connection.

19.2 cgitb – Detailed traceback reports

Purpose cgitb provides more detailed traceback information than `traceback`.

Available In 2.2 and later

`cgitb` was originally designed for showing errors and debugging information in web applications. It was later updated to include plain-text output as well, but unfortunately wasn't renamed. This has led to obscurity and the module is not used as often as it should be. Nonetheless, `cgitb` is a valuable debugging tool in the standard library.

19.2.1 Standard Traceback Dumps

Python's default exception handling behavior is to print a *traceback* to standard error with the call stack leading up to the error position. This basic output frequently contains enough information to understand the cause of the exception and permit a fix.

```
def func1(arg1):
    local_var = arg1 * 2
    return func2(local_var)

def func2(arg2):
    local_var = arg2 + 2
    return func3(local_var)

def func3(arg3):
    local_var = arg2 / 2
    return local_var

func1(1)
```

The above sample program has a subtle error in `func3()`.

```
$ python cgitb_basic_traceback.py

Traceback (most recent call last):
  File "cgitb_basic_traceback.py", line 22, in <module>
    func1(1)
  File "cgitb_basic_traceback.py", line 12, in func1
    return func2(local_var)
  File "cgitb_basic_traceback.py", line 16, in func2
    return func3(local_var)
  File "cgitb_basic_traceback.py", line 19, in func3
    local_var = arg2 / 2
NameError: global name 'arg2' is not defined
```

19.2.2 Enabling Detailed Tracebacks

While the basic traceback includes enough information for us to spot the error, enabling cgitb replaces `sys.excepthook` with a function that gives extended tracebacks with even more detail.

```
import cgitb
cgitb.enable(format='text')

def func1(arg1):
    local_var = arg1 * 2
    return func2(local_var)
```

```
def func2(arg2):
    local_var = arg2 + 2
    return func3(local_var)

def func3(arg3):
    local_var = arg2 / 2
    return local_var

func1(1)
```

As you can see below, the error report is much more extensive. Each frame of the stack is listed, along with:

- the full path to the source file, instead of just the base name
- the values of the arguments to each function in the stack
- a few lines of source context from around the line in the error path
- the values of variables in the expression causing the error

```
$ python cgitb_extended_traceback.py

<type 'exceptions.NameError'>
Python 2.7.2: /Users/dhellmann/Envs/pymotw/bin/python
Thu Feb 21 06:35:39 2013

A problem occurred in a Python script.  Here is the sequence of
function calls leading up to the error, in the order they occurred.

 /Users/dhellmann/Documents/PyMOTW/src/PyMOTW/cgitb/cgitb_extended_traceback.py in <module>()
   21 def func3(arg3):
   22     local_var = arg2 / 2
   23     return local_var
   24
   25 func1(1)
func1 = <function func1>

 /Users/dhellmann/Documents/PyMOTW/src/PyMOTW/cgitb/cgitb_extended_traceback.py in func1(arg1=1)
   13 def func1(arg1):
   14     local_var = arg1 * 2
   15     return func2(local_var)
   16
   17 def func2(arg2):
global func2 = <function func2>
local_var = 2

 /Users/dhellmann/Documents/PyMOTW/src/PyMOTW/cgitb/cgitb_extended_traceback.py in func2(arg2=2)
   17 def func2(arg2):
   18     local_var = arg2 + 2
   19     return func3(local_var)
   20
   21 def func3(arg3):
global func3 = <function func3>
local_var = 4

 /Users/dhellmann/Documents/PyMOTW/src/PyMOTW/cgitb/cgitb_extended_traceback.py in func3(arg3=4)
   20
   21 def func3(arg3):
   22     local_var = arg2 / 2
   23     return local_var
   24
local_var undefined
arg2 undefined
<type 'exceptions.NameError'>: global name 'arg2' is not defined
    __class__ = <type 'exceptions.NameError'>
    __delattr__ = <method-wrapper '__delattr__' of exceptions.NameError object>
    __dict__ = {}
    __doc__ = 'Name not found globally.'
    __format__ = <built-in method __format__ of exceptions.NameError object>
    __getattribute__ = <method-wrapper '__getattribute__' of exceptions.NameError object>
    __getitem__ = <method-wrapper '__getitem__' of exceptions.NameError object>
    __getslice__ = <method-wrapper '__getslice__' of exceptions.NameError object>
    __hash__ = <method-wrapper '__hash__' of exceptions.NameError object>
    __init__ = <method-wrapper '__init__' of exceptions.NameError object>
    __new__ = <built-in method __new__ of type object>
    __reduce__ = <built-in method __reduce__ of exceptions.NameError object>
    __reduce_ex__ = <built-in method __reduce_ex__ of exceptions.NameError object>
    __repr__ = <method-wrapper '__repr__' of exceptions.NameError object>
    __setattr__ = <method-wrapper '__setattr__' of exceptions.NameError object>
    __setstate__ = <built-in method __setstate__ of exceptions.NameError object>
    __sizeof__ = <built-in method __sizeof__ of exceptions.NameError object>
    __str__ = <method-wrapper '__str__' of exceptions.NameError object>
    __subclasshook__ = <built-in method __subclasshook__ of type object>
    __unicode__ = <built-in method __unicode__ of exceptions.NameError object>
    args = ("global name 'arg2' is not defined",)
    message = "global name 'arg2' is not defined"

The above is a description of an error in a Python program.  Here is
the original traceback:

Traceback (most recent call last):
  File "cgitb_extended_traceback.py", line 25, in <module>
    func1(1)
  File "cgitb_extended_traceback.py", line 15, in func1
    return func2(local_var)
  File "cgitb_extended_traceback.py", line 19, in func2
    return func3(local_var)
  File "cgitb_extended_traceback.py", line 22, in func3
    local_var = arg2 / 2
NameError: global name 'arg2' is not defined
```

The end of the output also includes the full details of the exception object (in case it has attributes other than `message` that would be useful for debugging) and the original form of a traceback dump.

19.2.3 Local Variables in Tracebacks

Having access to the variables involved in the error stack can help find a logical error that occurs somewhere higher in the stack than the line where the actual exception is generated.

```python
import cgitb
cgitb.enable(format='text')

def func2(a, divisor):
    return a / divisor

def func1(a, b):
    c = b - 5
    return func2(a, c)

func1(1, 5)
```

In the case of this code with a *ZeroDivisionError*, we can see that the problem is introduced in the computation of the value of `c` in `func1()`, rather than where the value is used in `func2()`.

```
$ python cgitb_local_vars.py

<type 'exceptions.ZeroDivisionError'>
Python 2.7.2: /Users/dhellmann/Envs/pymotw/bin/python
Thu Feb 21 06:35:39 2013

A problem occurred in a Python script.  Here is the sequence of
function calls leading up to the error, in the order they occurred.

 /Users/dhellmann/Documents/PyMOTW/src/PyMOTW/cgitb/cgitb_local_vars.py in <module>()
   16 def func1(a, b):
   17     c = b - 5
   18     return func2(a, c)
   19
   20 func1(1, 5)
func1 = <function func1>

 /Users/dhellmann/Documents/PyMOTW/src/PyMOTW/cgitb/cgitb_local_vars.py in func1(a=1, b=5)
   16 def func1(a, b):
   17     c = b - 5
   18     return func2(a, c)
   19
   20 func1(1, 5)
global func2 = <function func2>
a = 1
c = 0

 /Users/dhellmann/Documents/PyMOTW/src/PyMOTW/cgitb/cgitb_local_vars.py in func2(a=1, divisor=0)
   12
   13 def func2(a, divisor):
   14     return a / divisor
   15
   16 def func1(a, b):
a = 1
divisor = 0
<type 'exceptions.ZeroDivisionError'>: integer division or modulo by zero
    __class__ = <type 'exceptions.ZeroDivisionError'>
    __delattr__ = <method-wrapper '__delattr__' of exceptions.ZeroDivisionError object>
    __dict__ = {}
    __doc__ = 'Second argument to a division or modulo operation was zero.'
    __format__ = <built-in method __format__ of exceptions.ZeroDivisionError object>
    __getattribute__ = <method-wrapper '__getattribute__' of exceptions.ZeroDivisionError object>
    __getitem__ = <method-wrapper '__getitem__' of exceptions.ZeroDivisionError object>
    __getslice__ = <method-wrapper '__getslice__' of exceptions.ZeroDivisionError object>
    __hash__ = <method-wrapper '__hash__' of exceptions.ZeroDivisionError object>
    __init__ = <method-wrapper '__init__' of exceptions.ZeroDivisionError object>
    __new__ = <built-in method __new__ of type object>
    __reduce__ = <built-in method __reduce__ of exceptions.ZeroDivisionError object>
    __reduce_ex__ = <built-in method __reduce_ex__ of exceptions.ZeroDivisionError object>
    __repr__ = <method-wrapper '__repr__' of exceptions.ZeroDivisionError object>
    __setattr__ = <method-wrapper '__setattr__' of exceptions.ZeroDivisionError object>
    __setstate__ = <built-in method __setstate__ of exceptions.ZeroDivisionError object>
    __sizeof__ = <built-in method __sizeof__ of exceptions.ZeroDivisionError object>
    __str__ = <method-wrapper '__str__' of exceptions.ZeroDivisionError object>
    __subclasshook__ = <built-in method __subclasshook__ of type object>
    __unicode__ = <built-in method __unicode__ of exceptions.ZeroDivisionError object>
    args = ('integer division or modulo by zero',)
    message = 'integer division or modulo by zero'

The above is a description of an error in a Python program.  Here is
the original traceback:

Traceback (most recent call last):
  File "cgitb_local_vars.py", line 20, in <module>
    func1(1, 5)
  File "cgitb_local_vars.py", line 18, in func1
    return func2(a, c)
  File "cgitb_local_vars.py", line 14, in func2
    return a / divisor
ZeroDivisionError: integer division or modulo by zero
```

The code in `cgitb` that examines the variables used in the stack frame leading to the error is smart enough to evaluate object attributes to display them, too.

```python
import cgitb
cgitb.enable(format='text')

class BrokenClass(object):
    """This class has an error.
    """

    def __init__(self, a, b):
        """Be careful passing arguments in here.
        """
        self.a = a
        self.b = b
        self.c = self.a * self.b
        self.d = self.a / self.b
        return

o = BrokenClass(1, 0)
```

Here we see that `self.a` and `self.b` are involved in the error-prone code.

```
$ python cgitb_with_classes.py

<type 'exceptions.ZeroDivisionError'>
Python 2.7.2: /Users/dhellmann/Envs/pymotw/bin/python
Thu Feb 21 06:35:39 2013

A problem occurred in a Python script.  Here is the sequence of
function calls leading up to the error, in the order they occurred.

 /Users/dhellmann/Documents/PyMOTW/src/PyMOTW/cgitb/cgitb_with_classes.py in <module>()
   24         return
   25
   26 o = BrokenClass(1, 0)
   27
   28
```

```
o undefined
BrokenClass = <class '__main__.BrokenClass'>

 /Users/dhellmann/Documents/PyMOTW/src/PyMOTW/cgitb/cgitb_with_classes.py in __init__(self=<__main__
   21         self.b = b
   22         self.c = self.a * self.b
   23         self.d = self.a / self.b
   24         return
   25
self = <__main__.BrokenClass object>
self.d undefined
self.a = 1
self.b = 0
<type 'exceptions.ZeroDivisionError'>: integer division or modulo by zero
    __class__ = <type 'exceptions.ZeroDivisionError'>
    __delattr__ = <method-wrapper '__delattr__' of exceptions.ZeroDivisionError object>
    __dict__ = {}
    __doc__ = 'Second argument to a division or modulo operation was zero.'
    __format__ = <built-in method __format__ of exceptions.ZeroDivisionError object>
    __getattribute__ = <method-wrapper '__getattribute__' of exceptions.ZeroDivisionError object>
    __getitem__ = <method-wrapper '__getitem__' of exceptions.ZeroDivisionError object>
    __getslice__ = <method-wrapper '__getslice__' of exceptions.ZeroDivisionError object>
    __hash__ = <method-wrapper '__hash__' of exceptions.ZeroDivisionError object>
    __init__ = <method-wrapper '__init__' of exceptions.ZeroDivisionError object>
    __new__ = <built-in method __new__ of type object>
    __reduce__ = <built-in method __reduce__ of exceptions.ZeroDivisionError object>
    __reduce_ex__ = <built-in method __reduce_ex__ of exceptions.ZeroDivisionError object>
    __repr__ = <method-wrapper '__repr__' of exceptions.ZeroDivisionError object>
    __setattr__ = <method-wrapper '__setattr__' of exceptions.ZeroDivisionError object>
    __setstate__ = <built-in method __setstate__ of exceptions.ZeroDivisionError object>
    __sizeof__ = <built-in method __sizeof__ of exceptions.ZeroDivisionError object>
    __str__ = <method-wrapper '__str__' of exceptions.ZeroDivisionError object>
    __subclasshook__ = <built-in method __subclasshook__ of type object>
    __unicode__ = <built-in method __unicode__ of exceptions.ZeroDivisionError object>
    args = ('integer division or modulo by zero',)
    message = 'integer division or modulo by zero'

The above is a description of an error in a Python program.  Here is
the original traceback:

Traceback (most recent call last):
  File "cgitb_with_classes.py", line 26, in <module>
    o = BrokenClass(1, 0)
  File "cgitb_with_classes.py", line 23, in __init__
    self.d = self.a / self.b
ZeroDivisionError: integer division or modulo by zero
```

19.2.4 Adding More Context

Suppose your function includes a lot of inline comments, whitespace, or other code that makes it very long. Having the default of 5 lines of context may not be enough help in that case, if the body of the function is pushed out of the code window displayed. Using a larger context value when enabling cgitb gets around this.

```python
import cgitb
import sys

context_length = int(sys.argv[1])
```

```
cgitb.enable(format='text', context=context_length)

def func2(a, divisor):
    return a / divisor

def func1(a, b):
    c = b - 5
    # Really
    # long
    # comment
    # goes
    # here.
    return func2(a, c)

func1(1, 5)
```

You can pass *context* to `enable()` to control the amount of code displayed for each line of the traceback.

```
$ python cgitb_more_context.py 5

<type 'exceptions.ZeroDivisionError'>
Python 2.7.2: /Users/dhellmann/Envs/pymotw/bin/python
Thu Feb 21 06:35:39 2013

A problem occurred in a Python script.  Here is the sequence of
function calls leading up to the error, in the order they occurred.

 /Users/dhellmann/Documents/PyMOTW/src/PyMOTW/cgitb/cgitb_more_context.py in <module>()
   24     # goes
   25     # here.
   26     return func2(a, c)
   27
   28 func1(1, 5)
func1 = <function func1>

 /Users/dhellmann/Documents/PyMOTW/src/PyMOTW/cgitb/cgitb_more_context.py in func1(a=1, b=5)
   24     # goes
   25     # here.
   26     return func2(a, c)
   27
   28 func1(1, 5)
global func2 = <function func2>
a = 1
c = 0

 /Users/dhellmann/Documents/PyMOTW/src/PyMOTW/cgitb/cgitb_more_context.py in func2(a=1, divisor=0)
   15
   16 def func2(a, divisor):
   17     return a / divisor
   18
   19 def func1(a, b):
a = 1
divisor = 0
<type 'exceptions.ZeroDivisionError'>: integer division or modulo by zero
    __class__ = <type 'exceptions.ZeroDivisionError'>
    __delattr__ = <method-wrapper '__delattr__' of exceptions.ZeroDivisionError object>
    __dict__ = {}
    __doc__ = 'Second argument to a division or modulo operation was zero.'
    __format__ = <built-in method __format__ of exceptions.ZeroDivisionError object>
    __getattribute__ = <method-wrapper '__getattribute__' of exceptions.ZeroDivisionError object>
    __getitem__ = <method-wrapper '__getitem__' of exceptions.ZeroDivisionError object>
    __getslice__ = <method-wrapper '__getslice__' of exceptions.ZeroDivisionError object>
    __hash__ = <method-wrapper '__hash__' of exceptions.ZeroDivisionError object>
    __init__ = <method-wrapper '__init__' of exceptions.ZeroDivisionError object>
    __new__ = <built-in method __new__ of type object>
    __reduce__ = <built-in method __reduce__ of exceptions.ZeroDivisionError object>
    __reduce_ex__ = <built-in method __reduce_ex__ of exceptions.ZeroDivisionError object>
    __repr__ = <method-wrapper '__repr__' of exceptions.ZeroDivisionError object>
    __setattr__ = <method-wrapper '__setattr__' of exceptions.ZeroDivisionError object>
    __setstate__ = <built-in method __setstate__ of exceptions.ZeroDivisionError object>
    __sizeof__ = <built-in method __sizeof__ of exceptions.ZeroDivisionError object>
    __str__ = <method-wrapper '__str__' of exceptions.ZeroDivisionError object>
    __subclasshook__ = <built-in method __subclasshook__ of type object>
    __unicode__ = <built-in method __unicode__ of exceptions.ZeroDivisionError object>
    args = ('integer division or modulo by zero',)
    message = 'integer division or modulo by zero'

The above is a description of an error in a Python program.  Here is
the original traceback:

Traceback (most recent call last):
  File "cgitb_more_context.py", line 28, in <module>
    func1(1, 5)
  File "cgitb_more_context.py", line 26, in func1
    return func2(a, c)
  File "cgitb_more_context.py", line 17, in func2
    return a / divisor
ZeroDivisionError: integer division or modulo by zero
```

Increasing the value gets us enough of the function that we can spot the problem in the code, again.

```
$ python cgitb_more_context.py 10

<type 'exceptions.ZeroDivisionError'>
Python 2.7.2: /Users/dhellmann/Envs/pymotw/bin/python
Thu Feb 21 06:35:39 2013

A problem occurred in a Python script.  Here is the sequence of
function calls leading up to the error, in the order they occurred.

 /Users/dhellmann/Documents/PyMOTW/src/PyMOTW/cgitb/cgitb_more_context.py in <module>()
   19 def func1(a, b):
   20     c = b - 5
   21     # Really
   22     # long
   23     # comment
   24     # goes
   25     # here.
   26     return func2(a, c)
   27
   28 func1(1, 5)
func1 = <function func1>

 /Users/dhellmann/Documents/PyMOTW/src/PyMOTW/cgitb/cgitb_more_context.py in func1(a=1, b=5)
   19 def func1(a, b):
   20     c = b - 5
   21     # Really
   22     # long
   23     # comment
   24     # goes
   25     # here.
   26     return func2(a, c)
   27
   28 func1(1, 5)
global func2 = <function func2>
a = 1
c = 0

 /Users/dhellmann/Documents/PyMOTW/src/PyMOTW/cgitb/cgitb_more_context.py in func2(a=1, divisor=0)
   12
   13 context_length = int(sys.argv[1])
   14 cgitb.enable(format='text', context=context_length)
   15
   16 def func2(a, divisor):
   17     return a / divisor
   18
   19 def func1(a, b):
   20     c = b - 5
   21     # Really
a = 1
divisor = 0
<type 'exceptions.ZeroDivisionError'>: integer division or modulo by zero
    __class__ = <type 'exceptions.ZeroDivisionError'>
    __delattr__ = <method-wrapper '__delattr__' of exceptions.ZeroDivisionError object>
    __dict__ = {}
    __doc__ = 'Second argument to a division or modulo operation was zero.'
    __format__ = <built-in method __format__ of exceptions.ZeroDivisionError object>
    __getattribute__ = <method-wrapper '__getattribute__' of exceptions.ZeroDivisionError object>
    __getitem__ = <method-wrapper '__getitem__' of exceptions.ZeroDivisionError object>
    __getslice__ = <method-wrapper '__getslice__' of exceptions.ZeroDivisionError object>
    __hash__ = <method-wrapper '__hash__' of exceptions.ZeroDivisionError object>
    __init__ = <method-wrapper '__init__' of exceptions.ZeroDivisionError object>
    __new__ = <built-in method __new__ of type object>
    __reduce__ = <built-in method __reduce__ of exceptions.ZeroDivisionError object>
    __reduce_ex__ = <built-in method __reduce_ex__ of exceptions.ZeroDivisionError object>
    __repr__ = <method-wrapper '__repr__' of exceptions.ZeroDivisionError object>
    __setattr__ = <method-wrapper '__setattr__' of exceptions.ZeroDivisionError object>
    __setstate__ = <built-in method __setstate__ of exceptions.ZeroDivisionError object>
    __sizeof__ = <built-in method __sizeof__ of exceptions.ZeroDivisionError object>
    __str__ = <method-wrapper '__str__' of exceptions.ZeroDivisionError object>
    __subclasshook__ = <built-in method __subclasshook__ of type object>
    __unicode__ = <built-in method __unicode__ of exceptions.ZeroDivisionError object>
    args = ('integer division or modulo by zero',)
    message = 'integer division or modulo by zero'

The above is a description of an error in a Python program.  Here is
the original traceback:

Traceback (most recent call last):
  File "cgitb_more_context.py", line 28, in <module>
    func1(1, 5)
  File "cgitb_more_context.py", line 26, in func1
    return func2(a, c)
  File "cgitb_more_context.py", line 17, in func2
```

```
    return a / divisor
ZeroDivisionError: integer division or modulo by zero
```

19.2.5 Exception Properties

In addition to the local variables from each stack frame, `cgitb` shows all properties of the exception object. If you have a custom exception type with extra properties, they are printed as part of the error report.

```
import cgitb
cgitb.enable(format='text')

class MyException(Exception):
    """Add extra properties to a special exception
    """

    def __init__(self, message, bad_value):
        self.bad_value = bad_value
        Exception.__init__(self, message)
        return

raise MyException('Normal message', bad_value=99)
```

In this example, the *bad_value* property is included along with the standard *message* and *args* values.

```
$ python cgitb_exception_properties.py

<class '__main__.MyException'>
Python 2.7.2: /Users/dhellmann/Envs/pymotw/bin/python
Thu Feb 21 06:35:39 2013

A problem occurred in a Python script.  Here is the sequence of
function calls leading up to the error, in the order they occurred.

 /Users/dhellmann/Documents/PyMOTW/src/PyMOTW/cgitb/cgitb_exception_properties.py in <module>()
   18         self.bad_value = bad_value
   19         Exception.__init__(self, message)
   20         return
   21
   22 raise MyException('Normal message', bad_value=99)
MyException = <class '__main__.MyException'>
bad_value undefined
<class '__main__.MyException'>: Normal message
    __class__ = <class '__main__.MyException'>
    __delattr__ = <method-wrapper '__delattr__' of MyException object>
    __dict__ = {'bad_value': 99}
    __doc__ = 'Add extra properties to a special exception\n    '
    __format__ = <built-in method __format__ of MyException object>
    __getattribute__ = <method-wrapper '__getattribute__' of MyException object>
    __getitem__ = <method-wrapper '__getitem__' of MyException object>
    __getslice__ = <method-wrapper '__getslice__' of MyException object>
    __hash__ = <method-wrapper '__hash__' of MyException object>
    __init__ = <bound method MyException.__init__ of MyException('Normal message',)>
    __module__ = '__main__'
    __new__ = <built-in method __new__ of type object>
    __reduce__ = <built-in method __reduce__ of MyException object>
    __reduce_ex__ = <built-in method __reduce_ex__ of MyException object>
    __repr__ = <method-wrapper '__repr__' of MyException object>
    __setattr__ = <method-wrapper '__setattr__' of MyException object>
    __setstate__ = <built-in method __setstate__ of MyException object>
    __sizeof__ = <built-in method __sizeof__ of MyException object>
    __str__ = <method-wrapper '__str__' of MyException object>
    __subclasshook__ = <built-in method __subclasshook__ of type object>
    __unicode__ = <built-in method __unicode__ of MyException object>
    __weakref__ = None
    args = ('Normal message',)
    bad_value = 99
    message = 'Normal message'

The above is a description of an error in a Python program.  Here is
the original traceback:

Traceback (most recent call last):
  File "cgitb_exception_properties.py", line 22, in <module>
    raise MyException('Normal message', bad_value=99)
MyException: Normal message
```

19.2.6 Logging Tracebacks

For many situations, printing the traceback details to standard error is the best resolution. In a production system, however, logging the errors is even better. `enable()` includes an optional argument, *logdir*, to enable error logging. When a directory name is provided, each exception is logged to its own file in the given directory.

```
import cgitb
import os

cgitb.enable(logdir=os.path.join(os.path.dirname(__file__), 'LOGS'),
             display=False,
             format='text',
             )

def func2(a, divisor):
    return a / divisor

def func1(a, b):
    c = b - 5
    return func2(a, c)

func1(1, 5)
```

Even though the error display is suppressed, a message is printed describing where to go to find the error log.

```
$ python cgitb_log_exception.py

<p>A problem occurred in a Python script.
<p> /Users/dhellmann/Documents/PyMOTW/src/PyMOTW/cgitb/LOGS/tmpju23ip.txt contains the description o

$ ls LOGS

tmpju23ip.txt

$ cat LOGS/*.txt

<type 'exceptions.ZeroDivisionError'>
Python 2.7.2: /Users/dhellmann/Envs/pymotw/bin/python
```

```
Thu Feb 21 06:35:40 2013

A problem occurred in a Python script.  Here is the sequence of
function calls leading up to the error, in the order they occurred.

 /Users/dhellmann/Documents/PyMOTW/src/PyMOTW/cgitb/cgitb_log_exception.py in <module>()
   21 def func1(a, b):
   22     c = b - 5
   23     return func2(a, c)
   24
   25 func1(1, 5)
func1 = <function func1>

 /Users/dhellmann/Documents/PyMOTW/src/PyMOTW/cgitb/cgitb_log_exception.py in func1(a=1, b=5)
   21 def func1(a, b):
   22     c = b - 5
   23     return func2(a, c)
   24
   25 func1(1, 5)
global func2 = <function func2>
a = 1
c = 0

 /Users/dhellmann/Documents/PyMOTW/src/PyMOTW/cgitb/cgitb_log_exception.py in func2(a=1, divisor=0)
   17
   18 def func2(a, divisor):
   19     return a / divisor
   20
   21 def func1(a, b):
a = 1
divisor = 0
<type 'exceptions.ZeroDivisionError'>: integer division or modulo by zero
    __class__ = <type 'exceptions.ZeroDivisionError'>
    __delattr__ = <method-wrapper '__delattr__' of exceptions.ZeroDivisionError object>
    __dict__ = {}
    __doc__ = 'Second argument to a division or modulo operation was zero.'
    __format__ = <built-in method __format__ of exceptions.ZeroDivisionError object>
    __getattribute__ = <method-wrapper '__getattribute__' of exceptions.ZeroDivisionError object>
    __getitem__ = <method-wrapper '__getitem__' of exceptions.ZeroDivisionError object>
    __getslice__ = <method-wrapper '__getslice__' of exceptions.ZeroDivisionError object>
    __hash__ = <method-wrapper '__hash__' of exceptions.ZeroDivisionError object>
    __init__ = <method-wrapper '__init__' of exceptions.ZeroDivisionError object>
    __new__ = <built-in method __new__ of type object>
    __reduce__ = <built-in method __reduce__ of exceptions.ZeroDivisionError object>
    __reduce_ex__ = <built-in method __reduce_ex__ of exceptions.ZeroDivisionError object>
    __repr__ = <method-wrapper '__repr__' of exceptions.ZeroDivisionError object>
    __setattr__ = <method-wrapper '__setattr__' of exceptions.ZeroDivisionError object>
    __setstate__ = <built-in method __setstate__ of exceptions.ZeroDivisionError object>
    __sizeof__ = <built-in method __sizeof__ of exceptions.ZeroDivisionError object>
    __str__ = <method-wrapper '__str__' of exceptions.ZeroDivisionError object>
    __subclasshook__ = <built-in method __subclasshook__ of type object>
    __unicode__ = <built-in method __unicode__ of exceptions.ZeroDivisionError object>
    args = ('integer division or modulo by zero',)
    message = 'integer division or modulo by zero'

The above is a description of an error in a Python program.  Here is
the original traceback:
```

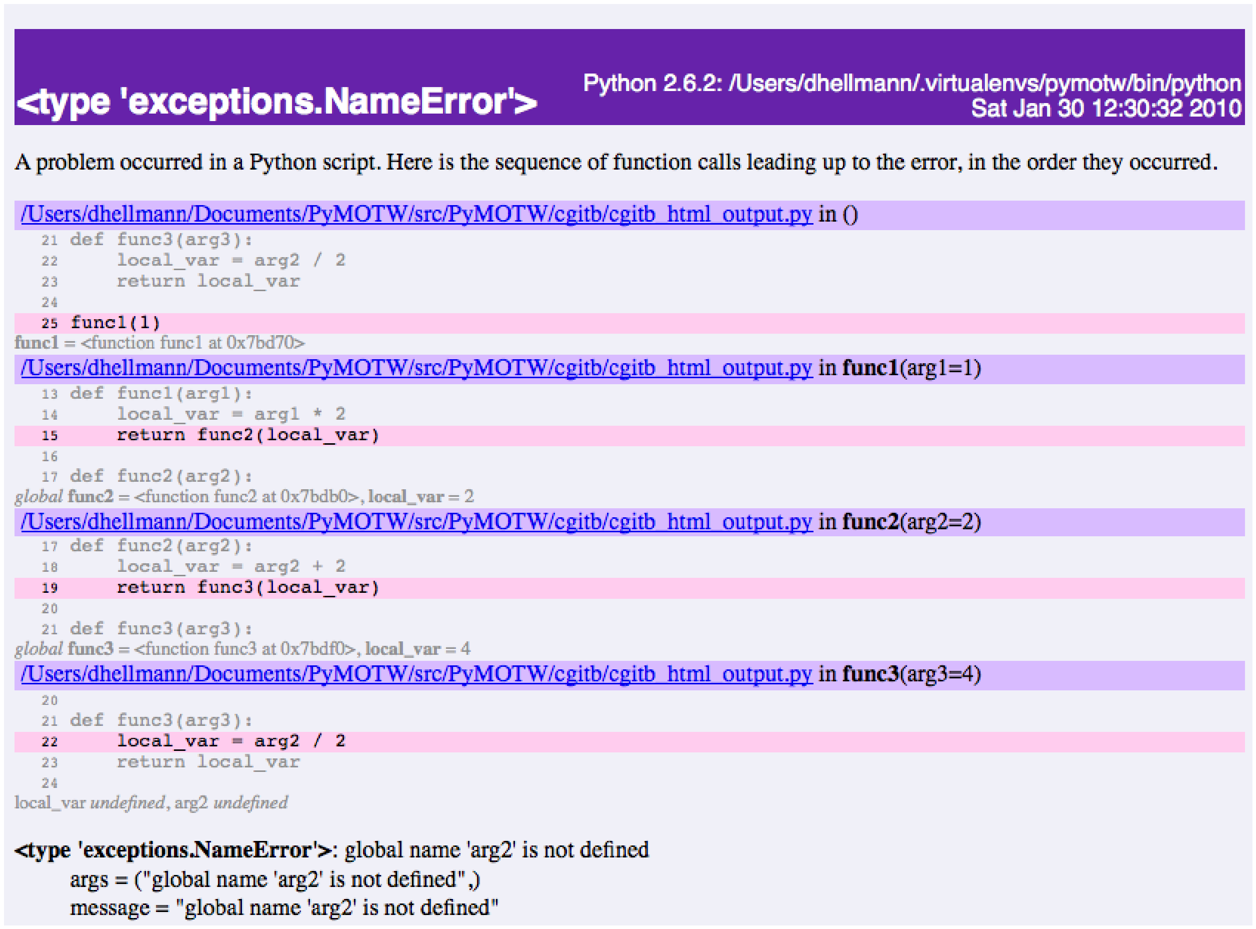
```
Traceback (most recent call last):
  File "cgitb_log_exception.py", line 25, in <module>
    func1(1, 5)
  File "cgitb_log_exception.py", line 23, in func1
    return func2(a, c)
  File "cgitb_log_exception.py", line 19, in func2
    return a / divisor
ZeroDivisionError: integer division or modulo by zero
```

19.2.7 HTML Output

Because `cgitb` was originally developed for handling exceptions in web apps, no discussion would be complete without an example of the HTML output it produces.

```
import cgitb
cgitb.enable()

def func1(arg1):
    local_var = arg1 * 2
    return func2(local_var)

def func2(arg2):
    local_var = arg2 + 2
    return func3(local_var)

def func3(arg3):
    local_var = arg2 / 2
    return local_var

func1(1)
```

By leaving out the *format* argument (or specifying `html`), the traceback format changes to HTML output.



```
<type 'exceptions.NameError'>          Python 2.6.2: /Users/dhellmann/.virtualenvs/pymotw/bin/python
                                                                     Sat Jan 30 12:30:32 2010

A problem occurred in a Python script. Here is the sequence of function calls leading up to the error, in the order they occurred.

/Users/dhellmann/Documents/PyMOTW/src/PyMOTW/cgitb/cgitb_html_output.py in ()
 def func3(arg3):
     local_var = arg2 / 2
     return local_var

 func1(1)
func1 = <function func1 at 0x7bd70>
/Users/dhellmann/Documents/PyMOTW/src/PyMOTW/cgitb/cgitb_html_output.py in func1(arg1=1)
 def func1(arg1):
     local_var = arg1 * 2
     return func2(local_var)

 def func2(arg2):
global func2 = <function func2 at 0x7bdb0>, local_var = 2
/Users/dhellmann/Documents/PyMOTW/src/PyMOTW/cgitb/cgitb_html_output.py in func2(arg2=2)
 def func2(arg2):
     local_var = arg2 + 2
     return func3(local_var)

 def func3(arg3):
global func3 = <function func3 at 0x7bdf0>, local_var = 4
/Users/dhellmann/Documents/PyMOTW/src/PyMOTW/cgitb/cgitb_html_output.py in func3(arg3=4)

 def func3(arg3):
     local_var = arg2 / 2
     return local_var

local_var undefined, arg2 undefined

<type 'exceptions.NameError'>: global name 'arg2' is not defined
      args = ("global name 'arg2' is not defined",)
      message = "global name 'arg2' is not defined"
```

See also:

cgitb (http://docs.python.org/library/cgitb.html) The standard library documentation for this module.

`traceback` Standard library module for working with tracebacks.

`inspect` The inspect module includes more functions for examining the stack.

`sys` The sys module provides access to the current exception value and the `excepthook` handler invoked when an exception occurs.

Improved traceback module (http://thread.gmane.org/gmane.comp.python.devel/110326) Python-dev discussion of improvements to the traceback module and related enhancements other developers use locally.

19.3 Cookie – HTTP Cookies

Purpose The Cookie module defines classes for parsing and creating HTTP cookie headers.

Available In 2.1 and later

Cookies have been a part of the HTTP protocol for a long time. All of the modern web development frameworks provide easy access to cookies so a programmer almost never has to worry about how to format them or make sure the headers are sent properly. It can be instructive to understand how cookies work, though, and the options they support.

The Cookie module implements a parser for cookies that is mostly **RFC 2109** (http://tools.ietf.org/html/rfc2109.html) compliant. It is a little less strict than the standard because MSIE 3.0x does not support the entire standard.

19.3.1 Creating and Setting a Cookie

Cookies are used as state management, and as such as usually set by the server to be stored and returned by the client. The most trivial example of creating a cookie looks something like:

```
import Cookie

c = Cookie.SimpleCookie()
c['mycookie'] = 'cookie_value'
print c
```

The output is a valid Set-Cookie header ready to be passed to the client as part of the HTTP response:

```
$ python Cookie_setheaders.py

Set-Cookie: mycookie=cookie_value
```

19.3.2 Morsels

It is also possible to control the other aspects of a cookie, such as the expiration, path, and domain. In fact, all of the RFC attributes for cookies can be managed through the Morsel object representing the cookie value.

```
import Cookie
import datetime

def show_cookie(c):
    print c
    for key, morsel in c.iteritems():
        print
        print 'key =', morsel.key
        print '  value =', morsel.value
        print '  coded_value =', morsel.coded_value
        for name in morsel.keys():
            if morsel[name]:
                print '  %s = %s' % (name, morsel[name])

c = Cookie.SimpleCookie()

# A cookie with a value that has to be encoded to fit into the header
c['encoded_value_cookie'] = '"cookie_value"'
c['encoded_value_cookie']['comment'] = 'Notice that this cookie value has escaped quotes'

# A cookie that only applies to part of a site
c['restricted_cookie'] = 'cookie_value'
c['restricted_cookie']['path'] = '/sub/path'
c['restricted_cookie']['domain'] = 'PyMOTW'
c['restricted_cookie']['secure'] = True

# A cookie that expires in 5 minutes
c['with_max_age'] = 'expires in 5 minutes'
c['with_max_age']['max-age'] = 300 # seconds

# A cookie that expires at a specific time
c['expires_at_time'] = 'cookie_value'
expires = datetime.datetime(2009, 2, 14, 18, 30, 14) + datetime.timedelta(hours=1)
c['expires_at_time']['expires'] = expires.strftime('%a, %d %b %Y %H:%M:%S') # Wdy, DD-Mon-YY HH:MM:S
```

```
show_cookie(c)
```

The above example includes two different methods for setting stored cookies that expire. You can set max-age to a number of seconds, or expires to a date and time when the cookie should be discarded.

```
$ python Cookie_Morsel.py

Set-Cookie: encoded_value_cookie="\"cookie_value\""; Comment=Notice that this cookie value has escape
Set-Cookie: expires_at_time=cookie_value; expires=Sat, 14 Feb 2009 19:30:14
Set-Cookie: restricted_cookie=cookie_value; Domain=PyMOTW; Path=/sub/path; secure
Set-Cookie: with_max_age="expires in 5 minutes"; Max-Age=300

key = restricted_cookie
  value = cookie_value
  coded_value = cookie_value
  domain = PyMOTW
  secure = True
  path = /sub/path

key = with_max_age
  value = expires in 5 minutes
  coded_value = "expires in 5 minutes"
  max-age = 300

key = encoded_value_cookie
  value = "cookie_value"
  coded_value = "\"cookie_value\""
  comment = Notice that this cookie value has escaped quotes

key = expires_at_time
  value = cookie_value
  coded_value = cookie_value
  expires = Sat, 14 Feb 2009 19:30:14
```

Both the Cookie and Morsel objects act like dictionaries. The Morsel responds to a fixed set of keys:

- expires
- path
- comment
- domain
- max-age
- secure
- version

The keys for the Cookie instance are the names of the individual cookies being stored. That information is also available from the key attribute of the Morsel.

19.3.3 Encoded Values

The cookie header may require values to be encoded so they can be parsed properly.

```
import Cookie

c = Cookie.SimpleCookie()
```

```
c['integer'] = 5
c['string_with_quotes'] = 'He said, "Hello, World!"'

for name in ['integer', 'string_with_quotes']:
    print c[name].key
    print '  %s' % c[name]
    print '  value=%s' % c[name].value, type(c[name].value)
    print '  coded_value=%s' % c[name].coded_value
    print
```

The Morsel.value is always the decoded value of the cookie, while Morsel.coded_value is always the representation to be used for transmitting the value to the client. Both values are always strings. Values saved to a cookie that are not strings are converted automatically.

```
$ python Cookie_coded_value.py

integer
  Set-Cookie: integer=5
  value=5 <type 'str'>
  coded_value=5

string_with_quotes
  Set-Cookie: string_with_quotes="He said\054 \"Hello\054 World!\""
  value=He said, "Hello, World!" <type 'str'>
  coded_value="He said\054 \"Hello\054 World!\""
```

19.3.4 Receiving and Parsing Cookie Headers

Once the Set-Cookie headers are received by the client, it will return those cookies to the server on subsequent requests using the Cookie header. The incoming header will look like:

```
Cookie: integer=5; string_with_quotes="He said, \"Hello, World!\""
```

Depending on your web server and framework, the cookies are either available directly from the headers or the `HTTP_COOKIE` environment variable. To decode them, pass the string without the header prefix to the SimpleCookie when instantiating it, or use the load() method.

```
import Cookie

HTTP_COOKIE = r'integer=5; string_with_quotes="He said, \"Hello, World!\""'

print 'From constructor:'
c = Cookie.SimpleCookie(HTTP_COOKIE)
print c

print
print 'From load():'
c = Cookie.SimpleCookie()
c.load(HTTP_COOKIE)
print c
```

```
$ python Cookie_parse.py

From constructor:
Set-Cookie: integer=5
Set-Cookie: string_with_quotes="He said, \"Hello, World!\""
```

```
From load():
Set-Cookie: integer=5
Set-Cookie: string_with_quotes="He said, \"Hello, World!\""
```

19.3.5 Alternative Output Formats

Besides using the Set-Cookie header, it is possible to use JavaScript to add cookies to a client. SimpleCookie and Morsel provide JavaScript output via the js_output() method.

```
import Cookie

c = Cookie.SimpleCookie()
c['mycookie'] = 'cookie_value'
c['another_cookie'] = 'second value'
print c.js_output()
```

```
$ python Cookie_js_output.py


        <script type="text/javascript">
        <!-- begin hiding
        document.cookie = "another_cookie=\"second value\"";
        // end hiding -->
        </script>

        <script type="text/javascript">
        <!-- begin hiding
        document.cookie = "mycookie=cookie_value";
        // end hiding -->
        </script>
```

19.3.6 Deprecated Classes

All of these examples have used SimpleCookie. The Cookie module also provides 2 other classes, SerialCookie and SmartCookie. SerialCookie can handle any values that can be pickled. SmartCookie figures out whether a value needs to be unpickled or if it is a simple value. Since both of these classes use pickles, they are potential security holes in your application and you should not use them. It is safer to store state on the server, and give the client a session key instead.

See also:

Cookie (http://docs.python.org/library/cookie.html) The standard library documentation for this module.

`cookielib` The `cookielib` module, for working with cookies on the client-side.

RFC 2109 (http://tools.ietf.org/html/rfc2109.html) HTTP State Management Mechanism

19.4 imaplib - IMAP4 client library

Purpose Client library for IMAP4 communication.

Available In 1.5.2 and later

imaplib implements a client for communicating with Internet Message Access Protocol (IMAP) version 4 servers. The IMAP protocol defines a set of *commands* sent to the server and the responses delivered back to the client. Most of the commands are available as methods of the IMAP4 object used to communicate with the server.

These examples discuss part of the IMAP protocol, but are by no means complete. Refer to **RFC 3501** (http://tools.ietf.org/html/rfc3501.html) for complete details.

19.4.1 Variations

There are 3 client classes for communicating with servers using various mechanisms. The first, IMAP4, uses clear text sockets; IMAP4_SSL uses encrypted communication over SSL sockets; and IMAP4_stream uses the standard input and standard output of an external command. All of the examples below will use IMAP4_SSL.

19.4.2 Connecting to a Server

There are two steps for establishing a connection with an IMAP server. First, set up the socket connection itself. Second, authenticate as a user with an account on the server. The following example code will read server and user information from a configuration file.

Warning: You probably do not want to store email passwords in clear text, but handling encryption will distract from the rest of the examples.

```
import imaplib
import ConfigParser
import os

def open_connection(verbose=False):
    # Read the config file
    config = ConfigParser.ConfigParser()
    config.read([os.path.expanduser('~/.pymotw')])

    # Connect to the server
    hostname = config.get('server', 'hostname')
    if verbose: print 'Connecting to', hostname
    connection = imaplib.IMAP4_SSL(hostname)

    # Login to our account
    username = config.get('account', 'username')
    password = config.get('account', 'password')
    if verbose: print 'Logging in as', username
    connection.login(username, password)
    return connection

if __name__ == '__main__':
    c = open_connection(verbose=True)
    try:
        print c
    finally:
        c.logout()
```

When run, open_connection() reads the configuration information from a file in your home directory, then opens the IMAP4_SSL connection and authenticates.

```
$ python imaplib_connect.py
Connecting to mail.example.com
```

```
Logging in as example
<imaplib.IMAP4_SSL instance at 0x928cb0>
```

Note: The other examples below will reuse this module, to avoid duplicating the code.

Authentication Failure

If the connection is established but authentication fails, an exception is raised.

```
import imaplib
import ConfigParser
import os

# Read the config file
config = ConfigParser.ConfigParser()
config.read([os.path.expanduser('~/.pymotw')])

# Connect to the server
hostname = config.get('server', 'hostname')
print 'Connecting to', hostname
connection = imaplib.IMAP4_SSL(hostname)

# Login to our account
username = config.get('account', 'username')
password = 'this_is_the_wrong_password'
print 'Logging in as', username
connection.login(username, password)
```

```
$ python imaplib_connect_fail.py
Connecting to mail.example.com
Logging in as example
Traceback (most recent call last):
  File "/Users/dhellmann/Documents/PyMOTW/in_progress/imaplib/PyMOTW/imaplib/imaplib_connect_fail.py'
    connection.login(username, password)
  File "/Library/Frameworks/Python.framework/Versions/2.5/lib/python2.5/imaplib.py", line 501, in log
    raise self.error(dat[-1])
imaplib.error: Authentication failed.
```

19.4.3 Example Configuration

The example account has 4 mailboxes, `INBOX`, `Apple Mail To Do`, `Archive`, and `2008` (a sub-folder of `Archive`). The mailbox hierarchy looks like:

- INBOX
- Apple Mail To Do
- Archive
  - 2008

There is one unread message in the `INBOX` folder, and one read message in `Archive/2008`.

19.4.4 Listing Mailboxes

To retrieve the mailboxes available for an account, use the `list()` method.

```
import imaplib
from pprint import pprint
from imaplib_connect import open_connection

c = open_connection()
try:
    typ, data = c.list()
    print 'Response code:', typ
    print 'Response:'
    pprint(data)
finally:
    c.logout()
```

The return value is a tuple with a response code and the data returned by the server. The response code is `OK`, unless there has been an error. The data for `list()` is a sequence of strings containing *flags*, the *hierarchy delimiter*, and *mailbox name* for each mailbox.

```
$ python imaplib_list.py
Response code: OK
Response:
['(\\HasNoChildren) "." INBOX',
 '(\\HasNoChildren) "." "Apple Mail To Do"',
 '(\\HasChildren) "." "Archive"',
 '(\\HasNoChildren) "." "Archive.2008"']
```

Each response string can be split into 3 parts using `re` or `csv` (see IMAP Backup Script (http://snipplr.com/view/7955/imap-backup-script/) for an example using `csv`).

```
import imaplib
import re

from imaplib_connect import open_connection

list_response_pattern = re.compile(r'\((?P<flags>.*?)\) "(?P<delimiter>.*)" (?P<name>.*)')

def parse_list_response(line):
    flags, delimiter, mailbox_name = list_response_pattern.match(line).groups()
    mailbox_name = mailbox_name.strip('"')
    return (flags, delimiter, mailbox_name)

if __name__ == '__main__':
    c = open_connection()
    try:
        typ, data = c.list()
    finally:
        c.logout()
    print 'Response code:', typ

    for line in data:
        print 'Server response:', line
        flags, delimiter, mailbox_name = parse_list_response(line)
        print 'Parsed response:', (flags, delimiter, mailbox_name)
```

Notice that the server quotes the mailbox name if it includes spaces, but we need to strip those quotes to use the mailbox name in other calls back to the server later.

```
$ python imaplib_list_parse.py
Response code: OK
Server response: (\HasNoChildren) "." INBOX
Parsed response: ('\\HasNoChildren', '.', 'INBOX')
Server response: (\HasNoChildren) "." "Apple Mail To Do"
Parsed response: ('\\HasNoChildren', '.', 'Apple Mail To Do')
Server response: (\HasChildren) "." "Archive"
Parsed response: ('\\HasChildren', '.', 'Archive')
Server response: (\HasNoChildren) "." "Archive.2008"
Parsed response: ('\\HasNoChildren', '.', 'Archive.2008')
```

`list()` takes arguments to let you ask for mailboxes in part of the hierarchy. For example, to list sub-folders of `Archive`, you can pass a value as the *directory* argument:

```
import imaplib

from imaplib_connect import open_connection

if __name__ == '__main__':
    c = open_connection()
    try:
        typ, data = c.list(directory='Archive')
    finally:
        c.logout()
    print 'Response code:', typ

    for line in data:
        print 'Server response:', line
```

Only the single subfolder is returned:

```
$ python imaplib_list_subfolders.py
Response code: OK
Server response: (\HasNoChildren) "." "Archive.2008"
```

Alternately, to list folders matching a pattern you can pass the *pattern* argument:

```
import imaplib

from imaplib_connect import open_connection

if __name__ == '__main__':
    c = open_connection()
    try:
        typ, data = c.list(pattern='*Archive*')
    finally:
        c.logout()
    print 'Response code:', typ

    for line in data:
        print 'Server response:', line
```

In this case, both `Archive` and `Archive.2008` are included in the response.

```
$ python imaplib_list_pattern.py
Response code: OK
Server response: (\HasChildren) "." "Archive"
Server response: (\HasNoChildren) "." "Archive.2008"
```

19.4.5 Mailbox Status

Use `status()` to ask for aggregated information about the contents. The standard defines these *status conditions*:

MESSAGES The number of messages in the mailbox.

RECENT The number of messages with the Recent flag set.

UIDNEXT The next unique identifier value of the mailbox.

UIDVALIDITY The unique identifier validity value of the mailbox.

UNSEEN The number of messages which do not have the Seen flag set.

The status conditions must be formatted as a space separated string enclosed in parentheses, the encoding for a "list" in the IMAP4 specification.

```
import imaplib
import re

from imaplib_connect import open_connection
from imaplib_list_parse import parse_list_response

if __name__ == '__main__':
    c = open_connection()
    try:
        typ, data = c.list()
        for line in data:
            flags, delimiter, mailbox_name = parse_list_response(line)
            print c.status(mailbox_name, '(MESSAGES RECENT UIDNEXT UIDVALIDITY UNSEEN)')
    finally:
        c.logout()
```

The return value is the usual tuple containing a response code and a list of information from the server. In this case, the list contains a single string formatted with the name of the mailbox in quotes, then the status conditions and values in parentheses.

```
$ python imaplib_status.py
('OK', ['"INBOX" (MESSAGES 1 RECENT 0 UIDNEXT 3 UIDVALIDITY 1222003700 UNSEEN 1)'])
('OK', ['"Apple Mail To Do" (MESSAGES 0 RECENT 0 UIDNEXT 1 UIDVALIDITY 1222003706 UNSEEN 0)'])
('OK', ['"Archive" (MESSAGES 0 RECENT 0 UIDNEXT 1 UIDVALIDITY 1222003809 UNSEEN 0)'])
('OK', ['"Archive.2008" (MESSAGES 1 RECENT 0 UIDNEXT 2 UIDVALIDITY 1222003831 UNSEEN 0)'])
```

19.4.6 Selecting a Mailbox

The basic mode of operation, once the client is authenticated, is to *select* a mailbox and then interrogate the server regarding messages in the mailbox. The connection is stateful, so once a mailbox is selected all commands operate on messages in that mailbox until a new mailbox is selected.

```
import imaplib
import imaplib_connect

c = imaplib_connect.open_connection()
try:
    typ, data = c.select('INBOX')
    print typ, data
    num_msgs = int(data[0])
    print 'There are %d messages in INBOX' % num_msgs
finally:
    c.close()
    c.logout()
```

The response data contains the total number of messages in the mailbox.

```
$ python imaplib_select.py
OK ['1']
There are 1 messages in INBOX
```

If an invalid mailbox is specified, the response code is `NO`.

```
import imaplib
import imaplib_connect

c = imaplib_connect.open_connection()
try:
    typ, data = c.select('Does Not Exist')
    print typ, data
finally:
    c.logout()
```

The data contains an error message describing the problem.

```
$ python imaplib_select_invalid.py
NO ["Mailbox doesn't exist: Does Not Exist"]
```

19.4.7 Searching for Messages

Once the mailbox is selected, use `search()` to retrieve the ids of messages in the mailbox.

```
import imaplib
import imaplib_connect
from imaplib_list_parse import parse_list_response

c = imaplib_connect.open_connection()
try:
    typ, mailbox_data = c.list()
    for line in mailbox_data:
        flags, delimiter, mailbox_name = parse_list_response(line)
        c.select(mailbox_name, readonly=True)
        typ, msg_ids = c.search(None, 'ALL')
        print mailbox_name, typ, msg_ids
finally:
    try:
        c.close()
    except:
        pass
    c.logout()
```

Message ids are assigned by the server, and are implementation dependent. The IMAP4 protocol makes a distinction between sequential ids for messages at a given point in time during a transaction and UID identifiers for messages, but not all servers seem to bother.

```
$ python imaplib_search_all.py
INBOX OK ['1']
Apple Mail To Do OK ['']
Archive OK ['']
Archive.2008 OK ['1']
```

In this case, INBOX and Archive.2008 each have a diffrerent message with id 1. The other mailboxes are empty.

19.4.8 Search Criteria

A variety of other search criteria can be used, including looking at dates for the message, flags, and other headers. Refer to section 6.4.4. of **RFC 3501** (http://tools.ietf.org/html/rfc3501.html) for complete details.

As one example, to look for messages with 'test message 2' in the subject, the search criteria could be constructed as:

```
(SUBJECT "test message 2")
```

This example finds all messages with the title "test message 2" in all mailboxes:

```
import imaplib
import imaplib_connect
from imaplib_list_parse import parse_list_response

c = imaplib_connect.open_connection()
try:
    typ, mailbox_data = c.list()
    for line in mailbox_data:
        flags, delimiter, mailbox_name = parse_list_response(line)
        c.select(mailbox_name, readonly=True)
        typ, msg_ids = c.search(None, '(SUBJECT "test message 2")')
        print mailbox_name, typ, msg_ids
finally:
    try:
        c.close()
    except:
        pass
    c.logout()
```

There is only one such message in the account, and it is in the INBOX.

```
$ python imaplib_search_subject.py
INBOX OK ['1']
Apple Mail To Do OK ['']
Archive OK ['']
Archive.2008 OK ['']
```

Search criteria can also be combined.

```
import imaplib
import imaplib_connect
from imaplib_list_parse import parse_list_response

c = imaplib_connect.open_connection()
try:
    typ, mailbox_data = c.list()
    for line in mailbox_data:
        flags, delimiter, mailbox_name = parse_list_response(line)
        c.select(mailbox_name, readonly=True)
        typ, msg_ids = c.search(None, '(FROM "Doug" SUBJECT "test message 2")')
        print mailbox_name, typ, msg_ids
finally:
    try:
        c.close()
    except:
        pass
    c.logout()
```

The combination is treated as a logical *and* operation.

```
$ python imaplib_search_from.py
INBOX OK ['1']
Apple Mail To Do OK ['']
Archive OK ['']
Archive.2008 OK ['']
```

19.4.9 Fetching Messages

The identifiers returned by `search()` are used to retrieve the contents, or partial contents, of messages for further processing via `fetch()`. `fetch()` takes 2 arguments, the message ids to fetch and the portion(s) of the message to retrieve.

The *message_ids* argument is a comma separated list of ids (`"1"`, `"1,2"`) or id ranges (`1:2`). The *message_parts* argument is an IMAP list of message segment names. As with search criteria for `search()`, the IMAP protocol specifies named message segments so clients can efficiently retrieve only the parts of the message they actually need. For example, to print the headers of the messages in a mailbox, we could `fetch()` the headers using `BODY.PEEK[HEADER]`.

Note: Another way to fetch the headers would be simply `BODY[HEADERS]`, but that form implicitly marks the message as read, which is undesirable in many cases.

```
import imaplib
import pprint
import imaplib_connect

imaplib.Debug = 4
c = imaplib_connect.open_connection()
try:
    c.select('INBOX', readonly=True)
    typ, msg_data = c.fetch('1', '(BODY.PEEK[HEADER] FLAGS)')
    pprint.pprint(msg_data)
finally:
    try:
        c.close()
    except:
        pass
    c.logout()
```

The return value of `fetch()` has been partially parsed so it is somewhat harder to work with than the return value of `list()`. If we turn on debugging, we can see the complete interaction between the client and server to understand why this is so.

```
$ python imaplib_fetch_raw.py
  13:12.54 imaplib version 2.58
  13:12.54 new IMAP4 connection, tag=CFKH
  13:12.54 < * OK dovecot ready.
  13:12.54 > CFKH0 CAPABILITY
  13:12.54 < * CAPABILITY IMAP4rev1 SORT THREAD=REFERENCES MULTIAPPEND UNSELECT IDLE CHILDREN LISTEXT
  13:12.54 < CFKH0 OK Capability completed.
  13:12.54 CAPABILITIES: ('IMAP4REV1', 'SORT', 'THREAD=REFERENCES', 'MULTIAPPEND', 'UNSELECT', 'IDLE'
  13:12.54 > CFKH1 LOGIN example "password"
  13:13.18 < CFKH1 OK Logged in.
  13:13.18 > CFKH2 EXAMINE INBOX
  13:13.20 < * FLAGS (\Answered \Flagged \Deleted \Seen \Draft $NotJunk $Junk)
  13:13.20 < * OK [PERMANENTFLAGS ()] Read-only mailbox.
  13:13.20 < * 2 EXISTS
  13:13.20 < * 1 RECENT
  13:13.20 < * OK [UNSEEN 1] First unseen.
  13:13.20 < * OK [UIDVALIDITY 1222003700] UIDs valid
  13:13.20 < * OK [UIDNEXT 4] Predicted next UID
  13:13.20 < CFKH2 OK [READ-ONLY] Select completed.
  13:13.20 > CFKH3 FETCH 1 (BODY.PEEK[HEADER] FLAGS)
  13:13.20 < * 1 FETCH (FLAGS ($NotJunk) BODY[HEADER] {595}
  13:13.20 read literal size 595
  13:13.20 < )
  13:13.20 < CFKH3 OK Fetch completed.
  13:13.20 > CFKH4 CLOSE
  13:13.21 < CFKH4 OK Close completed.
  13:13.21 > CFKH5 LOGOUT
  13:13.21 < * BYE Logging out
  13:13.21 BYE response: Logging out
  13:13.21 < CFKH5 OK Logout completed.
[('1 (FLAGS ($NotJunk) BODY[HEADER] {595}',
  'Return-Path: <dhellmann@example.com>\r\nReceived: from example.com (localhost [127.0.0.1])\r\n\tby
 ')']
```

The response from the `FETCH` command starts with the flags, then indicates that there are 595 bytes of header data. The client contructs a tuple with the response for the message, and then closes the sequence with a single string containing the `)` the server sends at the end of the fetch response. Because of this formatting, it may be easier to fetch different pieces of information separately, or to recombine the response and parse it yourself.

```
import imaplib
import pprint
import imaplib_connect

c = imaplib_connect.open_connection()
try:
    c.select('INBOX', readonly=True)

    print 'HEADER:'
    typ, msg_data = c.fetch('1', '(BODY.PEEK[HEADER])')
    for response_part in msg_data:
        if isinstance(response_part, tuple):
            print response_part[1]

    print 'BODY TEXT:'
    typ, msg_data = c.fetch('1', '(BODY.PEEK[TEXT])')
    for response_part in msg_data:
        if isinstance(response_part, tuple):
            print response_part[1]

    print '\nFLAGS:'
    typ, msg_data = c.fetch('1', '(FLAGS)')
    for response_part in msg_data:
        print response_part
        print imaplib.ParseFlags(response_part)
finally:
    try:
        c.close()
    except:
        pass
    c.logout()
```

Fetching values separately has the added benefit of making it easy to use `ParseFlags()` to parse the flags from the response.

```
$ python imaplib_fetch_separately.py
HEADER:
Return-Path: <dhellmann@example.com>
Received: from example.com (localhost [127.0.0.1])
    by example.com (8.13.4/8.13.4) with ESMTP id m8LDTGW4018260
    for <example@example.com>; Sun, 21 Sep 2008 09:29:16 -0400
Received: (from dhellmann@localhost)
    by example.com (8.13.4/8.13.4/Submit) id m8LDTGZ5018259
    for example@example.com; Sun, 21 Sep 2008 09:29:16 -0400
Date: Sun, 21 Sep 2008 09:29:16 -0400
From: Doug Hellmann <dhellmann@example.com>
Message-Id: <200809211329.m8LDTGZ5018259@example.com>
To: example@example.com
Subject: test message 2


BODY TEXT:
second message


FLAGS:
1 (FLAGS ($NotJunk))
('$NotJunk',)
```

19.4.10 Whole Messages

As illustrated above, the client can ask the server for individual parts of the message separately. It is also possible to retrieve the entire message as an **RFC 2822** (http://tools.ietf.org/html/rfc2822.html) formatted mail message and parse it with classes from the `email` module.

```
import imaplib
import email
import imaplib_connect

c = imaplib_connect.open_connection()
try:
    c.select('INBOX', readonly=True)

    typ, msg_data = c.fetch('1', '(RFC822)')
    for response_part in msg_data:
        if isinstance(response_part, tuple):
            msg = email.message_from_string(response_part[1])
            for header in [ 'subject', 'to', 'from' ]:
                print '%-8s: %s' % (header.upper(), msg[header])

finally:
    try:
        c.close()
    except:
        pass
    c.logout()
```

The parser in the `email` module make it very easy to access and manipulate messages. This example prints just a few of the headers for each message.

```
$ python imaplib_fetch_rfc822.py
SUBJECT : test message 2
TO      : example@example.com
FROM    : Doug Hellmann <dhellmann@example.com>
```

19.4.11 Uploading Messages

To add a new message to a mailbox, pass it to the `append()` method.

```
import imaplib
import time
import email.message
import imaplib_connect

new_message = email.message.Message()
new_message.set_unixfrom('pymotw')
new_message['Subject'] = 'subject goes here'
new_message['From'] = 'pymotw@example.com'
new_message['To'] = 'example@example.com'
new_message.set_payload('This is the body of the message.\n')

print new_message

c = imaplib_connect.open_connection()
try:
    c.append('INBOX', '', imaplib.Time2Internaldate(time.time()), str(new_message))

    c.select('INBOX')
    typ, [msg_ids] = c.search(None, 'ALL')
    for num in msg_ids.split():
        typ, msg_data = c.fetch(num, '(BODY.PEEK[HEADER])')
        for response_part in msg_data:
            if isinstance(response_part, tuple):
                print '\n%s:' % num
                print response_part[1]

finally:
    try:
        c.close()
    except:
        pass
    c.logout()
```

```
pymotw
Subject: subject goes here
From: pymotw@example.com
To: example@example.com

This is the body of the message.
```

```
1:
Return-Path: <dhellmann@example.com>
Received: from example.com (localhost [127.0.0.1])
    by example.com (8.13.4/8.13.4) with ESMTP id m8LDTGW4018260
    for <example@example.com>; Sun, 21 Sep 2008 09:29:16 -0400
Received: (from dhellmann@localhost)
    by example.com (8.13.4/8.13.4/Submit) id m8LDTGZ5018259
    for example@example.com; Sun, 21 Sep 2008 09:29:16 -0400
Date: Sun, 21 Sep 2008 09:29:16 -0400
From: Doug Hellmann <dhellmann@example.com>
Message-Id: <200809211329.m8LDTGZ5018259@example.com>
To: example@example.com
Subject: test message 2



2:
Return-Path: <doug.hellmann@example.com>
Message-Id: <0D9C3C50-462A-4FD7-9E5A-11EE222D721D@example.com>
From: Doug Hellmann <doug.hellmann@example.com>
To: example@example.com
Content-Type: text/plain; charset=US-ASCII; format=flowed; delsp=yes
Content-Transfer-Encoding: 7bit
Mime-Version: 1.0 (Apple Message framework v929.2)
Subject: lorem ipsum
Date: Sun, 21 Sep 2008 12:53:16 -0400
X-Mailer: Apple Mail (2.929.2)



3:
pymotw
Subject: subject goes here
From: pymotw@example.com
To: example@example.com
```

19.4.12 Moving and Copying Messages

Once a message is on the server, it can be moved or copied without downloading it using `move()` or `copy()`. These methods operate on message id ranges, just as `fetch()` does.

This example script creates a new mailbox under `Archive` and copies the read messages from `INBOX` into it.

```
import imaplib
import imaplib_connect

c = imaplib_connect.open_connection()
try:
    # Find the "SEEN" messages in INBOX
    c.select('INBOX')
    typ, [response] = c.search(None, 'SEEN')
    if typ != 'OK':
        raise RuntimeError(response)

    # Create a new mailbox, "Archive.Today"
    msg_ids = ','.join(response.split(' '))
    typ, create_response = c.create('Archive.Today')
    print 'CREATED Archive.Today:', create_response

    # Copy the messages
    print 'COPYING:', msg_ids
    c.copy(msg_ids, 'Archive.Today')

    # Look at the results
    c.select('Archive.Today')
    typ, [response] = c.search(None, 'ALL')
    print 'COPIED:', response

finally:
    c.close()
    c.logout()
```

```
$ python imaplib_archive_read.py
CREATED Archive.Today: ['Create completed.']
COPYING: 1,2
COPIED: 1 2
```

Running the same script again shows the importance to checking return codes. Instead of raising an exception, the call to `create()` to make the new mailbox reports that the mailbox already exists.

```
$ python imaplib_archive_read.py
CREATED Archive.Today: ['Mailbox exists.']
COPYING: 1,2
COPIED: 1 2 3 4
```

19.4.13 Deleting Messages

Although most modern mail clients use a "Trash folder" model for working with deleted messages, the messages are not usually moved into an actual folder. Instead, their flags are updated to add `\Deleted`. *Emptying the trash* is implemented through an `EXPUNGE` command. This example script finds the archived messages with "Lorem ipsum" in the subject, sets the deleted flag, then shows that the messages are still present in the folder by querying the server again.

```
import imaplib
import imaplib_connect
from imaplib_list_parse import parse_list_response

c = imaplib_connect.open_connection()
try:
    c.select('Archive.Today')

    # What ids are in the mailbox?
    typ, [msg_ids] = c.search(None, 'ALL')
    print 'Starting messages:', msg_ids

    # Find the message(s)
    typ, [msg_ids] = c.search(None, '(SUBJECT "Lorem ipsum")')
    msg_ids = ','.join(msg_ids.split(' '))
    print 'Matching messages:', msg_ids

    # What are the current flags?
    typ, response = c.fetch(msg_ids, '(FLAGS)')
    print 'Flags before:', response
    # Change the Deleted flag
    typ, response = c.store(msg_ids, '+FLAGS', r'(\Deleted)')

    # What are the flags now?
    typ, response = c.fetch(msg_ids, '(FLAGS)')
    print 'Flags after:', response

    # Really delete the message.
    typ, response = c.expunge()
    print 'Expunged:', response

    # What ids are left in the mailbox?
    typ, [msg_ids] = c.search(None, 'ALL')
    print 'Remaining messages:', msg_ids

finally:
    try:
        c.close()
    except:
        pass
    c.logout()
```

This example explicitly calls `expunge()` to remove the messages, but calling `close()` has the same effect. The difference is the client is not notified about the deletions when you call `close()`.

```
$ python imaplib_delete_messages.py
Starting messages: 1 2 3 4
Matching messages: 1,3
Flags before: ['1 (FLAGS (\\Seen $NotJunk))', '3 (FLAGS (\\Seen \\Recent $NotJunk))']
Flags after: ['1 (FLAGS (\\Deleted \\Seen $NotJunk))',
'3 (FLAGS (\\Deleted \\Seen \\Recent $NotJunk))']
Expunged: ['1', '2']
Remaining messages: 1 2
```

See also:

imaplib (http://docs.python.org/library/imaplib.html) The standard library documentation for this module.

What is IMAP? (http://www.imap.org/about/whatisIMAP.html) imap.org description of the IMAP protocol

University of Washington IMAP Information Center (http://www.washington.edu/imap/) Good resource for IMAP information, along with source code.

RFC 3501 (http://tools.ietf.org/html/rfc3501.html) Internet Message Access Protocol

RFC 2822 (http://tools.ietf.org/html/rfc2822.html) Internet Message Format

IMAP Backup Script (http://snipplr.com/view/7955/imap-backup-script/) A script to backup email from an IMAP server.

`rfc822` The `rfc822` module includes an **RFC 822** (http://tools.ietf.org/html/rfc822.html) / **RFC 2822** (http://tools.ietf.org/html/rfc2822.html) parser

`email` The `email` module for parsing email messages.

`mailbox` Local mailbox parser.

`ConfigParser` Read and write configuration files.

IMAPClient (http://freshfoo.com/wiki/CodeIndex) A higher-level client for talking to IMAP servers, written by Menno Smits.

19.5 SimpleXMLRPCServer – Implements an XML-RPC server.

Purpose Implements an XML-RPC server.

Available In 2.2 and later

The SimpleXMLRPCServer module contains classes for creating your own cross-platform, language-independent server using the XML-RPC protocol. Client libraries exist for many other languages, making XML-RPC an easy choice for building RPC-style services.

Note: All of the examples provided here include a client module as well to interact with the demonstration server. If you want to download the code and run the examples, you will want to use 2 separate shell windows, one for the server and one for the client.

19.5.1 A Simple Server

This simple server example exposes a single function that takes the name of a directory and returns the contents. The first step is to create the SimpleXMLRPCServer instance and tell it where to listen for incoming requests ('localhost' port 9000 in this case). Then we define a function to be part of the service, and register the function so the server knows how to call it. The final step is to put the server into an infinite loop receiving and responding to requests.

```
from SimpleXMLRPCServer import SimpleXMLRPCServer
import logging
import os

# Set up logging
logging.basicConfig(level=logging.DEBUG)

server = SimpleXMLRPCServer(('localhost', 9000), logRequests=True)

# Expose a function
def list_contents(dir_name):
    logging.debug('list_contents(%s)', dir_name)
    return os.listdir(dir_name)
server.register_function(list_contents)

try:
    print 'Use Control-C to exit'
    server.serve_forever()
except KeyboardInterrupt:
    print 'Exiting'
```

The server can be accessed at the URL http://localhost:9000 using xmlrpclib. This client code illustrates how to call the `list_contents()` service from Python.

```
import xmlrpclib

proxy = xmlrpclib.ServerProxy('http://localhost:9000')
print proxy.list_contents('/tmp')
```

Notice that we simply connect the `ServerProxy` to the server using its base URL, and then call methods directly on the proxy. Each method invoked on the proxy is translated into a request to the server. The arguments are formatted using XML, and then POSTed to the server. The server unpacks the XML and figures out what function to call based on the method name invoked from the client. The arguments are passed to the function, and the return value is translated back to XML to be returned to the client.

Starting the server gives:

```
$ python SimpleXMLRPCServer_function.py
Use Control-C to exit
```

Running the client in a second window shows the contents of my `/tmp` directory:

```
$ python SimpleXMLRPCServer_function_client.py
['.s.PGSQL.5432', '.s.PGSQL.5432.lock', '.X0-lock', '.X11-unix', 'ccc_exclude.1mkahl',
'ccc_exclude.BKG3gb', 'ccc_exclude.M5jrgo', 'ccc_exclude.SPecwL', 'com.hp.launchport', 'emacs527',
'hsperfdata_dhellmann', 'launch-8hGHUp', 'launch-RQnlcc', 'launch-trsdly', 'launchd-242.T5UzTy',
'var_backups']
```

and after the request is finished, log output appears in the server window:

```
$ python SimpleXMLRPCServer_function.py
Use Control-C to exit
DEBUG:root:list_contents(/tmp)
localhost - - [29/Jun/2008 09:32:07] "POST /RPC2 HTTP/1.0" 200 -
```

The first line of output is from the `logging.debug()` call inside `list_contents()`. The second line is from the server logging the request because *logRequests* is `True`.

19.5.2 Alternate Names

Sometimes the function names you use inside your modules or libraries are not the names you want to use in your external API. You might need to load a platform-specific implementation, build the service API dynamically based on a configuration file, or replace real functions with stubs for testing. If you want to register a function with an alternate name, pass the name as the second argument to `register_function()`, like this:

```python
from SimpleXMLRPCServer import SimpleXMLRPCServer
import os

server = SimpleXMLRPCServer(('localhost', 9000))

# Expose a function with an alternate name
def list_contents(dir_name):
    return os.listdir(dir_name)
server.register_function(list_contents, 'dir')

try:
    print 'Use Control-C to exit'
    server.serve_forever()
except KeyboardInterrupt:
    print 'Exiting'
```

The client should now use the name `dir()` instead of `list_contents()`:

```python
import xmlrpclib

proxy = xmlrpclib.ServerProxy('http://localhost:9000')
print 'dir():', proxy.dir('/tmp')
print 'list_contents():', proxy.list_contents('/tmp')
```

Calling `list_contents()` results in an error, since the server no longer has a handler registered by that name.

```
$ python SimpleXMLRPCServer_alternate_name_client.py
dir(): ['.s.PGSQL.5432', '.s.PGSQL.5432.lock', '.X0-lock', '.X11-unix', 'ccc_exclude.1mkahl', 'ccc_e
list_contents():
```

```
Traceback (most recent call last):
  File "/Users/dhellmann/Documents/PyMOTW/in_progress/SimpleXMLRPCServer/SimpleXMLRPCServer_alternate
    print 'list_contents():', proxy.list_contents('/tmp')
  File "/Library/Frameworks/Python.framework/Versions/2.5/lib/python2.5/xmlrpclib.py", line 1147, in
    return self.__send(self.__name, args)
  File "/Library/Frameworks/Python.framework/Versions/2.5/lib/python2.5/xmlrpclib.py", line 1437, in
    verbose=self.__verbose
  File "/Library/Frameworks/Python.framework/Versions/2.5/lib/python2.5/xmlrpclib.py", line 1201, in
    return self._parse_response(h.getfile(), sock)
  File "/Library/Frameworks/Python.framework/Versions/2.5/lib/python2.5/xmlrpclib.py", line 1340, in
    return u.close()
  File "/Library/Frameworks/Python.framework/Versions/2.5/lib/python2.5/xmlrpclib.py", line 787, in c
    raise Fault(**self._stack[0])
xmlrpclib.Fault: <Fault 1: '<type \'exceptions.Exception\'>:method "list_contents" is not supported'>
```

19.5.3 Dotted Names

Individual functions can be registered with names that are not normally legal for Python identifiers. For example, you can include '.' in your names to separate the namespace in the service. This example extends our "directory" service to add "create" and "remove" calls. All of the functions are registered using the prefix "dir." so that the same server can provide other services using a different prefix. One other difference in this example is that some of the functions return None, so we have to tell the server to translate the None values to a nil value (see XML-RPC Extensions (http://ontosys.com/xml-rpc/extensions.php)).

```
from SimpleXMLRPCServer import SimpleXMLRPCServer
import os

server = SimpleXMLRPCServer(('localhost', 9000), allow_none=True)

server.register_function(os.listdir, 'dir.list')
server.register_function(os.mkdir, 'dir.create')
server.register_function(os.rmdir, 'dir.remove')

try:
    print 'Use Control-C to exit'
    server.serve_forever()
except KeyboardInterrupt:
    print 'Exiting'
```

To call the service functions in the client, simply refer to them with the dotted name, like so:

```
import xmlrpclib

proxy = xmlrpclib.ServerProxy('http://localhost:9000')
print 'BEFORE       :', 'EXAMPLE' in proxy.dir.list('/tmp')
print 'CREATE       :', proxy.dir.create('/tmp/EXAMPLE')
print 'SHOULD EXIST :', 'EXAMPLE' in proxy.dir.list('/tmp')
print 'REMOVE       :', proxy.dir.remove('/tmp/EXAMPLE')
print 'AFTER        :', 'EXAMPLE' in proxy.dir.list('/tmp')
```

and (assuming you don't have a /tmp/EXAMPLE file on your system) the output for the sample client script looks like:

```
$ python SimpleXMLRPCServer_dotted_name_client.py
BEFORE       : False
CREATE       : None
SHOULD EXIST : True
```

```
REMOVE       : None
AFTER        : False
```

19.5.4 Arbitrary Names

A less useful, but potentially interesting feature is the ability to register functions with names that are otherwise invalid attribute names. This example service registers a function with the name "`multiply args`".

```
from SimpleXMLRPCServer import SimpleXMLRPCServer

server = SimpleXMLRPCServer(('localhost', 9000))

def my_function(a, b):
    return a * b
server.register_function(my_function, 'multiply args')

try:
    print 'Use Control-C to exit'
    server.serve_forever()
except KeyboardInterrupt:
    print 'Exiting'
```

Since the registered name contains a space, we can't use dot notation to access it directly from the proxy. We can, however, use `getattr()`.

```
import xmlrpclib

proxy = xmlrpclib.ServerProxy('http://localhost:9000')
print getattr(proxy, 'multiply args')(5, 5)
```

You should avoid creating services with names like this, though. This example is provided not necessarily because it is a good idea, but because you may encounter existing services with arbitrary names and need to be able to call them.

```
$ python SimpleXMLRPCServer_arbitrary_name_client.py
25
```

19.5.5 Exposing Methods of Objects

The earlier sections talked about techniques for establishing APIs using good naming conventions and namespacing. Another way to incorporate namespacing into your API is to use instances of classes and expose their methods. We can recreate the first example using an instance with a single method.

```
from SimpleXMLRPCServer import SimpleXMLRPCServer
import os
import inspect

server = SimpleXMLRPCServer(('localhost', 9000), logRequests=True)

class DirectoryService:
    def list(self, dir_name):
        return os.listdir(dir_name)

server.register_instance(DirectoryService())

try:
    print 'Use Control-C to exit'
    server.serve_forever()
except KeyboardInterrupt:
    print 'Exiting'
```

A client can call the method directly:

```
import xmlrpclib

proxy = xmlrpclib.ServerProxy('http://localhost:9000')
print proxy.list('/tmp')
```

and receive output like:

```
$ python SimpleXMLRPCServer_instance_client.py
['.s.PGSQL.5432', '.s.PGSQL.5432.lock', '.X0-lock', '.X11-unix', 'ccc_exclude.1mkahl',
'ccc_exclude.BKG3gb', 'ccc_exclude.M5jrgo', 'ccc_exclude.SPecwL', 'com.hp.launchport',
'emacs527', 'hsperfdata_dhellmann', 'launch-8hGHUp', 'launch-RQnlcc', 'launch-trsdly',
'launchd-242.T5UzTy', 'temp_textmate.XNiIdy', 'var_backups']
```

We've lost the "`dir.`" prefix for the service, though, so let's define a class to let us set up a service tree that can be invoked from clients.

```
from SimpleXMLRPCServer import SimpleXMLRPCServer
import os
import inspect

server = SimpleXMLRPCServer(('localhost', 9000), logRequests=True)

class ServiceRoot:
    pass

class DirectoryService:
    def list(self, dir_name):
        return os.listdir(dir_name)

root = ServiceRoot()
root.dir = DirectoryService()

server.register_instance(root, allow_dotted_names=True)

try:
    print 'Use Control-C to exit'
    server.serve_forever()
except KeyboardInterrupt:
    print 'Exiting'
```

By registering the instance of `ServiceRoot` with *allow_dotted_names* enabled, we give the server permission to walk the tree of objects when a request comes in to find the named method using `getattr()`.

```
import xmlrpclib

proxy = xmlrpclib.ServerProxy('http://localhost:9000')
print proxy.dir.list('/tmp')
```

```
$ python SimpleXMLRPCServer_instance_dotted_names_client.py
['.s.PGSQL.5432', '.s.PGSQL.5432.lock', '.X0-lock', '.X11-unix', 'ccc_exclude.1mkahl', 'ccc_exclude.
```

19.5.6 Dispatching Calls Yourself

By default, `register_instance()` finds all callable attributes of the instance with names not starting with '_' and registers them with their name. If you want to be more careful about the exposed methods, you could provide your own dispatching logic. For example:

```
from SimpleXMLRPCServer import SimpleXMLRPCServer
import os
import inspect

server = SimpleXMLRPCServer(('localhost', 9000), logRequests=True)

def expose(f):
    "Decorator to set exposed flag on a function."
    f.exposed = True
    return f

def is_exposed(f):
    "Test whether another function should be publicly exposed."
    return getattr(f, 'exposed', False)

class MyService:
    PREFIX = 'prefix'

    def _dispatch(self, method, params):
        # Remove our prefix from the method name
        if not method.startswith(self.PREFIX + '.'):
            raise Exception('method "%s" is not supported' % method)

        method_name = method.partition('.')[2]
        func = getattr(self, method_name)
        if not is_exposed(func):
            raise Exception('method "%s" is not supported' % method)

        return func(*params)

    @expose
    def public(self):
        return 'This is public'

    def private(self):
        return 'This is private'

server.register_instance(MyService())

try:
    print 'Use Control-C to exit'
    server.serve_forever()
except KeyboardInterrupt:
    print 'Exiting'
```

The `public()` method of `MyService` is marked as exposed to the XML-RPC service while `private()` is not. The `_dispatch()` method is invoked when the client tries to access a function that is part of `MyService`. It first enforces the use of a prefix ("`prefix.`" in this case, but you can use any string). Then it requires the function to have an attribute called *exposed* with a true value. The exposed flag is set on a function using a decorator for convenience.

Here are a few sample client calls:

```
import xmlrpclib

proxy = xmlrpclib.ServerProxy('http://localhost:9000')
print 'public():', proxy.prefix.public()
try:
    print 'private():', proxy.prefix.private()
except Exception, err:
    print 'ERROR:', err
try:
    print 'public() without prefix:', proxy.public()
except Exception, err:
    print 'ERROR:', err
```

and the resulting output, with the expected error messages trapped and reported:

```
$ python SimpleXMLRPCServer_instance_with_prefix_client.py
public(): This is public
private(): ERROR: <Fault 1: '<type \'exceptions.Exception\'>:method "prefix.private" is not supporte
public() without prefix: ERROR: <Fault 1: '<type \'exceptions.Exception\'>:method "public" is not sup
```

There are several other ways to override the dispatching mechanism, including subclassing directly from SimpleXML-RPCServer. Check out the docstrings in the module for more details.

19.5.7 Introspection API

As with many network services, it is possible to query an XML-RPC server to ask it what methods it supports and learn how to use them. `SimpleXMLRPCServer` includes a set of public methods for performing this introspection. By default they are turned off, but can be enabled with `register_introspection_functions()`. You can add explicit support for `system.listMethods()` and `system.methodHelp()` by defining `_listMethods()` and `_methodHelp()` on your service class. For example,

```
from SimpleXMLRPCServer import SimpleXMLRPCServer, list_public_methods
import os
import inspect

server = SimpleXMLRPCServer(('localhost', 9000), logRequests=True)
server.register_introspection_functions()

class DirectoryService:

    def _listMethods(self):
        return list_public_methods(self)

    def _methodHelp(self, method):
        f = getattr(self, method)
        return inspect.getdoc(f)

    def list(self, dir_name):
        """list(dir_name) => [<filenames>]

        Returns a list containing the contents of the named directory.
        """
        return os.listdir(dir_name)

server.register_instance(DirectoryService())

try:
    print 'Use Control-C to exit'
    server.serve_forever()
except KeyboardInterrupt:
    print 'Exiting'
```

In this case, the convenience function `list_public_methods()` scans an instance to return the names of callable attributes that do not start with '_'. You can redefine `_listMethods()` to apply whatever rules you like. Similarly, for this basic example `_methodHelp()` returns the docstring of the function, but could be written to build a help string from another source.

This client queries the server and reports on all of the publicly callable methods.

```
import xmlrpclib

proxy = xmlrpclib.ServerProxy('http://localhost:9000')
for method_name in proxy.system.listMethods():
    print '=' * 60
    print method_name
    print '-' * 60
    print proxy.system.methodHelp(method_name)
    print
```

Notice that the system methods are included in the results.

```
$ python SimpleXMLRPCServer_introspection_client.py
============================================================
list
------------------------------------------------------------
list(dir_name) => [<filenames>]

Returns a list containing the contents of the named directory.

============================================================
system.listMethods
------------------------------------------------------------
system.listMethods() => ['add', 'subtract', 'multiple']

Returns a list of the methods supported by the server.

============================================================
system.methodHelp
------------------------------------------------------------
system.methodHelp('add') => "Adds two integers together"

Returns a string containing documentation for the specified method.

============================================================
system.methodSignature
------------------------------------------------------------
system.methodSignature('add') => [double, int, int]

Returns a list describing the signature of the method. In the
above example, the add method takes two integers as arguments
and returns a double result.

This server does NOT support system.methodSignature.
```

See also:

SimpleXMLRPCServer (http://docs.python.org/lib/module-SimpleXMLRPCServer.html) Standard library documentation for this module.

XML-RPC How To (http://www.tldp.org/HOWTO/XML-RPC-HOWTO/index.html) Describes how to use XML-RPC to implement clients and servers in a variety of languages.

XML-RPC Extensions (http://ontosys.com/xml-rpc/extensions.php) Specifies an extension to the XML-RPC protocol.

`xmlrpclib` XML-RPC client library

19.6 smtpd – Sample SMTP Servers

Purpose Includes classes for implementing SMTP servers.

Available In 2.1 and later

The `smtpd` module includes classes for building simple mail transport protocol servers. It is the server-side of the protocol used by `smtplib`.

19.6.1 SMTPServer

The base class for all of the provided example servers is `SMTPServer`. It handles communicating with the client, receiving the data, and provides a convenient hook to override to handle the message once it is fully available.

The constructor arguments are the local address to listen for connections and the remote address for proxying. The method `process_message()` is provided as a hook to be overridden by your derived class. It is called when the message is completely received, and given these arguments:

peer

The client's address, a tuple containing IP and incoming port.

mailfrom

The "from" information out of the message envelope, given to the server by the client when the message is delivered. This does not necessarily match the `From` header in all cases.

rcpttos

The list of recipients from the message envelope. Again, this does not always match the `To` header, especially if someone is blind carbon copied.

data

The full **RFC 2822** (http://tools.ietf.org/html/rfc2822.html) message body.

Since the default implementation of `process_message()` raises *NotImplementedError*, to demonstrate using `SMTPServer` we need to create a subclass and provide a useful implementation. This first example defines a server that prints information about the messages it receives.

```
import smtpd
import asyncore

class CustomSMTPServer(smtpd.SMTPServer):

    def process_message(self, peer, mailfrom, rcpttos, data):
        print 'Receiving message from:', peer
        print 'Message addressed from:', mailfrom
        print 'Message addressed to  :', rcpttos
        print 'Message length        :', len(data)
        return

server = CustomSMTPServer(('127.0.0.1', 1025), None)

asyncore.loop()
```

SMTPServer uses asyncore, so to run the server we call asyncore.loop().

Now, we need a client to send data. By adapting one of the examples from the smtplib page, we can set up a client to send data to our test server running locally on port 1025.

```
import smtplib
import email.utils
from email.mime.text import MIMEText

# Create the message
msg = MIMEText('This is the body of the message.')
msg['To'] = email.utils.formataddr(('Recipient', 'recipient@example.com'))
msg['From'] = email.utils.formataddr(('Author', 'author@example.com'))
msg['Subject'] = 'Simple test message'

server = smtplib.SMTP('127.0.0.1', 1025)
server.set_debuglevel(True) # show communication with the server
try:
    server.sendmail('author@example.com', ['recipient@example.com'], msg.as_string())
finally:
    server.quit()
```

Now if we run smtpd_custom.py in one terminal, and smtpd_senddata.py in another, we should see:

```
$ python smtpd_senddata.py
send: 'ehlo farnsworth.local\r\n'
reply: '502 Error: command "EHLO" not implemented\r\n'
reply: retcode (502); Msg: Error: command "EHLO" not implemented
send: 'helo farnsworth.local\r\n'
reply: '250 farnsworth.local\r\n'
reply: retcode (250); Msg: farnsworth.local
send: 'mail FROM:<author@example.com>\r\n'
reply: '250 Ok\r\n'
reply: retcode (250); Msg: Ok
send: 'rcpt TO:<recipient@example.com>\r\n'
reply: '250 Ok\r\n'
reply: retcode (250); Msg: Ok
send: 'data\r\n'
reply: '354 End data with <CR><LF>.<CR><LF>\r\n'
reply: retcode (354); Msg: End data with <CR><LF>.<CR><LF>
data: (354, 'End data with <CR><LF>.<CR><LF>')
send: 'Content-Type: text/plain; charset="us-ascii"\r\nMIME-Version: 1.0\r\nContent-Transfer-Encoding
reply: '250 Ok\r\n'
reply: retcode (250); Msg: Ok
data: (250, 'Ok')
send: 'quit\r\n'
reply: '221 Bye\r\n'
reply: retcode (221); Msg: Bye
```

and

```
$ python smtpd_custom.py
Receiving message from: ('127.0.0.1', 58541)
Message addressed from: author@example.com
Message addressed to  : ['recipient@example.com']
Message length        : 229
```

The port number for the incoming message will vary each time. Notice that the *rcpttos* argument is a list of values and *mailfrom* is a single string.

Note: To stop the server, press `Ctrl-C`.

19.6.2 DebuggingServer

The example above shows the arguments to `process_message()`, but `smtpd` also includes a server specifically designed for more complete debugging, called `DebuggingServer`. It prints the entire incoming message to stdout and then stops processing (it does not proxy the message to a real mail server).

```
import smtpd
import asyncore

server = smtpd.DebuggingServer(('127.0.0.1', 1025), None)

asyncore.loop()
```

Using the `smtpd_senddata.py` client program from above, the output of the `DebuggingServer` is:

```
$ python smtpd_debug.py
---------- MESSAGE FOLLOWS ----------
Content-Type: text/plain; charset="us-ascii"
MIME-Version: 1.0
Content-Transfer-Encoding: 7bit
To: Recipient <recipient@example.com>
From: Author <author@example.com>
Subject: Simple test message
X-Peer: 127.0.0.1

This is the body of the message.
------------ END MESSAGE ------------
```

19.6.3 PureProxy

The `PureProxy` class implements a straightforward proxy server. Incoming messages are forwarded upstream to the server given as argument to the constructor.

Warning: The stdlib docs say, "running this has a good chance to make you into an open relay, so please be careful."

Setting up the proxy server is just as easy as the debug server:

```
import smtpd
import asyncore

server = smtpd.PureProxy(('127.0.0.1', 1025), ('mail', 25))

asyncore.loop()
```

It prints no output, though, so to verify that it is working we need to look at the mail server logs.

```
Oct 19 19:16:34 homer sendmail[6785]: m9JNGXJb006785: from=<author@example.com>, size=248, class=0, r
```

19.6.4 MailmanProxy

smtpd also includes a special proxy that acts as a front-end for Mailman (http://www.gnu.org/software/mailman/index.html). If the local Mailman configuration recognizes the address, it is handled directly. Otherwise the message is delivered to the proxy.

See also:

smtpd (http://docs.python.org/lib/module-smtpd.html) Standard library documentation for this module.

smtplib Provides a client interface.

email Parses email messages.

asyncore Base module for writing asynchronous servers.

RFC 2822 (http://tools.ietf.org/html/rfc2822.html) Defines the email message format.

GNU Mailman mailing list software (http://www.gnu.org/software/mailman/index.html) An excellent example of Python software that works with email messages.

19.7 smtplib – Simple Mail Transfer Protocol client

Purpose Interact with SMTP servers, including sending email.

Available In 1.5.2 and later

smtplib includes the class SMTP, which is useful for communicating with mail servers to send mail.

Note: The email addresses, host names, and IP addresses in the following examples have been obscured, but otherwise the transcripts illustrate the sequence of commands and responses accurately.

19.7.1 Sending an Email Message

The most common use of SMTP is to connect to a mail server and send a message. The mail server host name and port can be passed to the constructor, or you can use connect() explicitly. Once connected, just call sendmail() with the envelope parameters and body of the message. The message text should be a fully formed **RFC 2882** (http://tools.ietf.org/html/rfc2882.html)-compliant message, since smtplib does not modify the contents or headers at all. That means you need to add the From and To headers yourself.

```python
import smtplib
import email.utils
from email.mime.text import MIMEText

# Create the message
msg = MIMEText('This is the body of the message.')
msg['To'] = email.utils.formataddr(('Recipient', 'recipient@example.com'))
msg['From'] = email.utils.formataddr(('Author', 'author@example.com'))
msg['Subject'] = 'Simple test message'

server = smtplib.SMTP('mail')
server.set_debuglevel(True) # show communication with the server
```

```
try:
    server.sendmail('author@example.com', ['recipient@example.com'], msg.as_string())
finally:
    server.quit()
```

In this example, debugging is also turned on to show the communication between client and server. Otherwise the example would produce no output at all.

```
$ python smtplib_sendmail.py
send: 'ehlo localhost.local\r\n'
reply: '250-mail.example.com Hello [192.168.1.17], pleased to meet you\r\n'
reply: '250-ENHANCEDSTATUSCODES\r\n'
reply: '250-PIPELINING\r\n'
reply: '250-8BITMIME\r\n'
reply: '250-SIZE\r\n'
reply: '250-DSN\r\n'
reply: '250-ETRN\r\n'
reply: '250-AUTH GSSAPI DIGEST-MD5 CRAM-MD5\r\n'
reply: '250-DELIVERBY\r\n'
reply: '250 HELP\r\n'
reply: retcode (250); Msg: mail.example.com Hello [192.168.1.17], pleased to meet you
ENHANCEDSTATUSCODES
PIPELINING
8BITMIME
SIZE
DSN
ETRN
AUTH GSSAPI DIGEST-MD5 CRAM-MD5
DELIVERBY
HELP
send: 'mail FROM:<author@example.com> size=266\r\n'
reply: '250 2.1.0 <author@example.com>... Sender ok\r\n'
reply: retcode (250); Msg: 2.1.0 <author@example.com>... Sender ok
send: 'rcpt TO:<recipient@example.com>\r\n'
reply: '250 2.1.5 <recipient@example.com>... Recipient ok\r\n'
reply: retcode (250); Msg: 2.1.5 <recipient@example.com>... Recipient ok
send: 'data\r\n'
reply: '354 Enter mail, end with "." on a line by itself\r\n'
reply: retcode (354); Msg: Enter mail, end with "." on a line by itself
data: (354, 'Enter mail, end with "." on a line by itself')
send: 'From nobody Sun Sep 28 10:02:48 2008\r\nContent-Type: text/plain; charset="us-ascii"\r\nMIME-V
reply: '250 2.0.0 m8SE2mpc015614 Message accepted for delivery\r\n'
reply: retcode (250); Msg: 2.0.0 m8SE2mpc015614 Message accepted for delivery
data: (250, '2.0.0 m8SE2mpc015614 Message accepted for delivery')
send: 'quit\r\n'
reply: '221 2.0.0 mail.example.com closing connection\r\n'
reply: retcode (221); Msg: 2.0.0 mail.example.com closing connection
```

Notice that the second argument to `sendmail()`, the recipients, is passed as a list. You can include any number of addresses in the list to have the message delivered to each of them in turn. Since the envelope information is separate from the message headers, you can even BCC someone by including them in the method argument but not in the message header.

19.7.2 Authentication and Encryption

The SMTP class also handles authentication and TLS (transport layer security) encryption, when the server supports them. To determine if the server supports TLS, call `ehlo()` directly to identify your computer to the server and ask it what extensions are available. Then call `has_extn()` to check the results. Once TLS is started, you must call `ehlo()` again before authenticating.

```
import smtplib
import email.utils
from email.mime.text import MIMEText
import getpass

# Prompt the user for connection info
to_email = raw_input('Recipient: ')
servername = raw_input('Mail server name: ')
username = raw_input('Mail user name: ')
password = getpass.getpass("%s's password: " % username)

# Create the message
msg = MIMEText('Test message from PyMOTW.')
msg.set_unixfrom('author')
msg['To'] = email.utils.formataddr(('Recipient', to_email))
msg['From'] = email.utils.formataddr(('Author', 'author@example.com'))
msg['Subject'] = 'Test from PyMOTW'

server = smtplib.SMTP(servername)
try:
    server.set_debuglevel(True)

    # identify ourselves, prompting server for supported features
    server.ehlo()

    # If we can encrypt this session, do it
    if server.has_extn('STARTTLS'):
        server.starttls()
        server.ehlo() # re-identify ourselves over TLS connection

    server.login(username, password)
    server.sendmail('author@example.com', [to_email], msg.as_string())
finally:
    server.quit()
```

Notice that `STARTTLS` does not appear in the list of extensions (in the reply to `EHLO`) once TLS is enabled.

```
$ python smtplib_authenticated.py
Recipient: recipient@example.com
Mail server name: smtpauth.isp.net
Mail user name: user@isp.net
user@isp.net's password:
send: 'ehlo localhost.local\r\n'
reply: '250-elasmtp-isp.net Hello localhost.local [<your IP here>]\r\n'
reply: '250-SIZE 14680064\r\n'
reply: '250-PIPELINING\r\n'
reply: '250-AUTH PLAIN LOGIN CRAM-MD5\r\n'
reply: '250-STARTTLS\r\n'
reply: '250 HELP\r\n'
reply: retcode (250); Msg: elasmtp-isp.net Hello localhost.local [<your IP here>]
SIZE 14680064
PIPELINING
AUTH PLAIN LOGIN CRAM-MD5
STARTTLS
HELP
send: 'STARTTLS\r\n'
```

```
reply: '220 TLS go ahead\r\n'
reply: retcode (220); Msg: TLS go ahead
send: 'ehlo localhost.local\r\n'
reply: '250-elasmtp-isp.net Hello localhost.local [<your IP here>]\r\n'
reply: '250-SIZE 14680064\r\n'
reply: '250-PIPELINING\r\n'
reply: '250-AUTH PLAIN LOGIN CRAM-MD5\r\n'
reply: '250 HELP\r\n'
reply: retcode (250); Msg: elasmtp-isp.net Hello farnsworth.local [<your IP here>]
SIZE 14680064
PIPELINING
AUTH PLAIN LOGIN CRAM-MD5
HELP
send: 'AUTH CRAM-MD5\r\n'
reply: '334 PDExNjkyLjEyMjI2MTI1NzlAZWxhc210cC1tZWFseS5hdGwuc2EuZWFydGhsaW5rLm5ldD4=\r\n'
reply: retcode (334); Msg: PDExNjkyLjEyMjI2MTI1NzlAZWxhc210cC1tZWFseS5hdGwuc2EuZWFydGhsaW5rLm5ldD4=
send: 'ZGhlbGxtYW5uQGVhcnRobGluay5uZXQgN2Q1YjAyYTRmMGQ1YzZjM2NjOTNjZDc1MDQxN2ViYjg=\r\n'
reply: '235 Authentication succeeded\r\n'
reply: retcode (235); Msg: Authentication succeeded
send: 'mail FROM:<author@example.com> size=221\r\n'
reply: '250 OK\r\n'
reply: retcode (250); Msg: OK
send: 'rcpt TO:<recipient@example.com>\r\n'
reply: '250 Accepted\r\n'
reply: retcode (250); Msg: Accepted
send: 'data\r\n'
reply: '354 Enter message, ending with "." on a line by itself\r\n'
reply: retcode (354); Msg: Enter message, ending with "." on a line by itself
data: (354, 'Enter message, ending with "." on a line by itself')
send: 'Content-Type: text/plain; charset="us-ascii"\r\nMIME-Version: 1.0\r\nContent-Transfer-Encoding
reply: '250 OK id=1KjxNj-00032a-Ux\r\n'
reply: retcode (250); Msg: OK id=1KjxNj-00032a-Ux
data: (250, 'OK id=1KjxNj-00032a-Ux')
send: 'quit\r\n'
reply: '221 elasmtp-isp.net closing connection\r\n'
reply: retcode (221); Msg: elasmtp-isp.net closing connection
```

19.7.3 Verifying an Email Address

The SMTP protocol includes a command to ask a server whether an address is valid. Usually VRFY is disabled to prevent spammers from finding legitimate email addresses, but if it is enabled you can ask the server about an address and receive a status code indicating validity along with the user's full name, if it is available.

```python
import smtplib

server = smtplib.SMTP('mail')
server.set_debuglevel(True) # show communication with the server
try:
    dhellmann_result = server.verify('dhellmann')
    notthere_result = server.verify('notthere')
finally:
    server.quit()

print 'dhellmann:', dhellmann_result
print 'notthere :', notthere_result
```

As the last 2 lines of output here show, the address dhellmann is valid but notthere is not.

```
$ python smtplib_verify.py
send: 'vrfy <dhellmann>\r\n'
reply: '250 2.1.5 Doug Hellmann <dhellmann@mail.example.com>\r\n'
reply: retcode (250); Msg: 2.1.5 Doug Hellmann <dhellmann@mail.example.com>
send: 'vrfy <notthere>\r\n'
reply: '550 5.1.1 <notthere>... User unknown\r\n'
reply: retcode (550); Msg: 5.1.1 <notthere>... User unknown
send: 'quit\r\n'
reply: '221 2.0.0 mail.example.com closing connection\r\n'
reply: retcode (221); Msg: 2.0.0 mail.example.com closing connection
dhellmann: (250, '2.1.5 Doug Hellmann <dhellmann@mail.example.com>')
notthere : (550, '5.1.1 <notthere>... User unknown')
```

See also:

smtplib (http://docs.python.org/lib/module-smtplib.html) Standard library documentation for this module.

RFC 821 (http://tools.ietf.org/html/rfc821.html) The Simple Mail Transfer Protocol (SMTP) specification.

RFC 1869 (http://tools.ietf.org/html/rfc1869.html) SMTP Service Extensions to the base protocol.

RFC 822 (http://tools.ietf.org/html/rfc822.html) "Standard for the Format of ARPA Internet Text Messages", the original email message format specification.

RFC 2822 (http://tools.ietf.org/html/rfc2822.html) "Internet Message Format", updates to the email message format.

`email` Standard library module for parsing email messages.

`smtpd` Implements a simple SMTP server.

19.8 socket – Network Communication

Purpose Provides access to network communication

Available In 1.4 and later

The `socket` module exposes the low-level C API for communicating over a network using the BSD socket interface. It includes the `socket` class, for handling the actual data channel, and functions for network-related tasks such as converting a server's name to an address and formatting data to be sent across the network.

19.8.1 Addressing, Protocol Families and Socket Types

A *socket* is one endpoint of a communication channel used by programs to pass data back and forth locally or across the Internet. Sockets have two primary properties controlling the way they send data: the *address family* controls the OSI network layer protocol used and the *socket type* controls the transport layer protocol.

Python supports three address families. The most common, `AF_INET`, is used for IPv4 Internet addressing. IPv4 addresses are made up of four octal values separated by dots (e.g., `10.1.1.5` and `127.0.0.1`). These values are more commonly referred to as "IP addresses." Almost all Internet networking is done using IP version 4 at this time.

`AF_INET6` is used for IPv6 Internet addressing. IPv6 is the "next generation" version of the Internet protocol, and supports 128-bit addresses, traffic shaping, and routing features not available under IPv4. Adoption of IPv6 is still limited, but continues to grow.

`AF_UNIX` is the address family for Unix Domain Sockets (UDS), an interprocess communication protocol available on POSIX-compliant systems. The implementation of UDS typically allows the operating system to pass data directly from process to process, without going through the network stack. This is more efficient than using `AF_INET`, but because the filesystem is used as the namespace for addressing, UDS is restricted to processes on the same system. The appeal of using UDS over other IPC mechanisms such as named pipes or shared memory is that the programming interface is the same as for IP networking, so the application can take advantage of efficient communication when running on a single host, but use the same code when sending data across the network.

Note: The `AF_UNIX` constant is only defined on systems where UDS is supported.

The socket type is usually either `SOCK_DGRAM` for *user datagram protocol* (UDP) or `SOCK_STREAM` for *transmission control protocol* (TCP). UDP does not require transmission handshaking or other setup, but offers lower reliability of delivery. UDP messages may be delivered out of order, more than once, or not at all. TCP, by contrast, ensures that each message is delivered exactly once, and in the correct order. Most application protocols that deliver a large amount of data, such as HTTP, are built on top of TCP. UDP is commonly used for protocols where order is less important (since the message fits in a single packet, i.e., DNS), or for *multicasting* (sending the same data to several hosts).

Note: Python's `socket` module supports other socket types but they are less commonly used, so are not covered here. Refer to the standard library documentation for more details.

Looking up Hosts on the Network

`socket` includes functions to interface with the domain name services on the network, to convert the host name of a server into its numerical network address. Applications do not need to convert addresses explicitly before using them to connect to a server, but it can be useful when reporting errors to include the numerical address as well as the name value being used.

To find the official name of the current host, use `gethostname()`.

```
import socket

print socket.gethostname()
```

The name returned will depend on the network settings for the current system, and may change if it is on a different network (such as a laptop attached to a wireless LAN).

```
$ python socket_gethostname.py

farnsworth.hellfly.net
```

Use `gethostbyname()` to convert the name of a server to its numerical address:

```
import socket

for host in [ 'homer', 'www', 'www.python.org', 'nosuchname' ]:
    try:
        print '%15s : %s' % (host, socket.gethostbyname(host))
    except socket.error, msg:
        print '%15s : ERROR: %s' % (host, msg)
```

The name argument does not need to be a fully qualified name (i.e., it does not need to include the domain name as well as the base hostname). If the name cannot be found, an exception of type `socket.error` is raised.

```
$ python socket_gethostbyname.py

          homer : ERROR: [Errno 8] nodename nor servname provided, or not known
            www : ERROR: [Errno 8] nodename nor servname provided, or not known
 www.python.org : 82.94.164.162
     nosuchname : ERROR: [Errno 8] nodename nor servname provided, or not known
```

For access to more naming information about a server, use `gethostbyname_ex()`. It returns the canonical hostname of the server, any aliases, and all of the available IP addresses that can be used to reach it.

```
import socket

for host in [ 'homer', 'www', 'www.python.org', 'nosuchname' ]:
    print host
    try:
        hostname, aliases, addresses = socket.gethostbyname_ex(host)
        print '  Hostname:', hostname
        print '  Aliases :', aliases
        print ' Addresses:', addresses
    except socket.error, msg:
        print '%15s : ERROR: %s' % (host, msg)
    print
```

Having all known IP addresses for a server lets a client implement its own load balancing or fail-over algorithms.

```
$ python socket_gethostbyname_ex.py

homer
          homer : ERROR: [Errno 8] nodename nor servname provided, or not known

www
            www : ERROR: [Errno 8] nodename nor servname provided, or not known

www.python.org
  Hostname: www.python.org
  Aliases : []
 Addresses: ['82.94.164.162']

nosuchname
     nosuchname : ERROR: [Errno 8] nodename nor servname provided, or not known
```

Use `getfqdn()` to convert a partial name to a fully qualified domain name.

```
import socket

for host in [ 'homer', 'www' ]:
    print '%6s : %s' % (host, socket.getfqdn(host))
```

The name returned will not necessarily match the input argument in any way if the input is an alias, such as `www` is here.

```
$ python socket_getfqdn.py

 homer : homer
   www : www
```

When the address of a server is available, use `gethostbyaddr()` to do a "reverse" lookup for the name.

```
import socket

hostname, aliases, addresses = socket.gethostbyaddr('192.168.1.8')

print 'Hostname :', hostname
print 'Aliases  :', aliases
print 'Addresses:', addresses
```

The return value is a tuple containing the full hostname, any aliases, and all IP addresses associated with the name.

```
$ python socket_gethostbyaddr.py

Hostname : homer.hellfly.net
Aliases  : ['8.1.168.192.in-addr.arpa']
Addresses: ['192.168.1.8']
```

Finding Service Information

In addition to an IP address, each socket address includes an integer *port number*. Many applications can run on the same host, listening on a single IP address, but only one socket at a time can use a port at that address. The combination of IP address, protocol, and port number uniquely identify a communication channel and ensure that messages sent through a socket arrive at the correct destination.

Some of the port numbers are pre-allocated for a specific protocol. For example, communication between email servers using SMTP occurs over port number 25 using TCP, and web clients and servers use port 80 for HTTP. The port numbers for network services with standardized names can be looked up with `getservbyname()`.

```
import socket
from urlparse import urlparse

for url in [ 'http://www.python.org',
             'https://www.mybank.com',
             'ftp://prep.ai.mit.edu',
             'gopher://gopher.micro.umn.edu',
             'smtp://mail.example.com',
             'imap://mail.example.com',
             'imaps://mail.example.com',
             'pop3://pop.example.com',
             'pop3s://pop.example.com',
             ]:
    parsed_url = urlparse(url)
    port = socket.getservbyname(parsed_url.scheme)
    print '%6s : %s' % (parsed_url.scheme, port)
```

Although a standardized service is unlikely to change ports, looking up the value with a system call instead of hard-coding it is more flexible when new services are added in the future.

```
$ python socket_getservbyname.py

  http : 80
 https : 443
   ftp : 21
gopher : 70
  smtp : 25
  imap : 143
 imaps : 993
  pop3 : 110
 pop3s : 995
```

To reverse the service port lookup, use `getservbyport()`.

```
import socket
import urlparse

for port in [ 80, 443, 21, 70, 25, 143, 993, 110, 995 ]:
    print urlparse.urlunparse(
        (socket.getservbyport(port), 'example.com', '/', '', '', '')
        )
```

The reverse lookup is useful for constructing URLs to services from arbitrary addresses.

```
$ python socket_getservbyport.py

http://example.com/
https://example.com/
ftp://example.com/
gopher://example.com/
smtp://example.com/
imap://example.com/
imaps://example.com/
pop3://example.com/
pop3s://example.com/
```

The number assigned to a transport protocol can be retrieved with `getprotobyname()`.

```
import socket

def get_constants(prefix):
    """Create a dictionary mapping socket module constants to their names."""
    return dict( (getattr(socket, n), n)
                 for n in dir(socket)
                 if n.startswith(prefix)
                 )

protocols = get_constants('IPPROTO_')

for name in [ 'icmp', 'udp', 'tcp' ]:
    proto_num = socket.getprotobyname(name)
    const_name = protocols[proto_num]
    print '%4s -> %2d (socket.%-12s = %2d)' % \
        (name, proto_num, const_name, getattr(socket, const_name))
```

The values for protocol numbers are standardized, and defined as constants in `socket` with the prefix `IPPROTO_`.

```
$ python socket_getprotobyname.py

icmp ->  1 (socket.IPPROTO_ICMP =  1)
 udp -> 17 (socket.IPPROTO_UDP  = 17)
 tcp ->  6 (socket.IPPROTO_TCP  =  6)
```

Looking Up Server Addresses

`getaddrinfo()` converts the basic address of a service into a list of tuples with all of the information necessary to make a connection. The contents of each tuple will vary, containing different network families or protocols.

```
import socket

def get_constants(prefix):
    """Create a dictionary mapping socket module constants to their names."""
    return dict( (getattr(socket, n), n)
                 for n in dir(socket)
                 if n.startswith(prefix)
                 )
```

```
families = get_constants('AF_')
types = get_constants('SOCK_')
protocols = get_constants('IPPROTO_')

for response in socket.getaddrinfo('www.python.org', 'http'):

    # Unpack the response tuple
    family, socktype, proto, canonname, sockaddr = response

    print 'Family        :', families[family]
    print 'Type          :', types[socktype]
    print 'Protocol      :', protocols[proto]
    print 'Canonical name:', canonname
    print 'Socket address:', sockaddr
    print
```

This program demonstrates how to look up the connection information for `www.python.org`.

```
$ python socket_getaddrinfo.py

Family        : AF_INET
Type          : SOCK_DGRAM
Protocol      : IPPROTO_UDP
Canonical name:
Socket address: ('82.94.164.162', 80)

Family        : AF_INET
Type          : SOCK_STREAM
Protocol      : IPPROTO_TCP
Canonical name:
Socket address: ('82.94.164.162', 80)

Family        : AF_INET6
Type          : SOCK_DGRAM
Protocol      : IPPROTO_UDP
Canonical name:
Socket address: ('2001:888:2000:d::a2', 80, 0, 0)

Family        : AF_INET6
Type          : SOCK_STREAM
Protocol      : IPPROTO_TCP
Canonical name:
Socket address: ('2001:888:2000:d::a2', 80, 0, 0)
```

`getaddrinfo()` takes several arguments to filter the result list. The *host* and *port* values given in the example are required arguments. The optional arguments are *family*, *socktype*, *proto*, and *flags*. The family, socktype, and proto values should be `0` or one of the constants defined by `socket`.

```
import socket

def get_constants(prefix):
    """Create a dictionary mapping socket module constants to their names."""
    return dict( (getattr(socket, n), n)
                 for n in dir(socket)
                 if n.startswith(prefix)
                 )

families = get_constants('AF_')
types = get_constants('SOCK_')
```

```
protocols = get_constants('IPPROTO_')

for response in socket.getaddrinfo('www.doughellmann.com', 'http',
                                   socket.AF_INET,      # family
                                   socket.SOCK_STREAM,  # socktype
                                   socket.IPPROTO_TCP,  # protocol
                                   socket.AI_CANONNAME, # flags
                                   ):

    # Unpack the response tuple
    family, socktype, proto, canonname, sockaddr = response

    print 'Family        :', families[family]
    print 'Type          :', types[socktype]
    print 'Protocol      :', protocols[proto]
    print 'Canonical name:', canonname
    print 'Socket address:', sockaddr
    print
```

Since *flags* includes `AI_CANONNAME` the canonical name of the server (different from the value used for the lookup) is included in the results this time. Without the flag, the canonical name value is left empty.

```
$ python socket_getaddrinfo_extra_args.py

Family        : AF_INET
Type          : SOCK_STREAM
Protocol      : IPPROTO_TCP
Canonical name: homer.doughellmann.com
Socket address: ('192.168.1.8', 80)
```

IP Address Representations

Network programs written in C use the data type `struct sockaddr` to represent IP addresses as binary values (instead of the string addresses usually found in Python programs). Convert IPv4 addresses between the Python representation and the C representation with `inet_aton()` and `inet_ntoa()`.

```
import binascii
import socket
import struct
import sys

string_address = sys.argv[1]
packed = socket.inet_aton(string_address)

print 'Original:', string_address
print 'Packed  :', binascii.hexlify(packed)
print 'Unpacked:', socket.inet_ntoa(packed)
```

The four bytes in the packed format can be passed to C libraries, transmitted safely over the network, or saved to a database compactly.

```
$ python socket_address_packing.py 192.168.1.1

Original: 192.168.1.1
Packed  : c0a80101
Unpacked: 192.168.1.1
```

```
$ python socket_address_packing.py 127.0.0.1

Original: 127.0.0.1
Packed  : 7f000001
Unpacked: 127.0.0.1
```

The related functions `inet_pton()` and `inet_ntop()` work with both IPv4 and IPv6 addresses, producing the appropriate format based on the address family parameter passed in.

```
import binascii
import socket
import struct
import sys

string_address = sys.argv[1]
packed = socket.inet_pton(socket.AF_INET6, string_address)

print 'Original:', string_address
print 'Packed  :', binascii.hexlify(packed)
print 'Unpacked:', socket.inet_ntop(socket.AF_INET6, packed)
```

An IPv6 address is already a hexadecimal value, so converting the packed version to a series of hex digits produces a string similar to the original value.

```
$ python socket_ipv6_address_packing.py 2002:ac10:10a:1234:21e:52ff:fe74\
:40e

Original: 2002:ac10:10a:1234:21e:52ff:fe74:40e
Packed  : 2002ac10010a1234021e52fffe74040e
Unpacked: 2002:ac10:10a:1234:21e:52ff:fe74:40e
```

See also:

Wikipedia: IPv6 (http://en.wikipedia.org/wiki/IPv6) Article discussing Internet Protocol Version 6 (IPv6).

Wikipedia: OSI Networking Model (http://en.wikipedia.org/wiki/OSI_model) Article describing the seven layer model of networking implementation.

Assigned Internet Protocol Numbers (http://www.iana.org/assignments/protocol-numbers/protocol-numbers.xml) List of standard protocol names and numbers.

19.8.2 TCP/IP Client and Server

Sockets can be configured to act as a *server* and listen for incoming messages, or connect to other applications as a *client*. After both ends of a TCP/IP socket are connected, communication is bi-directional.

Echo Server

This sample program, based on the one in the standard library documentation, receives incoming messages and echos them back to the sender. It starts by creating a TCP/IP socket.

```
import socket
import sys

# Create a TCP/IP socket
sock = socket.socket(socket.AF_INET, socket.SOCK_STREAM)
```

Then `bind()` is used to associate the socket with the server address. In this case, the address is `localhost`, referring to the current server, and the port number is 10000.

```
# Bind the socket to the port
server_address = ('localhost', 10000)
print >>sys.stderr, 'starting up on %s port %s' % server_address
sock.bind(server_address)
```

Calling `listen()` puts the socket into server mode, and `accept()` waits for an incoming connection.

```
# Listen for incoming connections
sock.listen(1)

while True:
    # Wait for a connection
    print >>sys.stderr, 'waiting for a connection'
    connection, client_address = sock.accept()
```

`accept()` returns an open connection between the server and client, along with the address of the client. The connection is actually a different socket on another port (assigned by the kernel). Data is read from the connection with `recv()` and transmitted with `sendall()`.

```
    try:
        print >>sys.stderr, 'connection from', client_address

        # Receive the data in small chunks and retransmit it
        while True:
            data = connection.recv(16)
            print >>sys.stderr, 'received "%s"' % data
            if data:
                print >>sys.stderr, 'sending data back to the client'
                connection.sendall(data)
            else:
                print >>sys.stderr, 'no more data from', client_address
                break

    finally:
        # Clean up the connection
        connection.close()
```

When communication with a client is finished, the connection needs to be cleaned up using `close()`. This example uses a `try:finally` block to ensure that `close()` is always called, even in the event of an error.

Echo Client

The client program sets up its `socket` differently from the way a server does. Instead of binding to a port and listening, it uses `connect()` to attach the socket directly to the remote address.

```
import socket
import sys

# Create a TCP/IP socket
sock = socket.socket(socket.AF_INET, socket.SOCK_STREAM)

# Connect the socket to the port where the server is listening
server_address = ('localhost', 10000)
print >>sys.stderr, 'connecting to %s port %s' % server_address
sock.connect(server_address)
```

After the connection is established, data can be sent through the socket with `sendall()` and received with `recv()`, just as in the server.

```
try:

    # Send data
    message = 'This is the message.  It will be repeated.'
    print >>sys.stderr, 'sending "%s"' % message
    sock.sendall(message)

    # Look for the response
    amount_received = 0
    amount_expected = len(message)

    while amount_received < amount_expected:
        data = sock.recv(16)
        amount_received += len(data)
        print >>sys.stderr, 'received "%s"' % data

finally:
    print >>sys.stderr, 'closing socket'
    sock.close()
```

When the entire message is sent and a copy received, the socket is closed to free up the port.

Client and Server Together

The client and server should be run in separate terminal windows, so they can communicate with each other. The server output is:

```
$ python ./socket_echo_server.py

starting up on localhost port 10000
waiting for a connection
connection from ('127.0.0.1', 52186)
received "This is the mess"
sending data back to the client
received "age.  It will be"
sending data back to the client
received " repeated."
sending data back to the client
received ""
no more data from ('127.0.0.1', 52186)
waiting for a connection
```

The client output is:

```
$ python socket_echo_client.py

connecting to localhost port 10000
sending "This is the message.  It will be repeated."
received "This is the mess"
received "age.  It will be"
received " repeated."
closing socket

$
```

Easy Client Connections

TCP/IP clients can save a few steps by using the convenience function `create_connection()` to connect to a server. The function takes one argument, a two-value tuple containing the address of the server, and derives the best address to use for the connection.

```
import socket
import sys

def get_constants(prefix):
    """Create a dictionary mapping socket module constants to their names."""
    return dict( (getattr(socket, n), n)
                 for n in dir(socket)
                 if n.startswith(prefix)
                 )

families = get_constants('AF_')
types = get_constants('SOCK_')
protocols = get_constants('IPPROTO_')

# Create a TCP/IP socket
sock = socket.create_connection(('localhost', 10000))

print >>sys.stderr, 'Family  :', families[sock.family]
print >>sys.stderr, 'Type    :', types[sock.type]
print >>sys.stderr, 'Protocol:', protocols[sock.proto]
print >>sys.stderr

try:

    # Send data
    message = 'This is the message.  It will be repeated.'
    print >>sys.stderr, 'sending "%s"' % message
    sock.sendall(message)

    amount_received = 0
    amount_expected = len(message)

    while amount_received < amount_expected:
        data = sock.recv(16)
        amount_received += len(data)
        print >>sys.stderr, 'received "%s"' % data

finally:
    print >>sys.stderr, 'closing socket'
    sock.close()
```

`create_connection()` uses `getaddrinfo()` to find candidate connection parameters, and returns a `socket` opened with the first configuration that creates a successful connection. The `family`, `type`, and `proto` attributes can be examined to determine the type of `socket` being returned.

```
$ python socket_echo_client_easy.py

Family  : AF_INET
Type    : SOCK_STREAM
Protocol: IPPROTO_TCP

sending "This is the message.  It will be repeated."
received "This is the mess"
received "age.  It will be"
received " repeated."
closing socket
```

Choosing an Address for Listening

It is important to bind a server to the correct address, so that clients can communicate with it. The previous examples all used `'localhost'` as the IP address, which limits connections to clients running on the same server. Use a public address of the server, such as the value returned by `gethostname()`, to allow other hosts to connect. This example modifies the echo server to listen on an address specified via a command line argument.

```
import socket
import sys

# Create a TCP/IP socket
sock = socket.socket(socket.AF_INET, socket.SOCK_STREAM)

# Bind the socket to the address given on the command line
server_name = sys.argv[1]
server_address = (server_name, 10000)
print >>sys.stderr, 'starting up on %s port %s' % server_address
sock.bind(server_address)
sock.listen(1)

while True:
    print >>sys.stderr, 'waiting for a connection'
    connection, client_address = sock.accept()
    try:
        print >>sys.stderr, 'client connected:', client_address
        while True:
            data = connection.recv(16)
            print >>sys.stderr, 'received "%s"' % data
            if data:
                connection.sendall(data)
            else:
                break
    finally:
        connection.close()
```

A similar modification to the client program is needed before the server can be tested.

```
import socket
import sys

# Create a TCP/IP socket
sock = socket.socket(socket.AF_INET, socket.SOCK_STREAM)

# Connect the socket to the port on the server given by the caller
server_address = (sys.argv[1], 10000)
print >>sys.stderr, 'connecting to %s port %s' % server_address
sock.connect(server_address)

try:

    message = 'This is the message.  It will be repeated.'
    print >>sys.stderr, 'sending "%s"' % message
    sock.sendall(message)
    amount_received = 0
    amount_expected = len(message)
    while amount_received < amount_expected:
        data = sock.recv(16)
        amount_received += len(data)
        print >>sys.stderr, 'received "%s"' % data

finally:
    sock.close()
```

After starting the server with the argument `farnsworth.hellfly.net`, the **netstat** command shows it listening on the address for the named host.

```
$ host farnsworth.hellfly.net

farnsworth.hellfly.net has address 192.168.1.17

$ netstat -an

Active Internet connections (including servers)
Proto Recv-Q Send-Q  Local Address          Foreign Address        (state)
...
tcp4       0      0  192.168.1.17.10000     *.*                    LISTEN
...
```

Running the the client on another host, passing `farnsworth.hellfly.net` as the host where the server is running, produces:

```
$ hostname

homer

$ python socket_echo_client_explicit.py farnsworth.hellfly.net

connecting to farnsworth.hellfly.net port 10000
sending "This is the message.  It will be repeated."
received "This is the mess"
received "age.  It will be"
received " repeated."
```

And the server output is:

```
$ python ./socket_echo_server_explicit.py farnsworth.hellfly.net

starting up on farnsworth.hellfly.net port 10000
waiting for a connection
client connected: ('192.168.1.8', 57471)
received "This is the mess"
received "age.  It will be"
received " repeated."
received ""
waiting for a connection
```

Many servers have more than one network interface, and therefore more than one IP address. Rather than running separate copies of a service bound to each IP address, use the special address `INADDR_ANY` to listen on all addresses at the same time. Although `socket` defines a constant for `INADDR_ANY`, it is an integer value and must be converted to a dotted-notation string address before it can be passed to `bind()`. As a shortcut, use the empty string `''` instead of doing the conversion.

```
import socket
import sys

# Create a TCP/IP socket
sock = socket.socket(socket.AF_INET, socket.SOCK_STREAM)

# Bind the socket to the address given on the command line
server_address = ('', 10000)
sock.bind(server_address)
print >>sys.stderr, 'starting up on %s port %s' % sock.getsockname()
sock.listen(1)

while True:
    print >>sys.stderr, 'waiting for a connection'
    connection, client_address = sock.accept()
    try:
        print >>sys.stderr, 'client connected:', client_address
        while True:
            data = connection.recv(16)
            print >>sys.stderr, 'received "%s"' % data
            if data:
                connection.sendall(data)
            else:
                break
    finally:
        connection.close()
```

To see the actual address being used by a socket, call its `getsockname()` method. After starting the service, running **netstat** again shows it listening for incoming connections on any address.

```
$ netstat -an

Active Internet connections (including servers)
Proto Recv-Q Send-Q  Local Address          Foreign Address        (state)
...
tcp4       0      0  *.10000                *.*                    LISTEN
...
```

19.8.3 User Datagram Client and Server

The user datagram protocol (UDP) works differently from TCP/IP. Where TCP is a *stream oriented* protocol, ensuring that all of the data is transmitted in the right order, UDP is a *message oriented* protocol. UDP does not require a long-lived connection, so setting up a UDP socket is a little simpler. On the other hand, UDP messages must fit within a single packet (for IPv4, that means they can only hold 65,507 bytes because the 65,535 byte packet also includes header information) and delivery is not guaranteed as it is with TCP.

Echo Server

Since there is no connection, per se, the server does not need to listen for and accept connections. It only needs to use `bind()` to associate its socket with a port, and then wait for individual messages.

```
import socket
import sys

# Create a TCP/IP socket
sock = socket.socket(socket.AF_INET, socket.SOCK_DGRAM)
```

```
# Bind the socket to the port
server_address = ('localhost', 10000)
print >>sys.stderr, 'starting up on %s port %s' % server_address
sock.bind(server_address)
```

Messages are read from the socket using `recvfrom()`, which returns the data as well as the address of the client from which it was sent.

```
while True:
    print >>sys.stderr, '\nwaiting to receive message'
    data, address = sock.recvfrom(4096)

    print >>sys.stderr, 'received %s bytes from %s' % (len(data), address)
    print >>sys.stderr, data

    if data:
        sent = sock.sendto(data, address)
        print >>sys.stderr, 'sent %s bytes back to %s' % (sent, address)
```

Echo Client

The UDP echo client is similar the server, but does not use `bind()` to attach its socket to an address. It uses `sendto()` to deliver its message directly to the server, and `recvfrom()` to receive the response.

```
import socket
import sys

# Create a UDP socket
sock = socket.socket(socket.AF_INET, socket.SOCK_DGRAM)

server_address = ('localhost', 10000)
message = 'This is the message.  It will be repeated.'

try:

    # Send data
    print >>sys.stderr, 'sending "%s"' % message
    sent = sock.sendto(message, server_address)

    # Receive response
    print >>sys.stderr, 'waiting to receive'
    data, server = sock.recvfrom(4096)
    print >>sys.stderr, 'received "%s"' % data

finally:
    print >>sys.stderr, 'closing socket'
    sock.close()
```

Client and Server Together

Running the server produces:

```
$ python ./socket_echo_server_dgram.py

starting up on localhost port 10000
```

```
waiting to receive message
received 42 bytes from ('127.0.0.1', 50139)
This is the message.  It will be repeated.
sent 42 bytes back to ('127.0.0.1', 50139)

waiting to receive message
```

and the client output is:

```
$ python ./socket_echo_client_dgram.py

sending "This is the message.  It will be repeated."
waiting to receive
received "This is the message.  It will be repeated."
closing socket

$
```

19.8.4 Unix Domain Sockets

From the programmer's perspective there are two essential differences between using a Unix domain socket and an TCP/IP socket. First, the address of the socket is a path on the filesystem, rather than a tuple containing servername and port. Second, the node created in the filesystem to represent the socket persists after the socket is closed, and needs to be removed each time the server starts up. The echo server example from earlier can be updated to use UDS by making a few changes in the setup section.

```
import socket
import sys
import os

server_address = './uds_socket'

# Make sure the socket does not already exist
try:
    os.unlink(server_address)
except OSError:
    if os.path.exists(server_address):
        raise
```

The `socket` needs to be created with address family `AF_UNIX`.

```
# Create a UDS socket
sock = socket.socket(socket.AF_UNIX, socket.SOCK_STREAM)
```

Binding the socket and managing the incomming connections works the same as with TCP/IP sockets.

```
# Bind the socket to the port
print >>sys.stderr, 'starting up on %s' % server_address
sock.bind(server_address)

# Listen for incoming connections
sock.listen(1)

while True:
    # Wait for a connection
    print >>sys.stderr, 'waiting for a connection'
    connection, client_address = sock.accept()
    try:
        print >>sys.stderr, 'connection from', client_address

        # Receive the data in small chunks and retransmit it
        while True:
            data = connection.recv(16)
            print >>sys.stderr, 'received "%s"' % data
            if data:
                print >>sys.stderr, 'sending data back to the client'
                connection.sendall(data)
            else:
                print >>sys.stderr, 'no more data from', client_address
                break

    finally:
        # Clean up the connection
        connection.close()
```

The client setup also needs to be modified to work with UDS. It should assume the filesystem node for the socket exists, since the server creates it by binding to the address.

```
import socket
import sys

# Create a UDS socket
sock = socket.socket(socket.AF_UNIX, socket.SOCK_STREAM)

# Connect the socket to the port where the server is listening
server_address = './uds_socket'
print >>sys.stderr, 'connecting to %s' % server_address
try:
    sock.connect(server_address)
except socket.error, msg:
    print >>sys.stderr, msg
    sys.exit(1)
```

Sending and receiving data works the same way in the UDS client as the TCP/IP client from before.

```
try:

    # Send data
    message = 'This is the message.  It will be repeated.'
    print >>sys.stderr, 'sending "%s"' % message
    sock.sendall(message)

    amount_received = 0
    amount_expected = len(message)

    while amount_received < amount_expected:
        data = sock.recv(16)
        amount_received += len(data)
        print >>sys.stderr, 'received "%s"' % data

finally:
    print >>sys.stderr, 'closing socket'
    sock.close()
```

The program output is mostly the same, with appropriate updates for the address information. From the server:

```
$ python ./socket_echo_server_uds.py

starting up on ./uds_socket
waiting for a connection
connection from
received "This is the mess"
sending data back to the client
received "age.  It will be"
sending data back to the client
received " repeated."
sending data back to the client
received ""
no more data from
waiting for a connection
```

and from the client:

```
$ python socket_echo_client_uds.py

connecting to ./uds_socket
sending "This is the message.  It will be repeated."
received "This is the mess"
received "age.  It will be"
received " repeated."
closing socket
```

Permissions

Since the UDS socket is represented by a node on the filesystem, standard filesystem permissions can be used to control access to the server.

```
$ ls -l ./uds_socket
srwxr-xr-x  1 dhellmann  dhellmann  0 Sep 20 08:24 ./uds_socket

$ sudo chown root ./uds_socket

$ ls -l ./uds_socket
srwxr-xr-x  1 root  dhellmann  0 Sep 20 08:24 ./uds_socket
```

Running the client as a user other than `root` now results in an error because the process does not have permission to open the socket.

```
$ python socket_echo_client_uds.py

connecting to ./uds_socket
[Errno 13] Permission denied
```

Communication Between Parent and Child Processes

The `socketpair()` function is useful for setting up UDS sockets for interprocess communication under Unix. It creates a pair of connected sockets that can be used to communicate between a parent process and a child process after the child is forked.

```
import socket
import os
```

```
parent, child = socket.socketpair()

pid = os.fork()

if pid:
    print 'in parent, sending message'
    child.close()
    parent.sendall('ping')
    response = parent.recv(1024)
    print 'response from child:', response
    parent.close()

else:
    print 'in child, waiting for message'
    parent.close()
    message = child.recv(1024)
    print 'message from parent:', message
    child.sendall('pong')
    child.close()
```

By default, a UDS socket is created, but the caller can also pass address family, socket type, and even protocol options to control how the sockets are created.

```
$ python socket_socketpair.py

in parent, sending message
response from child: pong
in child, waiting for message
message from parent: ping
```

19.8.5 Multicast

Point-to-point connections handle a lot of communication needs, but passing the same information between many peers becomes challenging as the number of direct connections grows. Sending messages separately to each recipient consumes additional processing time and bandwidth, which can be a problem for applications such as streaming video or audio. Using *multicast* to deliver messages to more than one endpoint at a time achieves better efficiency because the network infrastructure ensures that the packets are delivered to all recipients.

Multicast messages are always sent using UDP, since TCP requires an end-to-end communication channel. The addresses for multicast, called *multicast groups*, are a subset of regular IPv4 address range (224.0.0.0 through 230.255.255.255) reserved for multicast traffic. These addresses are treated specially by network routers and switches, so messages sent to the group can be distributed over the Internet to all recipients that have joined the group.

Note: Some managed switches and routers have multicast traffic disabled by default. If you have trouble with the example programs, check your network hardware settings.

Sending Multicast Messages

This modified echo client will send a message to a multicast group, then report all of the responses it receives. Since it has no way of knowing how many responses to expect, it uses a timeout value on the socket to avoid blocking indefinitely waiting for an answer.

```
import socket
import struct
import sys

message = 'very important data'
multicast_group = ('224.3.29.71', 10000)

# Create the datagram socket
sock = socket.socket(socket.AF_INET, socket.SOCK_DGRAM)

# Set a timeout so the socket does not block indefinitely when trying
# to receive data.
sock.settimeout(0.2)
```

The socket also needs to be configured with a *time-to-live* value (TTL) for the messages. The TTL controls how many networks will receive the packet. Set the TTL with the `IP_MULTICAST_TTL` option and `setsockopt()`. The default, `1`, means that the packets are not forwarded by the router beyond the current network segment. The value can range up to 255, and should be packed into a single byte.

```
# Set the time-to-live for messages to 1 so they do not go past the
# local network segment.
ttl = struct.pack('b', 1)
sock.setsockopt(socket.IPPROTO_IP, socket.IP_MULTICAST_TTL, ttl)
```

The rest of the sender looks like the UDP echo client, except that it expects multiple responses so uses a loop to call `recvfrom()` until it times out.

```
try:

    # Send data to the multicast group
    print >>sys.stderr, 'sending "%s"' % message
    sent = sock.sendto(message, multicast_group)

    # Look for responses from all recipients
    while True:
        print >>sys.stderr, 'waiting to receive'
        try:
            data, server = sock.recvfrom(16)
        except socket.timeout:
            print >>sys.stderr, 'timed out, no more responses'
            break
        else:
            print >>sys.stderr, 'received "%s" from %s' % (data, server)

finally:
    print >>sys.stderr, 'closing socket'
    sock.close()
```

Receiving Multicast Messages

The first step to establishing a multicast receiver is to create the UDP socket.

```
import socket
import struct
import sys

multicast_group = '224.3.29.71'
server_address = ('', 10000)
```

```
# Create the socket
sock = socket.socket(socket.AF_INET, socket.SOCK_DGRAM)

# Bind to the server address
sock.bind(server_address)
```

After the regular socket is created and bound to a port, it can be added to the multicast group by using `setsockopt()` to change the `IP_ADD_MEMBERSHIP` option. The option value is the 8-byte packed representation of the multicast group address followed by the network interface on which the server should listen for the traffic, identified by its IP address. In this case, the receiver listens on all interfaces using `INADDR_ANY`.

```
# Tell the operating system to add the socket to the multicast group
# on all interfaces.
group = socket.inet_aton(multicast_group)
mreq = struct.pack('4sL', group, socket.INADDR_ANY)
sock.setsockopt(socket.IPPROTO_IP, socket.IP_ADD_MEMBERSHIP, mreq)
```

The main loop for the receiver is just like the regular UDP echo server.

```
# Receive/respond loop
while True:
    print >>sys.stderr, '\nwaiting to receive message'
    data, address = sock.recvfrom(1024)

    print >>sys.stderr, 'received %s bytes from %s' % (len(data), address)
    print >>sys.stderr, data

    print >>sys.stderr, 'sending acknowledgement to', address
    sock.sendto('ack', address)
```

Example Output

This example shows the multicast receiver running on two different hosts, `A` has address `192.168.1.17` and `B` has address `192.168.1.8`.

```
[A]$ python ./socket_multicast_receiver.py

waiting to receive message
received 19 bytes from ('192.168.1.17', 51382)
very important data
sending acknowledgement to ('192.168.1.17', 51382)

[B]$ python ./socket_multicast_receiver.py

binding to ('', 10000)

waiting to receive message
received 19 bytes from ('192.168.1.17', 51382)
very important data
sending acknowledgement to ('192.168.1.17', 51382)
```

The sender is running on host `A`.

```
$ python ./socket_multicast_sender.py

sending "very important data"
waiting to receive
received "ack" from ('192.168.1.17', 10000)
```

```
waiting to receive
received "ack" from ('192.168.1.8', 10000)
waiting to receive
timed out, no more responses
closing socket
```

The message is sent one time, and two acknowledgements of the outgoing message are received, one from each of host A and B.

See also:

Wikipedia: Multicast (http://en.wikipedia.org/wiki/Multicast) Article describing technical details of multicasting.

Wikipedia: IP Multicast (http://en.wikipedia.org/wiki/IP_multicast) Article about IP multicasting, with information about addressing.

19.8.6 Sending Binary Data

Sockets transmit streams of bytes. Those bytes can contain text messages, as in the previous examples, or they can be made up of binary data that has been encoded for transmission. To prepare binary data values for transmission, pack them into a buffer with `struct`.

This client program encodes an integer, a string of two characters, and a floating point value into a sequence of bytes that can be passed to the socket for transmission.

```python
import binascii
import socket
import struct
import sys

# Create a TCP/IP socket
sock = socket.socket(socket.AF_INET, socket.SOCK_STREAM)
server_address = ('localhost', 10000)
sock.connect(server_address)

values = (1, 'ab', 2.7)
packer = struct.Struct('I 2s f')
packed_data = packer.pack(*values)

try:

    # Send data
    print >>sys.stderr, 'sending "%s"' % binascii.hexlify(packed_data), values
    sock.sendall(packed_data)

finally:
    print >>sys.stderr, 'closing socket'
    sock.close()
```

The server program uses the same `Struct` specifier to unpack the bytes it receives.

```python
import binascii
import socket
import struct
import sys

# Create a TCP/IP socket
sock = socket.socket(socket.AF_INET, socket.SOCK_STREAM)
```

```
server_address = ('localhost', 10000)
sock.bind(server_address)
sock.listen(1)

unpacker = struct.Struct('I 2s f')

while True:
    print >>sys.stderr, '\nwaiting for a connection'
    connection, client_address = sock.accept()
    try:
        data = connection.recv(unpacker.size)
        print >>sys.stderr, 'received "%s"' % binascii.hexlify(data)

        unpacked_data = unpacker.unpack(data)
        print >>sys.stderr, 'unpacked:', unpacked_data

    finally:
        connection.close()
```

Running the client produces:

```
$ python ./socket_binary_client.py

sending "0100000061620000cdcc2c40" (1, 'ab', 2.7)
closing socket
```

And the server shows the values it receives:

```
$ python ./socket_binary_server.py

waiting for a connection
received "0100000061620000cdcc2c40"
unpacked: (1, 'ab', 2.700000047683716)

waiting for a connection
```

The floating point value loses some precision as it is packed and unpacked, but otherwise the data is transmitted as expected. One thing to keep in mind is that depending on the value of the integer, it may be more efficient to convert it to text and then transmit, instead of using `struct`. The integer `1` uses one byte when represented as a string, but four when packed into the structure.

See also:

`struct` Converting between strings and other data types.

19.8.7 Non-blocking Communication and Timeouts

By default a `socket` is configured so that sending or receiving data *blocks*, stopping program execution until the socket is ready. Calls to `send()` wait for buffer space to be available for the outgoing data, and calls to `recv()` wait for the other program to send data that can be read. This form of I/O operation is easy to understand, but can lead to inefficient operation and even deadlocks, if both programs end up waiting for the other to send or receive data.

There are a few ways to work around this situation. One is to use a separate thread for communicating with each socket. This can introduce other complexities, though, with communication between the threads.

Another option is to change the socket to not block at all, and return immediately if it is not ready to handle the operation. Use the `setblocking()` method to change the blocking flag for a socket. The default value is `1`, which means to block. Passing a value of `0` turns off blocking. If the socket is has blocking turned off and it is not ready for the operation, then `socket.error` is raised.

A compromise solution is to set a timeout value for socket operations. Use `settimeout()` to change the timeout of a `socket` to a floating point value representing the number of seconds to block before deciding the socket is not ready for the operation. When the timeout expires, a `timeout` exception is raised.

See also:

Non-blocking I/O is covered in more detail in the examples for `select`.

See also:

socket (http://docs.python.org/library/socket.html) The standard library documentation for this module.

Socket Programming HOWOTO (http://docs.python.org/howto/sockets.html) An instructional guide by Gordon McMillan, included in the standard library documentation.

`select` Testing a socket to see if it is ready for reading or writing.

`SocketServer` Framework for creating network servers.

`asyncore` and `asynchat` Frameworks for asynchronous communication.

`urllib` and `urllib2` Most network clients should use the more convenient libraries for accessing remote resoruces through a URL.

Unix Network Programming, Volume 1: The Sockets Networking API, 3/E By W. Richard Stevens, Bill Fenner, and Andrew M. Rudoff. Published by Addison-Wesley Professional, 2004. ISBN-10: 0131411551

19.9 select – Wait for I/O Efficiently

Purpose Wait for notification that an input or output channel is ready.

Available In 1.4 and later

The `select` module provides access to platform-specific I/O monitoring functions. The most portable interface is the POSIX function `select()`, which is available on Unix and Windows. The module also includes `poll()`, a Unix-only API, and several options that only work with specific variants of Unix.

19.9.1 select()

Python's `select()` function is a direct interface to the underlying operating system implementation. It monitors sockets, open files, and pipes (anything with a `fileno()` method that returns a valid file descriptor) until they become readable or writable, or a communication error occurs. `select()` makes it easier to monitor multiple connections at the same time, and is more efficient than writing a polling loop in Python using socket timeouts, because the monitoring happens in the operating system network layer, instead of the interpreter.

Note: Using Python's file objects with `select()` works for Unix, but is not supported under Windows.

The echo server example from the `socket` section can be extended to watch for more than one connection at a time by using `select()`. The new version starts out by creating a non-blocking TCP/IP socket and configuring it to listen on an address.

```
import select
import socket
import sys
import Queue
```

```
# Create a TCP/IP socket
server = socket.socket(socket.AF_INET, socket.SOCK_STREAM)
server.setblocking(0)

# Bind the socket to the port
server_address = ('localhost', 10000)
print >>sys.stderr, 'starting up on %s port %s' % server_address
server.bind(server_address)

# Listen for incoming connections
server.listen(5)
```

The arguments to `select()` are three lists containing communication channels to monitor. The first is a list of the objects to be checked for incoming data to be read, the second contains objects that will receive outgoing data when there is room in their buffer, and the third those that may have an error (usually a combination of the input and output channel objects). The next step in the server is to set up the lists containing input sources and output destinations to be passed to `select()`.

```
# Sockets from which we expect to read
inputs = [ server ]

# Sockets to which we expect to write
outputs = [ ]
```

Connections are added to and removed from these lists by the server main loop. Since this version of the server is going to wait for a socket to become writable before sending any data (instead of immediately sending the reply), each output connection needs a queue to act as a buffer for the data to be sent through it.

```
# Outgoing message queues (socket:Queue)
message_queues = {}
```

The main portion of the server program loops, calling `select()` to block and wait for network activity.

```
while inputs:

    # Wait for at least one of the sockets to be ready for processing
    print >>sys.stderr, '\nwaiting for the next event'
    readable, writable, exceptional = select.select(inputs, outputs, inputs)
```

`select()` returns three new lists, containing subsets of the contents of the lists passed in. All of the sockets in the `readable` list have incoming data buffered and available to be read. All of the sockets in the `writable` list have free space in their buffer and can be written to. The sockets returned in `exceptional` have had an error (the actual definition of "exceptional condition" depends on the platform).

The "readable" sockets represent three possible cases. If the socket is the main "server" socket, the one being used to listen for connections, then the "readable" condition means it is ready to accept another incoming connection. In addition to adding the new connection to the list of inputs to monitor, this section sets the client socket to not block.

```
    # Handle inputs
    for s in readable:

        if s is server:
            # A "readable" server socket is ready to accept a connection
            connection, client_address = s.accept()
            print >>sys.stderr, 'new connection from', client_address
            connection.setblocking(0)
            inputs.append(connection)
            # Give the connection a queue for data we want to send
            message_queues[connection] = Queue.Queue()
```

The next case is an established connection with a client that has sent data. The data is read with `recv()`, then placed on the queue so it can be sent through the socket and back to the client.

```
        else:
            data = s.recv(1024)
            if data:
                # A readable client socket has data
                print >>sys.stderr, 'received "%s" from %s' % (data, s.getpeername())
                message_queues[s].put(data)
                # Add output channel for response
                if s not in outputs:
                    outputs.append(s)
```

A readable socket *without* data available is from a client that has disconnected, and the stream is ready to be closed.

```
            else:
                # Interpret empty result as closed connection
                print >>sys.stderr, 'closing', client_address, 'after reading no data'
                # Stop listening for input on the connection
                if s in outputs:
                    outputs.remove(s)
                inputs.remove(s)
                s.close()

                # Remove message queue
                del message_queues[s]
```

There are fewer cases for the writable connections. If there is data in the queue for a connection, the next message is sent. Otherwise, the connection is removed from the list of output connections so that the next time through the loop `select()` does not indicate that the socket is ready to send data.

```
    # Handle outputs
    for s in writable:
        try:
            next_msg = message_queues[s].get_nowait()
        except Queue.Empty:
            # No messages waiting so stop checking for writability.
            print >>sys.stderr, 'output queue for', s.getpeername(), 'is empty'
            outputs.remove(s)
        else:
            print >>sys.stderr, 'sending "%s" to %s' % (next_msg, s.getpeername())
            s.send(next_msg)
```

Finally, if there is an error with a socket, it is closed.

```
    # Handle "exceptional conditions"
    for s in exceptional:
        print >>sys.stderr, 'handling exceptional condition for', s.getpeername()
        # Stop listening for input on the connection
        inputs.remove(s)
        if s in outputs:
            outputs.remove(s)
        s.close()

        # Remove message queue
        del message_queues[s]
```

The example client program uses two sockets to demonstrate how the server with `select()` manages multiple connections at the same time. The client starts by connecting each TCP/IP socket to the server.

```
import socket
import sys

messages = [ 'This is the message. ',
             'It will be sent ',
             'in parts.',
             ]
server_address = ('localhost', 10000)

# Create a TCP/IP socket
socks = [ socket.socket(socket.AF_INET, socket.SOCK_STREAM),
          socket.socket(socket.AF_INET, socket.SOCK_STREAM),
          ]

# Connect the socket to the port where the server is listening
print >>sys.stderr, 'connecting to %s port %s' % server_address
for s in socks:
    s.connect(server_address)
```

Then it sends one pieces of the message at a time via each socket, and reads all responses available after writing new data.

```
for message in messages:

    # Send messages on both sockets
    for s in socks:
        print >>sys.stderr, '%s: sending "%s"' % (s.getsockname(), message)
        s.send(message)

    # Read responses on both sockets
    for s in socks:
        data = s.recv(1024)
        print >>sys.stderr, '%s: received "%s"' % (s.getsockname(), data)
        if not data:
            print >>sys.stderr, 'closing socket', s.getsockname()
            s.close()
```

Run the server in one window and the client in another. The output will look like this, with different port numbers.

```
$ python ./select_echo_server.py
starting up on localhost port 10000

waiting for the next event
new connection from ('127.0.0.1', 55821)

waiting for the next event
new connection from ('127.0.0.1', 55822)
received "This is the message. " from ('127.0.0.1', 55821)

waiting for the next event
sending "This is the message. " to ('127.0.0.1', 55821)

waiting for the next event
output queue for ('127.0.0.1', 55821) is empty

waiting for the next event
```

```
received "This is the message. " from ('127.0.0.1', 55822)

waiting for the next event
sending "This is the message. " to ('127.0.0.1', 55822)

waiting for the next event
output queue for ('127.0.0.1', 55822) is empty

waiting for the next event
received "It will be sent " from ('127.0.0.1', 55821)
received "It will be sent " from ('127.0.0.1', 55822)

waiting for the next event
sending "It will be sent " to ('127.0.0.1', 55821)
sending "It will be sent " to ('127.0.0.1', 55822)

waiting for the next event
output queue for ('127.0.0.1', 55821) is empty
output queue for ('127.0.0.1', 55822) is empty

waiting for the next event
received "in parts." from ('127.0.0.1', 55821)
received "in parts." from ('127.0.0.1', 55822)

waiting for the next event
sending "in parts." to ('127.0.0.1', 55821)
sending "in parts." to ('127.0.0.1', 55822)

waiting for the next event
output queue for ('127.0.0.1', 55821) is empty
output queue for ('127.0.0.1', 55822) is empty

waiting for the next event
closing ('127.0.0.1', 55822) after reading no data
closing ('127.0.0.1', 55822) after reading no data

waiting for the next event
```

The client output shows the data being sent and received using both sockets.

```
$ python ./select_echo_multiclient.py
connecting to localhost port 10000
('127.0.0.1', 55821): sending "This is the message. "
('127.0.0.1', 55822): sending "This is the message. "
('127.0.0.1', 55821): received "This is the message. "
('127.0.0.1', 55822): received "This is the message. "
('127.0.0.1', 55821): sending "It will be sent "
('127.0.0.1', 55822): sending "It will be sent "
('127.0.0.1', 55821): received "It will be sent "
('127.0.0.1', 55822): received "It will be sent "
('127.0.0.1', 55821): sending "in parts."
('127.0.0.1', 55822): sending "in parts."
('127.0.0.1', 55821): received "in parts."
('127.0.0.1', 55822): received "in parts."
```

Timeouts

select() also takes an optional fourth parameter which is the number of seconds to wait before breaking off monitoring if no channels have become active. Using a timeout value lets a main program call select() as part of a larger processing loop, taking other actions in between checking for network input.

When the timeout expires, select() returns three empty lists. Updating the server example to use a timeout requires adding the extra argument to the select() call and handling the empty lists after select() returns.

```
    # Wait for at least one of the sockets to be ready for processing
    print >>sys.stderr, '\nwaiting for the next event'
    timeout = 1
    readable, writable, exceptional = select.select(inputs, outputs, inputs, timeout)

    if not (readable or writable or exceptional):
        print >>sys.stderr, '  timed out, do some other work here'
        continue
```

This "slow" version of the client program pauses after sending each message, to simulate latency or other delay in transmission.

```
import socket
import sys
import time

# Create a TCP/IP socket
sock = socket.socket(socket.AF_INET, socket.SOCK_STREAM)

# Connect the socket to the port where the server is listening
server_address = ('localhost', 10000)
print >>sys.stderr, 'connecting to %s port %s' % server_address
sock.connect(server_address)

time.sleep(1)

messages = [ 'Part one of the message.',
             'Part two of the message.',
             ]
amount_expected = len(''.join(messages))

try:

    # Send data
    for message in messages:
        print >>sys.stderr, 'sending "%s"' % message
        sock.sendall(message)
        time.sleep(1.5)

    # Look for the response
    amount_received = 0

    while amount_received < amount_expected:
        data = sock.recv(16)
        amount_received += len(data)
        print >>sys.stderr, 'received "%s"' % data

finally:
    print >>sys.stderr, 'closing socket'
    sock.close()
```

Running the new server with the slow client produces:

```
$ python ./select_echo_server_timeout.py
starting up on localhost port 10000

waiting for the next event
  timed out

waiting for the next event
  timed out

waiting for the next event
new connection from ('127.0.0.1', 57776)

waiting for the next event
received "Part one of the message." from ('127.0.0.1', 57776)

waiting for the next event
sending "Part one of the message." to ('127.0.0.1', 57776)

waiting for the next event
output queue for ('127.0.0.1', 57776) is empty

waiting for the next event
  timed out

waiting for the next event
received "Part two of the message." from ('127.0.0.1', 57776)

waiting for the next event
sending "Part two of the message." to ('127.0.0.1', 57776)

waiting for the next event
output queue for ('127.0.0.1', 57776) is empty

waiting for the next event
  timed out

waiting for the next event
closing ('127.0.0.1', 57776) after reading no data

waiting for the next event
  timed out

waiting for the next event
```

And the client output is:

```
$ python ./select_echo_slow_client.py
connecting to localhost port 10000
sending "Part one of the message."
sending "Part two of the message."
received "Part one of the "
received "message.Part two"
received " of the message."
closing socket
```

19.9.2 poll()

The `poll()` function provides similar features to `select()`, but the underlying implementation is more efficient. The trade-off is that `poll()` is not supported under Windows, so programs using `poll()` are less portable.

An echo server built on `poll()` starts with the same socket configuration code used in the other examples.

```
import select
import socket
import sys
import Queue

# Create a TCP/IP socket
server = socket.socket(socket.AF_INET, socket.SOCK_STREAM)
server.setblocking(0)

# Bind the socket to the port
server_address = ('localhost', 10000)
print >>sys.stderr, 'starting up on %s port %s' % server_address
server.bind(server_address)

# Listen for incoming connections
server.listen(5)

# Keep up with the queues of outgoing messages
message_queues = {}
```

The timeout value passed to `poll()` is represented in milliseconds, instead of seconds, so in order to pause for a full second the timeout must be set to `1000`.

```
# Do not block forever (milliseconds)
TIMEOUT = 1000
```

Python implements `poll()` with a class that manages the registered data channels being monitored. Channels are added by calling `register()` with flags indicating which events are interesting for that channel. The full set of flags is:

Event	Description
`POLLIN`	Input ready
`POLLPRI`	Priority input ready
`POLLOUT`	Able to receive output
`POLLERR`	Error
`POLLHUP`	Channel closed
`POLLNVAL`	Channel not open

The echo server will be setting up some sockets just for reading, and others to be read from or written to. The appropriate combinations of flags are saved to the local variables `READ_ONLY` and `READ_WRITE`.

```
# Commonly used flag setes
READ_ONLY = select.POLLIN | select.POLLPRI | select.POLLHUP | select.POLLERR
READ_WRITE = READ_ONLY | select.POLLOUT
```

The `server` socket is registered so that any incoming connections or data triggers an event.

```
# Set up the poller
poller = select.poll()
poller.register(server, READ_ONLY)
```

Since `poll()` returns a list of tuples containing the file descriptor for the socket and the event flag, a mapping from file descriptor numbers to objects is needed to retrieve the `socket` to read or write from it.

```
# Map file descriptors to socket objects
fd_to_socket = { server.fileno(): server,
               }
```

The server's loop calls `poll()`, then processes the "events" returned by looking up the socket and taking action based on the flag in the event.

```
while True:

    # Wait for at least one of the sockets to be ready for processing
    print >>sys.stderr, '\nwaiting for the next event'
    events = poller.poll(TIMEOUT)

    for fd, flag in events:

        # Retrieve the actual socket from its file descriptor
        s = fd_to_socket[fd]
```

As with `select()`, when the main server socket is "readable," that really means there is a pending connection from a client. The new connection is registered with the `READ_ONLY` flags to watch for new data to come through it.

```
        # Handle inputs
        if flag & (select.POLLIN | select.POLLPRI):

            if s is server:
                # A "readable" server socket is ready to accept a connection
                connection, client_address = s.accept()
                print >>sys.stderr, 'new connection from', client_address
                connection.setblocking(0)
                fd_to_socket[ connection.fileno() ] = connection
                poller.register(connection, READ_ONLY)

                # Give the connection a queue for data we want to send
                message_queues[connection] = Queue.Queue()
```

Sockets other than the server are existing clients, and `recv()` is used to access the data waiting to be read.

```
            else:
                data = s.recv(1024)
```

If `recv()` returns any data, it is placed into the outgoing queue for the socket and the flags for that socket are changed using `modify()` so `poll()` will watch for the socket to be ready to receive data.

```
                if data:
                    # A readable client socket has data
                    print >>sys.stderr, 'received "%s" from %s' % (data, s.getpeername())
                    message_queues[s].put(data)
                    # Add output channel for response
                    poller.modify(s, READ_WRITE)
```

An empty string returned by `recv()` means the client disconnected, so `unregister()` is used to tell the `poll` object to ignore the socket.

```
                else:
                    # Interpret empty result as closed connection
                    print >>sys.stderr, 'closing', client_address, 'after reading no data'
                    # Stop listening for input on the connection
                    poller.unregister(s)
                    s.close()
                    # Remove message queue
                    del message_queues[s]
```

The POLLHUP flag indicates a client that "hung up" the connection without closing it cleanly. The server stops polling clients that disappear.

```
        elif flag & select.POLLHUP:
            # Client hung up
            print >>sys.stderr, 'closing', client_address, 'after receiving HUP'
            # Stop listening for input on the connection
            poller.unregister(s)
            s.close()
```

The handling for writable sockets looks like the version used in the example for `select()`, except that `modify()` is used to change the flags for the socket in the poller, instead of removing it from the output list.

```
        elif flag & select.POLLOUT:
            # Socket is ready to send data, if there is any to send.
            try:
                next_msg = message_queues[s].get_nowait()
            except Queue.Empty:
                # No messages waiting so stop checking for writability.
                print >>sys.stderr, 'output queue for', s.getpeername(), 'is empty'
                poller.modify(s, READ_ONLY)
            else:
                print >>sys.stderr, 'sending "%s" to %s' % (next_msg, s.getpeername())
                s.send(next_msg)
```

And finally, any events with POLLERR cause the server to close the socket.

```
        elif flag & select.POLLERR:
            print >>sys.stderr, 'handling exceptional condition for', s.getpeername()
            # Stop listening for input on the connection
            poller.unregister(s)
            s.close()

            # Remove message queue
            del message_queues[s]
```

When the poll-based server is run together with `select_echo_multiclient.py` (the client program that uses multiple sockets), the output is:

```
$ python ./select_poll_echo_server.py
starting up on localhost port 10000

waiting for the next event

waiting for the next event

waiting for the next event
new connection from ('127.0.0.1', 58447)

waiting for the next event
new connection from ('127.0.0.1', 58448)
received "This is the message. " from ('127.0.0.1', 58447)

waiting for the next event
sending "This is the message. " to ('127.0.0.1', 58447)
received "This is the message. " from ('127.0.0.1', 58448)
```

```
waiting for the next event
output queue for ('127.0.0.1', 58447) is empty
sending "This is the message. " to ('127.0.0.1', 58448)

waiting for the next event
output queue for ('127.0.0.1', 58448) is empty

waiting for the next event
received "It will be sent " from ('127.0.0.1', 58447)
received "It will be sent " from ('127.0.0.1', 58448)

waiting for the next event
sending "It will be sent " to ('127.0.0.1', 58447)
sending "It will be sent " to ('127.0.0.1', 58448)

waiting for the next event
output queue for ('127.0.0.1', 58447) is empty
output queue for ('127.0.0.1', 58448) is empty

waiting for the next event
received "in parts." from ('127.0.0.1', 58447)
received "in parts." from ('127.0.0.1', 58448)

waiting for the next event
sending "in parts." to ('127.0.0.1', 58447)
sending "in parts." to ('127.0.0.1', 58448)

waiting for the next event
output queue for ('127.0.0.1', 58447) is empty
output queue for ('127.0.0.1', 58448) is empty

waiting for the next event
closing ('127.0.0.1', 58448) after reading no data
closing ('127.0.0.1', 58448) after reading no data

waiting for the next event
```

19.9.3 Platform-specific Options

Less portable options provided by `select` are `epoll`, the *edge polling* API supported by Linux; `kqueue`, which uses BSD's *kernel queue*; and `kevent`, BSD's *kernel event* interface. Refer to the operating system library documentation for more detail about how they work.

See also:

select **(http://docs.python.org/library/select.html)** The standard library documentation for this module.

Socket Programming HOWOTO **(http://docs.python.org/howto/sockets.html)** An instructional guide by Gordon McMillan, included in the standard library documentation.

`socket` Low-level network communication.

`SocketServer` Framework for creating network server applications.

`asyncore` **and** **`asynchat`** Asynchronous I/O framework.

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19.10 SocketServer – Creating network servers.

Purpose Creating network servers.

Available In 1.4

The `SocketServer` module is a framework for creating network servers. It defines classes for handling synchronous network requests (the server request handler blocks until the request is completed) over TCP, UDP, Unix streams, and Unix datagrams. It also provides mix-in classes for easily converting servers to use a separate thread or process for each request, depending on what is most appropriate for your situation.

Responsibility for processing a request is split between a server class and a request handler class. The server deals with the communication issues (listing on a socket, accepting connections, etc.) and the request handler deals with the "protocol" issues (interpreting incoming data, processing it, sending data back to the client). This division of responsibility means that in many cases you can simply use one of the existing server classes without any modifications, and provide a request handler class for it to work with your protocol.

19.10.1 Server Types

There are five different server classes defined in `SocketServer`. `BaseServer` defines the API, and is not really intended to be instantiated and used directly. `TCPServer` uses TCP/IP sockets to communicate. `UDPServer` uses datagram sockets. `UnixStreamServer` and `UnixDatagramServer` use Unix-domain sockets and are only available on Unix platforms.

19.10.2 Server Objects

To construct a server, pass it an address on which to listen for requests and a request handler *class* (not instance). The address format depends on the server type and the socket family used. Refer to the `socket` module documentation for details.

Once the server object is instantiated, use either `handle_request()` or `serve_forever()` to process requests. The `serve_forever()` method simply calls `handle_request()` in an infinite loop, so if you need to integrate the server with another event loop or use `select()` to monitor several sockets for different servers, you could call `handle_request()` on your own. See the example below for more detail.

19.10.3 Implementing a Server

If you are creating a server, it is usually possible to re-use one of the existing classes and simply provide a custom request handler class. If that does not meet your needs, there are several methods of `BaseServer` available to override in a subclass:

- `verify_request(request, client_address)` - Return True to process the request or False to ignore it. You could, for example, refuse requests from an IP range if you want to block certain clients from accessing the server.
- `process_request(request, client_address)` - Typically just calls `finish_request()` to actually do the work. It can also create a separate thread or process, as the mix-in classes do (see below).
- `finish_request(request, client_address)` - Creates a request handler instance using the class given to the server's constructor. Calls `handle()` on the request handler to process the request.

19.10.4 Request Handlers

Request handlers do most of the work of receiving incoming requests and deciding what action to take. The handler is responsible for implementing the "protocol" on top of the socket layer (for example, HTTP or XML-RPC). The request handler reads the request from the incoming data channel, processes it, and writes a response back out. There are 3 methods available to be over-ridden.

- `setup()` - Prepare the request handler for the request. In the `StreamRequestHandler`, for example, the `setup()` method creates file-like objects for reading from and writing to the socket.
- `handle()` - Do the real work for the request. Parse the incoming request, process the data, and send a response.
- `finish()` - Clean up anything created during `setup()`.

In many cases, you can simply provide a `handle()` method.

19.10.5 Echo Example

Let's look at a simple server/request handler pair that accepts TCP connectcions and echos back any data sent by the client. The only method that actually needs to be provided in the sample code is `EchoRequestHandler.handle()`, but all of the methods described above are overridden to insert `logging` calls so the output of the sample program illustrates the sequence of calls made.

The only thing left is to have simple program that creates the server, runs it in a thread, and connects to it to illustrate which methods are called as the data is echoed back.

```
import logging
import sys
import SocketServer

logging.basicConfig(level=logging.DEBUG,
                    format='%(name)s: %(message)s',
                    )

class EchoRequestHandler(SocketServer.BaseRequestHandler):

    def __init__(self, request, client_address, server):
        self.logger = logging.getLogger('EchoRequestHandler')
        self.logger.debug('__init__')
        SocketServer.BaseRequestHandler.__init__(self, request, client_address, server)
        return

    def setup(self):
        self.logger.debug('setup')
        return SocketServer.BaseRequestHandler.setup(self)

    def handle(self):
        self.logger.debug('handle')

        # Echo the back to the client
        data = self.request.recv(1024)
        self.logger.debug('recv()->"%s"', data)
        self.request.send(data)
        return

    def finish(self):
        self.logger.debug('finish')
        return SocketServer.BaseRequestHandler.finish(self)
```

```
class EchoServer(SocketServer.TCPServer):

    def __init__(self, server_address, handler_class=EchoRequestHandler):
        self.logger = logging.getLogger('EchoServer')
        self.logger.debug('__init__')
        SocketServer.TCPServer.__init__(self, server_address, handler_class)
        return

    def server_activate(self):
        self.logger.debug('server_activate')
        SocketServer.TCPServer.server_activate(self)
        return

    def serve_forever(self):
        self.logger.debug('waiting for request')
        self.logger.info('Handling requests, press <Ctrl-C> to quit')
        while True:
            self.handle_request()
        return

    def handle_request(self):
        self.logger.debug('handle_request')
        return SocketServer.TCPServer.handle_request(self)

    def verify_request(self, request, client_address):
        self.logger.debug('verify_request(%s, %s)', request, client_address)
        return SocketServer.TCPServer.verify_request(self, request, client_address)

    def process_request(self, request, client_address):
        self.logger.debug('process_request(%s, %s)', request, client_address)
        return SocketServer.TCPServer.process_request(self, request, client_address)

    def server_close(self):
        self.logger.debug('server_close')
        return SocketServer.TCPServer.server_close(self)

    def finish_request(self, request, client_address):
        self.logger.debug('finish_request(%s, %s)', request, client_address)
        return SocketServer.TCPServer.finish_request(self, request, client_address)

    def close_request(self, request_address):
        self.logger.debug('close_request(%s)', request_address)
        return SocketServer.TCPServer.close_request(self, request_address)

if __name__ == '__main__':
    import socket
    import threading

    address = ('localhost', 0) # let the kernel give us a port
    server = EchoServer(address, EchoRequestHandler)
    ip, port = server.server_address # find out what port we were given

    t = threading.Thread(target=server.serve_forever)
    t.setDaemon(True) # don't hang on exit
    t.start()

    logger = logging.getLogger('client')
    logger.info('Server on %s:%s', ip, port)
    # Connect to the server
    logger.debug('creating socket')
    s = socket.socket(socket.AF_INET, socket.SOCK_STREAM)
    logger.debug('connecting to server')
    s.connect((ip, port))

    # Send the data
    message = 'Hello, world'
    logger.debug('sending data: "%s"', message)
    len_sent = s.send(message)

    # Receive a response
    logger.debug('waiting for response')
    response = s.recv(len_sent)
    logger.debug('response from server: "%s"', response)

    # Clean up
    logger.debug('closing socket')
    s.close()
    logger.debug('done')
    server.socket.close()
```

The output for the program should look something like this:

```
$ python SocketServer_echo.py

EchoServer: __init__
EchoServer: server_activate
EchoServer: waiting for request
client: Server on 127.0.0.1:56210
EchoServer: Handling requests, press <Ctrl-C> to quit
client: creating socket
EchoServer: handle_request
client: connecting to server
client: sending data: "Hello, world"
EchoServer: verify_request(<socket._socketobject object at 0x1004cdfa0>, ('127.0.0.1', 56211))
EchoServer: process_request(<socket._socketobject object at 0x1004cdfa0>, ('127.0.0.1', 56211))
client: waiting for response
EchoServer: finish_request(<socket._socketobject object at 0x1004cdfa0>, ('127.0.0.1', 56211))
EchoRequestHandler: __init__
EchoRequestHandler: setup
EchoRequestHandler: handle
EchoRequestHandler: recv()->"Hello, world"
EchoRequestHandler: finish
client: response from server: "Hello, world"
EchoServer: close_request(<socket._socketobject object at 0x1004cdfa0>)
client: closing socket
EchoServer: handle_request
client: done
```

The port number used will change each time you run it, as the kernel allocates an available port automatically. If you want the server to listen on a specific port each time you run it, provide that number in the address tuple instead of the `0`.

Here is a simpler version of the same thing, without the `logging`:

```
import SocketServer

class EchoRequestHandler(SocketServer.BaseRequestHandler):
    def handle(self):
        # Echo the back to the client
        data = self.request.recv(1024)
        self.request.send(data)
        return

if __name__ == '__main__':
    import socket
    import threading

    address = ('localhost', 0) # let the kernel give us a port
    server = SocketServer.TCPServer(address, EchoRequestHandler)
    ip, port = server.server_address # find out what port we were given

    t = threading.Thread(target=server.serve_forever)
    t.setDaemon(True) # don't hang on exit
    t.start()

    # Connect to the server
    s = socket.socket(socket.AF_INET, socket.SOCK_STREAM)
    s.connect((ip, port))

    # Send the data
    message = 'Hello, world'
    print 'Sending : "%s"' % message
    len_sent = s.send(message)

    # Receive a response
    response = s.recv(len_sent)
    print 'Received: "%s"' % response

    # Clean up
    s.close()
    server.socket.close()
```

In this case, no special server class is required since the `TCPServer` handles all of the server requirements.

```
$ python SocketServer_echo_simple.py

Sending : "Hello, world"
Received: "Hello, world"
```

19.10.6 Threading and Forking

Adding threading or forking support to a server is as simple as including the appropriate mix-in in the class hierarchy for the server. The mix-in classes override `process_request()` to start a new thread or process when a request is ready to be handled, and the work is done in the new child.

For threads, use the `ThreadingMixIn`:

```
import threading
import SocketServer

class ThreadedEchoRequestHandler(SocketServer.BaseRequestHandler):

    def handle(self):
        # Echo the back to the client
        data = self.request.recv(1024)
        cur_thread = threading.currentThread()
        response = '%s: %s' % (cur_thread.getName(), data)
        self.request.send(response)
        return

class ThreadedEchoServer(SocketServer.ThreadingMixIn, SocketServer.TCPServer):
    pass

if __name__ == '__main__':
    import socket
    import threading

    address = ('localhost', 0) # let the kernel give us a port
    server = ThreadedEchoServer(address, ThreadedEchoRequestHandler)
    ip, port = server.server_address # find out what port we were given

    t = threading.Thread(target=server.serve_forever)
    t.setDaemon(True) # don't hang on exit
    t.start()
    print 'Server loop running in thread:', t.getName()

    # Connect to the server
    s = socket.socket(socket.AF_INET, socket.SOCK_STREAM)
    s.connect((ip, port))

    # Send the data
    message = 'Hello, world'
    print 'Sending : "%s"' % message
    len_sent = s.send(message)

    # Receive a response
    response = s.recv(1024)
    print 'Received: "%s"' % response

    # Clean up
    s.close()
    server.socket.close()
```

The response from the server includes the id of the thread where the request is handled:

```
$ python SocketServer_threaded.py

Server loop running in thread: Thread-1
Sending : "Hello, world"
Received: "Thread-2: Hello, world"
```

To use separate processes, use the `ForkingMixIn`:

```
import os
import SocketServer

class ForkingEchoRequestHandler(SocketServer.BaseRequestHandler):

    def handle(self):
        # Echo the back to the client
        data = self.request.recv(1024)
        cur_pid = os.getpid()
        response = '%s: %s' % (cur_pid, data)
        self.request.send(response)
        return

class ForkingEchoServer(SocketServer.ForkingMixIn, SocketServer.TCPServer):
    pass

if __name__ == '__main__':
    import socket
    import threading

    address = ('localhost', 0) # let the kernel give us a port
    server = ForkingEchoServer(address, ForkingEchoRequestHandler)
    ip, port = server.server_address # find out what port we were given

    t = threading.Thread(target=server.serve_forever)
    t.setDaemon(True) # don't hang on exit
    t.start()
    print 'Server loop running in process:', os.getpid()

    # Connect to the server
    s = socket.socket(socket.AF_INET, socket.SOCK_STREAM)
    s.connect((ip, port))

    # Send the data
    message = 'Hello, world'
    print 'Sending : "%s"' % message
    len_sent = s.send(message)

    # Receive a response
    response = s.recv(1024)
    print 'Received: "%s"' % response

    # Clean up
    s.close()
    server.socket.close()
```

In this case, the process id of the child is included in the response from the server:

```
$ python SocketServer_forking.py

Server loop running in process: 14610
Sending : "Hello, world"
Received: "14611: Hello, world"
```

See also:

SocketServer **(http://docs.python.org/lib/module-SocketServer.html)** Standard library documentation for this module.

`asyncore` Use asyncore to create asynchronous servers that do not block while processing a request.

`SimpleXMLRPCServer` XML-RPC server built using `SocketServer`.

19.11 urllib – simple interface for network resource access

Purpose Accessing remote resources that don't need authentication, cookies, etc.

Available In 1.4 and later

The urllib module provides a simple interface for network resource access. Although urllib can be used with gopher and ftp, these examples all use http.

19.11.1 HTTP GET

Note: The test server for these examples is in BaseHTTPServer_GET.py, from the PyMOTW examples for BaseHTTPServer. Start the server in one terminal window, then run these examples in another.

An HTTP GET operation is the simplest use of urllib. Simply pass the URL to `urlopen()` to get a "file-like" handle to the remote data.

```
import urllib

response = urllib.urlopen('http://localhost:8080/')
print 'RESPONSE:', response
print 'URL     :', response.geturl()

headers = response.info()
print 'DATE    :', headers['date']
print 'HEADERS :'
print '---------'
print headers

data = response.read()
print 'LENGTH  :', len(data)
print 'DATA    :'
print '---------'
print data
```

The example server takes the incoming values and formats a plain text response to send back. The return value from `urlopen()` gives access to the headers from the HTTP server through the `info()` method, and the data for the remote resource via methods like `read()` and `readlines()`.

```
$ python urllib_urlopen.py
RESPONSE: <addinfourl at 10180248 whose fp = <socket._fileobject object at 0x935c30>>
URL     : http://localhost:8080/
DATE    : Sun, 30 Mar 2008 16:27:10 GMT
HEADERS :
---------
Server: BaseHTTP/0.3 Python/2.5.1
Date: Sun, 30 Mar 2008 16:27:10 GMT

LENGTH  : 221
DATA    :
---------
CLIENT VALUES:
client_address=('127.0.0.1', 54354) (localhost)
command=GET
path=/
real path=/
query=
request_version=HTTP/1.0

SERVER VALUES:
server_version=BaseHTTP/0.3
sys_version=Python/2.5.1
protocol_version=HTTP/1.0
```

The file-like object is also iterable:

```
import urllib

response = urllib.urlopen('http://localhost:8080/')
for line in response:
    print line.rstrip()
```

Since the lines are returned with newlines and carriage returns intact, this example strips them before printing the output.

```
$ python urllib_urlopen_iterator.py
CLIENT VALUES:
client_address=('127.0.0.1', 54380) (localhost)
command=GET
path=/
real path=/
query=
request_version=HTTP/1.0

SERVER VALUES:
server_version=BaseHTTP/0.3
sys_version=Python/2.5.1
protocol_version=HTTP/1.0
```

19.11.2 Encoding Arguments

Arguments can be passed to the server by encoding them and appending them to the URL.

```
import urllib

query_args = { 'q':'query string', 'foo':'bar' }
encoded_args = urllib.urlencode(query_args)
print 'Encoded:', encoded_args

url = 'http://localhost:8080/?' + encoded_args
print urllib.urlopen(url).read()
```

Notice that the query, in the list of client values, contains the encoded query arguments.

```
$ python urllib_urlencode.py
Encoded: q=query+string&foo=bar
CLIENT VALUES:
client_address=('127.0.0.1', 54415) (localhost)
command=GET
path=/?q=query+string&foo=bar
real path=/
query=q=query+string&foo=bar
request_version=HTTP/1.0

SERVER VALUES:
server_version=BaseHTTP/0.3
sys_version=Python/2.5.1
protocol_version=HTTP/1.0
```

To pass a sequence of values using separate occurrences of the variable in the query string, set *doseq* to True when calling `urlencode()`.

```
import urllib

query_args = { 'foo':['foo1', 'foo2'] }
print 'Single  :', urllib.urlencode(query_args)
print 'Sequence:', urllib.urlencode(query_args, doseq=True )
```

```
$ python urllib_urlencode_doseq.py
Single  : foo=%5B%27foo1%27%2C+%27foo2%27%5D
Sequence: foo=foo1&foo=foo2
```

To decode the query string, see the `FieldStorage` class from the `cgi` module.

Special characters within the query arguments that might cause parse problems with the URL on the server side are "quoted" when passed to `urlencode()`. To quote them locally to make safe versions of the strings, you can use the `quote()` or `quote_plus()` functions directly.

```
import urllib

url = 'http://localhost:8080/~dhellmann/'
print 'urlencode() :', urllib.urlencode({'url':url})
print 'quote()     :', urllib.quote(url)
print 'quote_plus():', urllib.quote_plus(url)
```

Notice that `quote_plus()` is more aggressive about the characters it replaces.

```
$ python urllib_quote.py

urlencode() : url=http%3A%2F%2Flocalhost%3A8080%2F%7Edhellmann%2F
quote()     : http%3A//localhost%3A8080/%7Edhellmann/
quote_plus(): http%3A%2F%2Flocalhost%3A8080%2F%7Edhellmann%2F
```

To reverse the quote operations, use `unquote()` or `unquote_plus()`, as appropriate.

```
import urllib

print urllib.unquote('http%3A//localhost%3A8080/%7Edhellmann/')
print urllib.unquote_plus('http%3A%2F%2Flocalhost%3A8080%2F%7Edhellmann%2F')
```

```
$ python urllib_unquote.py

http://localhost:8080/~dhellmann/
http://localhost:8080/~dhellmann/
```

19.11.3 HTTP POST

Note: The test server for these examples is in BaseHTTPServer_POST.py, from the PyMOTW examples for the `BaseHTTPServer`. Start the server in one terminal window, then run these examples in another.

To POST data to the remote server, instead of using GET, pass the encoded query arguments as data to `urlopen()` instead of appending them to the URL.

```
import urllib

query_args = { 'q':'query string', 'foo':'bar' }
encoded_args = urllib.urlencode(query_args)
url = 'http://localhost:8080/'
print urllib.urlopen(url, encoded_args).read()
```

```
$ python urllib_urlopen_post.py
Client: ('127.0.0.1', 54545)
Path: /
Form data:
    q=query string
    foo=bar
```

You can send any byte-string as data, in case the server expects something other than url-encoded form arguments in the posted data.

19.11.4 Paths vs. URLs

Some operating systems use different values for separating the components of paths in local files than URLs. To make your code portable, you should use the functions `pathname2url()` and `url2pathname()` to convert back and forth. Since I am working on a Mac, I have to explicitly import the Windows versions of the functions. Using the versions of the functions exported by `urllib` gives you the correct defaults for your platform, so you do not need to do this.

```
import os

from urllib import pathname2url, url2pathname

print '== Default =='
path = '/a/b/c'
print 'Original:', path
print 'URL     :', pathname2url(path)
print 'Path    :', url2pathname('/d/e/f')
print

from nturl2path import pathname2url, url2pathname

print '== Windows, without drive letter =='
path = path.replace('/', '\\')
print 'Original:', path
print 'URL     :', pathname2url(path)
print 'Path    :', url2pathname('/d/e/f')
print

print '== Windows, with drive letter =='
path = 'C:\\' + path.replace('/', '\\')
print 'Original:', path
print 'URL     :', pathname2url(path)
print 'Path    :', url2pathname('/d/e/f')
```

There are two Windows examples, with and without the drive letter at the prefix of the path.

```
$ python urllib_pathnames.py

== Default ==
Original: /a/b/c
URL     : /a/b/c
Path    : /d/e/f

== Windows, without drive letter ==
Original: \a\b\c
URL     : /a/b/c
Path    : \d\e\f
```

```
== Windows, with drive letter ==
Original: C:\\a\b\c
URL     : ///C:/a/b/c
Path    : \d\e\f
```

19.11.5 Simple Retrieval with Cache

Retrieving data is a common operation, and `urllib` includes the `urlretrieve()` function so you don't have to write your own. `urlretrieve()` takes arguments for the URL, a temporary file to hold the data, a function to report on download progress, and data to pass if the URL refers to a form where data should be POSTed. If no filename is given, `urlretrieve()` creates a temporary file. You can delete the file yourself, or treat the file as a cache and use `urlcleanup()` to remove it.

This example uses GET to retrieve some data from a web server:

```
import urllib
import os

def reporthook(blocks_read, block_size, total_size):
    if not blocks_read:
        print 'Connection opened'
        return
    if total_size < 0:
        # Unknown size
        print 'Read %d blocks' % blocks_read
    else:
        amount_read = blocks_read * block_size
        print 'Read %d blocks, or %d/%d' % (blocks_read, amount_read, total_size)
    return

try:
    filename, msg = urllib.urlretrieve('http://blog.doughellmann.com/', reporthook=reporthook)
    print
    print 'File:', filename
    print 'Headers:'
    print msg
    print 'File exists before cleanup:', os.path.exists(filename)

finally:
    urllib.urlcleanup()

    print 'File still exists:', os.path.exists(filename)
```

Since the server does not return a `Content-length` header, `urlretrieve()` does not know how big the data should be, and passes -1 as the *total_size* argument to `reporthook()`.

```
$ python urllib_urlretrieve.py
Connection opened
Read 1 blocks
Read 2 blocks
Read 3 blocks
Read 4 blocks
Read 5 blocks
Read 6 blocks
Read 7 blocks
Read 8 blocks
Read 9 blocks
Read 10 blocks
Read 11 blocks
Read 12 blocks
Read 13 blocks
Read 14 blocks
Read 15 blocks
Read 16 blocks
Read 17 blocks
Read 18 blocks
Read 19 blocks

File: /var/folders/9R/9R1t+tR02Raxzk+F71Q50U+++Uw/-Tmp-/tmp3HRpZP
Headers:
Content-Type: text/html; charset=UTF-8
Last-Modified: Tue, 25 Mar 2008 23:09:10 GMT
Cache-Control: max-age=0 private
ETag: "904b02e0-c7ff-47f6-9f35-cc6de5d2a2e5"
Server: GFE/1.3
Date: Sun, 30 Mar 2008 17:36:48 GMT
Connection: Close

File exists before cleanup: True
File still exists: False
```

19.11.6 URLopener

`urllib` provides a `URLopener` base class, and `FancyURLopener` with default handling for the supported protocols. If you find yourself needing to change their behavior, you are probably better off looking at the `urllib2` module, added in Python 2.1.

See also:

urllib (http://docs.python.org/lib/module-urllib.html) Standard library documentation for this module.

`urllib2` Updated API for working with URL-based services.

`urlparse` Parse URL values to access their components.

19.12 urllib2 – Library for opening URLs.

Purpose A library for opening URLs that can be extended by defining custom protocol handlers.

Available In 2.1

The `urllib2` module provides an updated API for using internet resources identified by URLs. It is designed to be extended by individual applications to support new protocols or add variations to existing protocols (such as handling HTTP basic authentication).

19.12.1 HTTP GET

Note: The test server for these examples is in BaseHTTPServer_GET.py, from the PyMOTW examples for `BaseHTTPServer`. Start the server in one terminal window, then run these examples in another.

As with urllib, an HTTP GET operation is the simplest use of urllib2. Pass the URL to `urlopen()` to get a "file-like" handle to the remote data.

```
import urllib2

response = urllib2.urlopen('http://localhost:8080/')
print 'RESPONSE:', response
print 'URL     :', response.geturl()

headers = response.info()
print 'DATE    :', headers['date']
print 'HEADERS :'
print '---------'
print headers

data = response.read()
print 'LENGTH  :', len(data)
print 'DATA    :'
print '---------'
print data
```

The example server accepts the incoming values and formats a plain text response to send back. The return value from `urlopen()` gives access to the headers from the HTTP server through the `info()` method, and the data for the remote resource via methods like `read()` and `readlines()`.

```
$ python urllib2_urlopen.py
RESPONSE: <addinfourl at 11940488 whose fp = <socket._fileobject object at 0xb573f0>>
URL     : http://localhost:8080/
DATE    : Sun, 19 Jul 2009 14:01:31 GMT
HEADERS :
---------
Server: BaseHTTP/0.3 Python/2.6.2
Date: Sun, 19 Jul 2009 14:01:31 GMT

LENGTH  : 349
DATA    :
---------
CLIENT VALUES:
client_address=('127.0.0.1', 55836) (localhost)
command=GET
path=/
real path=/
query=
request_version=HTTP/1.1

SERVER VALUES:
server_version=BaseHTTP/0.3
sys_version=Python/2.6.2
protocol_version=HTTP/1.0

HEADERS RECEIVED:
accept-encoding=identity
connection=close
host=localhost:8080
user-agent=Python-urllib/2.6
```

The file-like object returned by `urlopen()` is iterable:

```
import urllib2

response = urllib2.urlopen('http://localhost:8080/')
for line in response:
    print line.rstrip()
```

This example strips the trailing newlines and carriage returns before printing the output.

```
$ python urllib2_urlopen_iterator.py
CLIENT VALUES:
client_address=('127.0.0.1', 55840) (localhost)
command=GET
path=/
real path=/
query=
request_version=HTTP/1.1

SERVER VALUES:
server_version=BaseHTTP/0.3
sys_version=Python/2.6.2
protocol_version=HTTP/1.0

HEADERS RECEIVED:
accept-encoding=identity
connection=close
host=localhost:8080
user-agent=Python-urllib/2.6
```

Encoding Arguments

Arguments can be passed to the server by encoding them with *urllib.urlencode()* and appending them to the URL.

```
import urllib
import urllib2

query_args = { 'q':'query string', 'foo':'bar' }
encoded_args = urllib.urlencode(query_args)
print 'Encoded:', encoded_args

url = 'http://localhost:8080/?' + encoded_args
print urllib2.urlopen(url).read()
```

The list of client values returned in the example output contains the encoded query arguments.

```
$ python urllib2_http_get_args.py
Encoded: q=query+string&foo=bar
CLIENT VALUES:
client_address=('127.0.0.1', 55849) (localhost)
command=GET
path=/?q=query+string&foo=bar
real path=/
query=q=query+string&foo=bar
request_version=HTTP/1.1

SERVER VALUES:
server_version=BaseHTTP/0.3
sys_version=Python/2.6.2
protocol_version=HTTP/1.0
```

```
HEADERS RECEIVED:
accept-encoding=identity
connection=close
host=localhost:8080
user-agent=Python-urllib/2.6
```

19.12.2 HTTP POST

Note: The test server for these examples is in BaseHTTPServer_POST.py, from the PyMOTW examples for the BaseHTTPServer. Start the server in one terminal window, then run these examples in another.

To POST form-encoded data to the remote server, instead of using GET, pass the encoded query arguments as data to `urlopen()`.

```
import urllib
import urllib2

query_args = { 'q':'query string', 'foo':'bar' }
encoded_args = urllib.urlencode(query_args)
url = 'http://localhost:8080/'
print urllib2.urlopen(url, encoded_args).read()
```

The server can decode the form data and access the individual values by name.

```
$ python urllib2_urlopen_post.py
Client: ('127.0.0.1', 55943)
User-agent: Python-urllib/2.6
Path: /
Form data:
    q=query string
    foo=bar
```

19.12.3 Working with Requests Directly

`urlopen()` is a convenience function that hides some of the details of how the request is made and handled for you. For more precise control, you may want to instantiate and use a `Request` object directly.

Adding Outgoing Headers

As the examples above illustrate, the default *User-agent* header value is made up of the constant `Python-urllib`, followed by the Python interpreter version. If you are creating an application that will access other people's web resources, it is courteous to include real user agent information in your requests, so they can identify the source of the hits more easily. Using a custom agent also allows them to control crawlers using a `robots.txt` file (see robotparser).

```
import urllib2

request = urllib2.Request('http://localhost:8080/')
request.add_header('User-agent', 'PyMOTW (http://www.doughellmann.com/PyMOTW/)')

response = urllib2.urlopen(request)
data = response.read()
print data
```

After creating a `Request` object, use `add_header()` to set the user agent value before opening the request. The last line of the output shows our custom value.

```
$ python urllib2_request_header.py
CLIENT VALUES:
client_address=('127.0.0.1', 55876) (localhost)
command=GET
path=/
real path=/
query=
request_version=HTTP/1.1

SERVER VALUES:
server_version=BaseHTTP/0.3
sys_version=Python/2.6.2
protocol_version=HTTP/1.0

HEADERS RECEIVED:
accept-encoding=identity
connection=close
host=localhost:8080
user-agent=PyMOTW (http://www.doughellmann.com/PyMOTW/)
```

Posting Form Data

You can set the outgoing data on the `Request` to post it to the server.

```
import urllib
import urllib2

query_args = { 'q':'query string', 'foo':'bar' }

request = urllib2.Request('http://localhost:8080/')
print 'Request method before data:', request.get_method()

request.add_data(urllib.urlencode(query_args))
print 'Request method after data :', request.get_method()
request.add_header('User-agent', 'PyMOTW (http://www.doughellmann.com/PyMOTW/)')

print
print 'OUTGOING DATA:'
print request.get_data()

print
print 'SERVER RESPONSE:'
print urllib2.urlopen(request).read()
```

The HTTP method used by the `Request` changes from GET to POST automatically after the data is added.

```
$ python urllib2_request_post.py
Request method before data: GET
Request method after data : POST

OUTGOING DATA:
q=query+string&foo=bar

SERVER RESPONSE:
Client: ('127.0.0.1', 56044)
```

```
User-agent: PyMOTW (http://www.doughellmann.com/PyMOTW/)
Path: /
Form data:
    q=query string
    foo=bar
```

Note: Although the method is `add_data()`, its effect is *not* cumulative. Each call replaces the previous data.

Uploading Files

Encoding files for upload requires a little more work than simple forms. A complete MIME message needs to be constructed in the body of the request, so that the server can distinguish incoming form fields from uploaded files.

```
import itertools
import mimetools
import mimetypes
from cStringIO import StringIO
import urllib
import urllib2

class MultiPartForm(object):
    """Accumulate the data to be used when posting a form."""

    def __init__(self):
        self.form_fields = []
        self.files = []
        self.boundary = mimetools.choose_boundary()
        return

    def get_content_type(self):
        return 'multipart/form-data; boundary=%s' % self.boundary

    def add_field(self, name, value):
        """Add a simple field to the form data."""
        self.form_fields.append((name, value))
        return

    def add_file(self, fieldname, filename, fileHandle, mimetype=None):
        """Add a file to be uploaded."""
        body = fileHandle.read()
        if mimetype is None:
            mimetype = mimetypes.guess_type(filename)[0] or 'application/octet-stream'
        self.files.append((fieldname, filename, mimetype, body))
        return

    def __str__(self):
        """Return a string representing the form data, including attached files."""
        # Build a list of lists, each containing "lines" of the
        # request.  Each part is separated by a boundary string.
        # Once the list is built, return a string where each
        # line is separated by '\r\n'.
        parts = []
        part_boundary = '--' + self.boundary

        # Add the form fields
        parts.extend(
            [ part_boundary,
              'Content-Disposition: form-data; name="%s"' % name,
              '',
              value,
            ]
            for name, value in self.form_fields
            )

        # Add the files to upload
        parts.extend(
            [ part_boundary,
              'Content-Disposition: file; name="%s"; filename="%s"' % \
                 (field_name, filename),
              'Content-Type: %s' % content_type,
              '',
              body,
            ]
            for field_name, filename, content_type, body in self.files
            )

        # Flatten the list and add closing boundary marker,
        # then return CR+LF separated data
        flattened = list(itertools.chain(*parts))
        flattened.append('--' + self.boundary + '--')
        flattened.append('')
        return '\r\n'.join(flattened)

if __name__ == '__main__':
    # Create the form with simple fields
    form = MultiPartForm()
    form.add_field('firstname', 'Doug')
    form.add_field('lastname', 'Hellmann')

    # Add a fake file
    form.add_file('biography', 'bio.txt',
                  fileHandle=StringIO('Python developer and blogger.'))

    # Build the request
    request = urllib2.Request('http://localhost:8080/')
    request.add_header('User-agent', 'PyMOTW (http://www.doughellmann.com/PyMOTW/)')
    body = str(form)
    request.add_header('Content-type', form.get_content_type())
    request.add_header('Content-length', len(body))
    request.add_data(body)

    print
    print 'OUTGOING DATA:'
    print request.get_data()

    print
    print 'SERVER RESPONSE:'
    print urllib2.urlopen(request).read()
```

The `MultiPartForm` class can represent an arbitrary form as a multi-part MIME message with attached files.

```
$ python urllib2_upload_files.py

OUTGOING DATA:
```

```
--192.168.1.17.527.30074.1248020372.206.1
Content-Disposition: form-data; name="firstname"

Doug
--192.168.1.17.527.30074.1248020372.206.1
Content-Disposition: form-data; name="lastname"

Hellmann
--192.168.1.17.527.30074.1248020372.206.1
Content-Disposition: file; name="biography"; filename="bio.txt"
Content-Type: text/plain

Python developer and blogger.
--192.168.1.17.527.30074.1248020372.206.1--


SERVER RESPONSE:
Client: ('127.0.0.1', 57126)
User-agent: PyMOTW (http://www.doughellmann.com/PyMOTW/)
Path: /
Form data:
    lastname=Hellmann
    Uploaded biography as "bio.txt" (29 bytes)
    firstname=Doug
```

19.12.4 Custom Protocol Handlers

`urllib2` has built-in support for HTTP(S), FTP, and local file access. If you need to add support for other URL types, you can register your own protocol handler to be invoked as needed. For example, if you want to support URLs pointing to arbitrary files on remote NFS servers, without requiring your users to mount the path manually, would create a class derived from `BaseHandler` and with a method `nfs_open()`.

The protocol `open()` method takes a single argument, the `Request` instance, and it should return an object with a `read()` method that can be used to read the data, an `info()` method to return the response headers, and `geturl()` to return the actual URL of the file being read. A simple way to achieve that is to create an instance of `urllib.addurlinfo`, passing the headers, URL, and open file handle in to the constructor.

```python
import mimetypes
import os
import tempfile
import urllib
import urllib2

class NFSFile(file):
    def __init__(self, tempdir, filename):
        self.tempdir = tempdir
        file.__init__(self, filename, 'rb')
    def close(self):
        print
        print 'NFSFile:'
        print '  unmounting %s' % self.tempdir
        print '  when %s is closed' % os.path.basename(self.name)
        return file.close(self)

class FauxNFSHandler(urllib2.BaseHandler):

    def __init__(self, tempdir):
        self.tempdir = tempdir

    def nfs_open(self, req):
        url = req.get_selector()
        directory_name, file_name = os.path.split(url)
        server_name = req.get_host()
        print
        print 'FauxNFSHandler simulating mount:'
        print '  Remote path: %s' % directory_name
        print '  Server     : %s' % server_name
        print '  Local path : %s' % tempdir
        print '  File name  : %s' % file_name
        local_file = os.path.join(tempdir, file_name)
        fp = NFSFile(tempdir, local_file)
        content_type = mimetypes.guess_type(file_name)[0] or 'application/octet-stream'
        stats = os.stat(local_file)
        size = stats.st_size
        headers = { 'Content-type': content_type,
                    'Content-length': size,
                  }
        return urllib.addinfourl(fp, headers, req.get_full_url())

if __name__ == '__main__':
    tempdir = tempfile.mkdtemp()
    try:
        # Populate the temporary file for the simulation
        with open(os.path.join(tempdir, 'file.txt'), 'wt') as f:
            f.write('Contents of file.txt')

        # Construct an opener with our NFS handler
        # and register it as the default opener.
        opener = urllib2.build_opener(FauxNFSHandler(tempdir))
        urllib2.install_opener(opener)

        # Open the file through a URL.
        response = urllib2.urlopen('nfs://remote_server/path/to/the/file.txt')
        print
        print 'READ CONTENTS:', response.read()
        print 'URL          :', response.geturl()
        print 'HEADERS:'
        for name, value in sorted(response.info().items()):
            print '  %-15s = %s' % (name, value)
        response.close()
    finally:
        os.remove(os.path.join(tempdir, 'file.txt'))
        os.removedirs(tempdir)
```

The `FauxNFSHandler` and `NFSFile` classes print messages to illustrate where a real implementation would add mount and unmount calls. Since this is just a simulation, `FauxNFSHandler` is primed with the name of a temporary directory where it should look for all of its files.

```
$ python urllib2_nfs_handler.py

FauxNFSHandler simulating mount:
  Remote path: /path/to/the
  Server     : remote_server
  Local path : /var/folders/9R/9R1t+tR02Raxzk+F71Q50U+++Uw/-Tmp-/tmppv5Efn
  File name  : file.txt
```

```
READ CONTENTS: Contents of file.txt
URL          : nfs://remote_server/path/to/the/file.txt
HEADERS:
  Content-length  = 20
  Content-type    = text/plain

NFSFile:
  unmounting /var/folders/9R/9R1t+tR02Raxzk+F71Q50U+++Uw/-Tmp-/tmppv5Efn
  when file.txt is closed
```

See also:

urllib2 (http://docs.python.org/library/urllib2.html) The standard library documentation for this module.

urllib Original URL handling library.

urlparse Work with the URL string itself.

urllib2 – The Missing Manual (http://www.voidspace.org.uk/python/articles/urllib2.shtml) Michael Foord's write-up on using urllib2.

Upload Scripts (http://www.voidspace.org.uk/python/cgi.shtml#upload) Example scripts from Michael Foord that illustrate how to upload a file using HTTP and then receive the data on the server.

HTTP client to POST using multipart/form-data (http://code.activestate.com/recipes/146306/) Python cookbook recipe showing how to encode and post data, including files, over HTTP.

Form content types (http://www.w3.org/TR/REC-html40/interact/forms.html#h-17.13.4) W3C specification for posting files or large amounts of data via HTTP forms.

mimetypes Map filenames to mimetype.

mimetools Tools for parsing MIME messages.

19.13 urlparse – Split URL into component pieces.

Purpose Split URL into component pieces.

Available In since 1.4

The `urlparse` module provides functions for breaking URLs down into their component parts, as defined by the relevant RFCs.

19.13.1 Parsing

The return value from the `urlparse()` function is an object which acts like a tuple with 6 elements.

```
from urlparse import urlparse
parsed = urlparse('http://netloc/path;parameters?query=argument#fragment')
print parsed
```

The parts of the URL available through the tuple interface are the scheme, network location, path, parameters, query, and fragment.

```
$ python urlparse_urlparse.py

ParseResult(scheme='http', netloc='netloc', path='/path', params='parameters', query='query=argument'
```

Although the return value acts like a tuple, it is really based on a *namedtuple*, a subclass of tuple that supports accessing the parts of the URL via named attributes instead of indexes. That's especially useful if, like me, you can't remember the index order. In addition to being easier to use for the programmer, the attribute API also offers access to several values not available in the tuple API.

```
from urlparse import urlparse
parsed = urlparse('http://user:pass@NetLoc:80/path;parameters?query=argument#fragment')
print 'scheme  :', parsed.scheme
print 'netloc  :', parsed.netloc
print 'path    :', parsed.path
print 'params  :', parsed.params
print 'query   :', parsed.query
print 'fragment:', parsed.fragment
print 'username:', parsed.username
print 'password:', parsed.password
print 'hostname:', parsed.hostname, '(netloc in lower case)'
print 'port    :', parsed.port
```

The *username* and *password* are available when present in the input URL and `None` when not. The *hostname* is the same value as *netloc*, in all lower case. And the *port* is converted to an integer when present and `None` when not.

```
$ python urlparse_urlparseattrs.py

scheme  : http
netloc  : user:pass@NetLoc:80
path    : /path
params  : parameters
query   : query=argument
fragment: fragment
username: user
password: pass
hostname: netloc (netloc in lower case)
port    : 80
```

The `urlsplit()` function is an alternative to `urlparse()`. It behaves a little different, because it does not split the parameters from the URL. This is useful for URLs following **RFC 2396** (http://tools.ietf.org/html/rfc2396.html), which supports parameters for each segment of the path.

```
from urlparse import urlsplit
parsed = urlsplit('http://user:pass@NetLoc:80/path;parameters/path2;parameters2?query=argument#fragme
print parsed
print 'scheme  :', parsed.scheme
print 'netloc  :', parsed.netloc
print 'path    :', parsed.path
print 'query   :', parsed.query
print 'fragment:', parsed.fragment
print 'username:', parsed.username
print 'password:', parsed.password
print 'hostname:', parsed.hostname, '(netloc in lower case)'
print 'port    :', parsed.port
```

Since the parameters are not split out, the tuple API will show 5 elements instead of 6, and there is no *params* attribute.

```
$ python urlparse_urlsplit.py

SplitResult(scheme='http', netloc='user:pass@NetLoc:80', path='/path;parameters/path2;parameters2', q
scheme  : http
netloc  : user:pass@NetLoc:80
path    : /path;parameters/path2;parameters2
```

```
query   : query=argument
fragment: fragment
username: user
password: pass
hostname: netloc (netloc in lower case)
port    : 80
```

To simply strip the fragment identifier from a URL, as you might need to do to find a base page name from a URL, use `urldefrag()`.

```
from urlparse import urldefrag
original = 'http://netloc/path;parameters?query=argument#fragment'
print original
url, fragment = urldefrag(original)
print url
print fragment
```

The return value is a tuple containing the base URL and the fragment.

```
$ python urlparse_urldefrag.py

http://netloc/path;parameters?query=argument#fragment
http://netloc/path;parameters?query=argument
fragment
```

19.13.2 Unparsing

There are several ways to assemble a split URL back together into a single string. The parsed URL object has a `geturl()` method.

```
from urlparse import urlparse
original = 'http://netloc/path;parameters?query=argument#fragment'
print 'ORIG  :', original
parsed = urlparse(original)
print 'PARSED:', parsed.geturl()
```

`geturl()` only works on the object returned by `urlparse()` or `urlsplit()`.

```
$ python urlparse_geturl.py

ORIG  : http://netloc/path;parameters?query=argument#fragment
PARSED: http://netloc/path;parameters?query=argument#fragment
```

If you have a regular tuple of values, you can use `urlunparse()` to combine them into a URL.

```
from urlparse import urlparse, urlunparse
original = 'http://netloc/path;parameters?query=argument#fragment'
print 'ORIG  :', original
parsed = urlparse(original)
print 'PARSED:', type(parsed), parsed
t = parsed[:]
print 'TUPLE :', type(t), t
print 'NEW   :', urlunparse(t)
```

While the `ParseResult` returned by `urlparse()` can be used as a tuple, in this example I explicitly create a new tuple to show that `urlunparse()` works with normal tuples, too.

```
$ python urlparse_urlunparse.py

ORIG  : http://netloc/path;parameters?query=argument#fragment
PARSED: <class 'urlparse.ParseResult'> ParseResult(scheme='http', netloc='netloc', path='/path', para
TUPLE : <type 'tuple'> ('http', 'netloc', '/path', 'parameters', 'query=argument', 'fragment')
NEW   : http://netloc/path;parameters?query=argument#fragment
```

If the input URL included superfluous parts, those may be dropped from the unparsed version of the URL.

```
from urlparse import urlparse, urlunparse
original = 'http://netloc/path;?#'
print 'ORIG  :', original
parsed = urlparse(original)
print 'PARSED:', type(parsed), parsed
t = parsed[:]
print 'TUPLE :', type(t), t
print 'NEW   :', urlunparse(t)
```

In this case, the *parameters*, *query*, and *fragment* are all missing in the original URL. The new URL does not look the same as the original, but is equivalent according to the standard.

```
$ python urlparse_urlunparseextra.py

ORIG  : http://netloc/path;?#
PARSED: <class 'urlparse.ParseResult'> ParseResult(scheme='http', netloc='netloc', path='/path', para
TUPLE : <type 'tuple'> ('http', 'netloc', '/path', '', '', '')
NEW   : http://netloc/path
```

19.13.3 Joining

In addition to parsing URLs, `urlparse` includes `urljoin()` for constructing absolute URLs from relative fragments.

```
from urlparse import urljoin
print urljoin('http://www.example.com/path/file.html', 'anotherfile.html')
print urljoin('http://www.example.com/path/file.html', '../anotherfile.html')
```

In the example, the relative portion of the path (`"../"`) is taken into account when the second URL is computed.

```
$ python urlparse_urljoin.py

http://www.example.com/path/anotherfile.html
http://www.example.com/anotherfile.html
```

See also:

urlparse (http://docs.python.org/lib/module-urlparse.html) Standard library documentation for this module.

`urllib` Retrieve the contents of a resource identified by a URL.

`urllib2` Alternative API for accessing remote URLs.

19.14 uuid – Universally unique identifiers

Purpose The `uuid` module implements Universally Unique Identifiers as described in **RFC 4122** (http://tools.ietf.org/html/rfc4122.html).

Available In 2.5 and later

RFC 4122 (http://tools.ietf.org/html/rfc4122.html) defines a system for creating universally unique identifiers for resources in a way that does not require a central registrar. UUID values are 128 bits long and "can guarantee uniqueness across space and time". They are useful for identifiers for documents, hosts, application clients, and other situations where a unique value is necessary. The RFC is specifically geared toward creating a Uniform Resource Name namespace.

Three main algorithms are covered by the spec:

- Using IEEE 802 MAC addresses as a source of uniqueness
- Using pseudo-random numbers
- Using well-known strings combined with cryptographic hashing

In all cases the seed value is combined with the system clock and a clock sequence value (to maintain uniqueness in case the clock was set backwards).

19.14.1 UUID 1 - IEEE 802 MAC Address

UUID version 1 values are computed using the MAC address of the host. The `uuid` module uses `getnode()` to retrieve the MAC value on a given system:

```
import uuid

print hex(uuid.getnode())
```

```
$ python uuid_getnode.py

0x70cd60f2c980
```

If a system has more than one network card, and so more than one MAC, any one of the values may be returned.

To generate a UUID for a given host, identified by its MAC address, use the `uuid1()` function. You can pass a node identifier, or leave the field blank to use the value returned by `getnode()`.

```
import uuid

u = uuid.uuid1()

print u
print type(u)
print 'bytes   :', repr(u.bytes)
print 'hex     :', u.hex
print 'int     :', u.int
print 'urn     :', u.urn
print 'variant :', u.variant
print 'version :', u.version
print 'fields  :', u.fields
print '\ttime_low            : ', u.time_low
print '\ttime_mid            : ', u.time_mid
print '\ttime_hi_version     : ', u.time_hi_version
print '\tclock_seq_hi_variant: ', u.clock_seq_hi_variant
print '\tclock_seq_low       : ', u.clock_seq_low
print '\tnode                : ', u.node
print '\ttime                : ', u.time
print '\tclock_seq           : ', u.clock_seq
```

The components of the UUID object returned can be accessed through read-only instance attributes. Some attributes, such as *hex*, *int*, and *urn*, are different representations of the UUID value.

```
$ python uuid_uuid1.py

2500b32e-7c1b-11e2-830a-70cd60f2c980
<class 'uuid.UUID'>
bytes   : '%\x00\xb3.|\x1b\x11\xe2\x83\np\xcd`\xf2\xc9\x80'
hex     : 2500b32e7c1b11e2830a70cd60f2c980
int     : 49185070078265283276219513639424674176
urn     : urn:uuid:2500b32e-7c1b-11e2-830a-70cd60f2c980
variant : specified in RFC 4122
version : 1
fields  : (620802862L, 31771L, 4578L, 131L, 10L, 124027397130624L)
        time_low             :  620802862
        time_mid             :  31771
        time_hi_version      :  4578
        clock_seq_hi_variant:  131
        clock_seq_low        :  10
        node                 :  124027397130624
        time                 :  135807394801300270
        clock_seq            :  778
```

Because of the time component, each time `uuid1()` is called a new value is returned.

```python
import uuid

for i in xrange(3):
    print uuid.uuid1()
```

Notice in this output that only the time component (at the beginning of the string) changes.

```
$ python uuid_uuid1_repeat.py

2507ba51-7c1b-11e2-8ee5-70cd60f2c980
250938c7-7c1b-11e2-b456-70cd60f2c980
25093ae3-7c1b-11e2-940c-70cd60f2c980
```

Because your computer has a different MAC address than mine, you will see entirely different values if you run the examples, because the node identifier at the end of the UUID will change, too.

```python
import uuid

node1 = uuid.getnode()
print hex(node1), uuid.uuid1(node1)

node2 =  0x1e5274040e
print hex(node2), uuid.uuid1(node2)
```

```
$ python uuid_uuid1_othermac.py

0x70cd60f2c980 250ff58c-7c1b-11e2-9808-70cd60f2c980
0x1e5274040e 25106559-7c1b-11e2-9e48-001e5274040e
```

19.14.2 UUID 3 and 5 - Name-Based Values

It is also useful in some contexts to create UUID values from names instead of random or time-based values. Versions 3 and 5 of the UUID specification use cryptographic hash values (MD5 or SHA-1) to combine namespace-specific seed values with "names" (DNS hostnames, URLs, object ids, etc.). There are several well-known namespaces, identified by pre-defined UUID values, for working with DNS, URLs, ISO OIDs, and X.500 Distinguished Names. You can also define your own application- specific namespaces by generating and saving UUID values.

To create a UUID from a DNS name, pass `uuid.NAMESPACE_DNS` as the namespace argument to `uuid3()` or `uuid5()`:

```
import uuid

hostnames = ['www.doughellmann.com', 'blog.doughellmann.com']

for name in hostnames:
    print name
    print '\tMD5   :', uuid.uuid3(uuid.NAMESPACE_DNS, name)
    print '\tSHA-1 :', uuid.uuid5(uuid.NAMESPACE_DNS, name)
```

```
$ python uuid_uuid3_uuid5.py

www.doughellmann.com
        MD5   : bcd02e22-68f0-3046-a512-327cca9def8f
        SHA-1 : e3329b12-30b7-57c4-8117-c2cd34a87ce9
blog.doughellmann.com
        MD5   : 9bdabfce-dfd6-37ab-8a3f-7f7293bcf111
        SHA-1 : fa829736-7ef8-5239-9906-b4775a5abacb
```

The UUID value for a given name in a namespace is always the same, no matter when or where it is calculated. Values for the same name in different namespaces are different.

```
import uuid

for i in xrange(3):
    print uuid.uuid3(uuid.NAMESPACE_DNS, 'www.doughellmann.com')
```

```
$ python uuid_uuid3_repeat.py

bcd02e22-68f0-3046-a512-327cca9def8f
bcd02e22-68f0-3046-a512-327cca9def8f
bcd02e22-68f0-3046-a512-327cca9def8f
```

19.14.3 UUID 4 - Random Values

Sometimes host-based and namespace-based UUID values are not "different enough". For example, in cases where you want to use the UUID as a lookup key, a more random sequence of values with more differentiation is desirable to avoid collisions in a hash table. Having values with fewer common digits also makes it easier to find them in log files. To add greater differentiation in your UUIDs, use `uuid4()` to generate them using random input values.

```
import uuid

for i in xrange(3):
    print uuid.uuid4()
```

```
$ python uuid_uuid4.py

025b0d74-00a2-4048-bf57-227c5111bb34
6491c2a5-acb2-40ef-b2c0-bc1fc4cd7e6c
3a99e70f-5ca4-4c0c-bf25-b05b441dfcae
```

19.14.4 Working with UUID Objects

In addition to generating new UUID values, you can parse strings in various formats to create UUID objects. This makes it easier to compare them, sort them, etc.

```
import uuid

def show(msg, l):
    print msg
    for v in l:
        print '\t', v
    print

input_values = [
    'urn:uuid:f2f84497-b3bf-493a-bba9-7c68e6def80b',
    '{417a5ebb-01f7-4ed5-aeac-3d56cd5037b0}',
    '2115773a-5bf1-11dd-ab48-001ec200d9e0',
    ]

show('input_values', input_values)

uuids = [ uuid.UUID(s) for s in input_values ]
show('converted to uuids', uuids)

uuids.sort()
show('sorted', uuids)
```

```
$ python uuid_uuid_objects.py

input_values
        urn:uuid:f2f84497-b3bf-493a-bba9-7c68e6def80b
        {417a5ebb-01f7-4ed5-aeac-3d56cd5037b0}
        2115773a-5bf1-11dd-ab48-001ec200d9e0

converted to uuids
        f2f84497-b3bf-493a-bba9-7c68e6def80b
        417a5ebb-01f7-4ed5-aeac-3d56cd5037b0
        2115773a-5bf1-11dd-ab48-001ec200d9e0

sorted
        2115773a-5bf1-11dd-ab48-001ec200d9e0
        417a5ebb-01f7-4ed5-aeac-3d56cd5037b0
        f2f84497-b3bf-493a-bba9-7c68e6def80b
```

See also:

uuid (http://docs.python.org/lib/module-uuid.html) Standard library documentation for this module.

RFC 4122 (http://tools.ietf.org/html/rfc4122.html) A Universally Unique IDentifier (UUID) URN Namespace

19.15 webbrowser – Displays web pages

Purpose Use the *webbrowser* module to display web pages to your users.

Available In 2.1.3 and later

The `webbrowser` module includes functions to open URLs in interactive browser applications. The module includes a registry of available browsers, in case multiple options are available on the system. It can also be controlled with the

BROWSER environment variable.

19.15.1 Simple Example

To open a page in the browser, use the open() function.

```
import webbrowser

webbrowser.open('http://docs.python.org/lib/module-webbrowser.html')
```

The URL is opened in a browser window, and that window is raised to the top of the window stack. The documentation says that an existing window will be reused, if possible, but the actual behavior may depend on your browser's settings. Using Firefox on my Mac, a new window was always created.

19.15.2 Windows vs. Tabs

If you always want a new window used, use open_new().

```
import webbrowser

webbrowser.open_new('http://docs.python.org/lib/module-webbrowser.html')
```

If you would rather create a new tab, use open_new_tab() instead.

19.15.3 Using a specific browser

If for some reason your application needs to use a specific browser, you can access the set of registered browser controllers using the get() function. The browser controller has methods to open(), open_new(), and open_new_tab(). This example forces the use of the lynx browser:

```
import webbrowser

b = webbrowser.get('lynx')
b.open('http://docs.python.org/lib/module-webbrowser.html')
```

Refer to the module documentation for a list of available browser types.

19.15.4 BROWSER variable

Users can control the module from outside your application by setting the environment variable BROWSER to the browser names or commands to try. The value should consist of a series of browser names separated by os.pathsep. If the name includes %s, the name is interpreted as a literal command and executed directly with the %s replaced by the URL. Otherwise, the name is passed to get() to obtain a controller object from the registry.

For example, this command opens the web page in lynx, assuming it is available, no matter what other browsers are registered.

```
$ BROWSER=lynx python webbrowser_open.py
```

If none of the names in BROWSER work, webbrowser falls back to its default behavior.

19.15.5 Command Line Interface

All of the features of the webbrowser module are available via the command line as well as from within your Python program.

```
$ python -m webbrowser
Usage: /Library/Frameworks/Python.framework/Versions/2.5/lib/python2.5/webbrowser.py [-n | -t] url
    -n: open new window
    -t: open new tab
```

See also:

webbrowser (http://docs.python.org/lib/module-webbrowser.html) Standard library documentation for this module.

19.16 xmlrpclib – Client-side library for XML-RPC communication

Purpose Client-side library for XML-RPC communication.

Available In 2.2 and later

We have already looked at SimpleXMLRPCServer, the library for creating an XML-RPC server. The xmlrpclib module lets you communicate from Python with any XML-RPC server written in any language.

Note: All of the examples below use the server defined in xmlrpclib_server.py, available in the source distribution and repeated here for reference:

```
from SimpleXMLRPCServer import SimpleXMLRPCServer
from xmlrpclib import Binary
import datetime

server = SimpleXMLRPCServer(('localhost', 9000), logRequests=True, allow_none=True)
server.register_introspection_functions()
server.register_multicall_functions()

class ExampleService:

    def ping(self):
        """Simple function to respond when called to demonstrate connectivity."""
        return True

    def now(self):
        """Returns the server current date and time."""
        return datetime.datetime.now()

    def show_type(self, arg):
        """Illustrates how types are passed in and out of server methods.

        Accepts one argument of any type.
        Returns a tuple with string representation of the value,
        the name of the type, and the value itself.
        """
        return (str(arg), str(type(arg)), arg)

    def raises_exception(self, msg):
        "Always raises a RuntimeError with the message passed in"
        raise RuntimeError(msg)
    def send_back_binary(self, bin):
        "Accepts single Binary argument, unpacks and repacks it to return it"
        data = bin.data
        response = Binary(data)
        return response

server.register_instance(ExampleService())

try:
    print 'Use Control-C to exit'
    server.serve_forever()
except KeyboardInterrupt:
    print 'Exiting'
```

19.16.1 Connecting to a Server

The simplest way to connect a client to a server is to instantiate a `ServerProxy` object, giving it the URI of the server. For example, the demo server runs on port 9000 of localhost:

```
import xmlrpclib

server = xmlrpclib.ServerProxy('http://localhost:9000')
print 'Ping:', server.ping()
```

In this case, the `ping()` method of the service takes no arguments and returns a single boolean value.

```
$ python xmlrpclib_ServerProxy.py
Ping: True
```

Other options are available to support alternate transport. Both HTTP and HTTPS are supported out of the box, as are basic authentication. You would only need to provide a transport class if your communication channel was not one of the supported types. It would be an interesting exercise, for example, to implement XML-RPC over SMTP. Not terribly useful, but interesting.

The verbose option gives you debugging information useful for working out where communication errors might be happening.

```
import xmlrpclib

server = xmlrpclib.ServerProxy('http://localhost:9000', verbose=True)
print 'Ping:', server.ping()
```

```
$ python xmlrpclib_ServerProxy_verbose.py
Ping: connect: (localhost, 9000)
connect fail: ('localhost', 9000)
connect: (localhost, 9000)
connect fail: ('localhost', 9000)
connect: (localhost, 9000)
send: 'POST /RPC2 HTTP/1.0\r\nHost: localhost:9000\r\nUser-Agent: xmlrpclib.py/1.0.1 (by www.pythonwa
send: "<?xml version='1.0'?>\n<methodCall>\n<methodName>ping</methodName>\n<params>\n</params>\n</met
reply: 'HTTP/1.0 200 OK\r\n'
header: Server: BaseHTTP/0.3 Python/2.5.1
header: Date: Sun, 06 Jul 2008 19:56:13 GMT
header: Content-type: text/xml
header: Content-length: 129
body: "<?xml version='1.0'?>\n<methodResponse>\n<params>\n<param>\n<value><boolean>1</boolean></value
True
```

You can change the default encoding from UTF-8 if you need to use an alternate system.

```
import xmlrpclib

server = xmlrpclib.ServerProxy('http://localhost:9000', encoding='ISO-8859-1')
print 'Ping:', server.ping()
```

The server should automatically detect the correct encoding.

```
$ python xmlrpclib_ServerProxy_encoding.py
Ping: True
```

The *allow_none* option controls whether Python's `None` value is automatically translated to a nil value or if it causes an error.

```
import xmlrpclib

server = xmlrpclib.ServerProxy('http://localhost:9000', allow_none=True)
print 'Allowed:', server.show_type(None)

server = xmlrpclib.ServerProxy('http://localhost:9000', allow_none=False)
print 'Not allowed:', server.show_type(None)
```

The error is raised locally if the client does not allow `None`, but can also be raised from within the server if it is not configured to allow `None`.

```
$ python xmlrpclib_ServerProxy_allow_none.py
Allowed: ['None', "<type 'NoneType'>", None]
Not allowed:
Traceback (most recent call last):
  File "/Users/dhellmann/Documents/PyMOTW/in_progress/xmlrpclib/xmlrpclib_ServerProxy_allow_none.py",
    print 'Not allowed:', server.show_type(None)
  File "/Library/Frameworks/Python.framework/Versions/2.5/lib/python2.5/xmlrpclib.py", line 1147, in
    return self.__send(self.__name, args)
  File "/Library/Frameworks/Python.framework/Versions/2.5/lib/python2.5/xmlrpclib.py", line 1431, in
    allow_none=self.__allow_none)
  File "/Library/Frameworks/Python.framework/Versions/2.5/lib/python2.5/xmlrpclib.py", line 1080, in
    data = m.dumps(params)
  File "/Library/Frameworks/Python.framework/Versions/2.5/lib/python2.5/xmlrpclib.py", line 623, in
    dump(v, write)
  File "/Library/Frameworks/Python.framework/Versions/2.5/lib/python2.5/xmlrpclib.py", line 635, in
    f(self, value, write)
  File "/Library/Frameworks/Python.framework/Versions/2.5/lib/python2.5/xmlrpclib.py", line 639, in
    raise TypeError, "cannot marshal None unless allow_none is enabled"
TypeError: cannot marshal None unless allow_none is enabled
```

The *use_datetime* option lets you pass `datetime` and related objects in to the proxy or receive them from the server. If *use_datetime* is False, the internal `DateTime` class is used to represent dates instead.

19.16.2 Data Types

The XML-RPC protocol recognizes a limited set of common data types. The types can be passed as arguments or return values and combined to create more complex data structures.

```
import xmlrpclib
import datetime

server = xmlrpclib.ServerProxy('http://localhost:9000')
```

```
for t, v in [ ('boolean', True),
              ('integer', 1),
              ('floating-point number', 2.5),
              ('string', 'some text'),
              ('datetime', datetime.datetime.now()),
              ('array', ['a', 'list']),
              ('array', ('a', 'tuple')),
              ('structure', {'a':'dictionary'}),
            ]:
    print '%-22s:' % t, server.show_type(v)
```

The simple types:

```
$ python xmlrpclib_types.py
boolean               : ['True', "<type 'bool'>", True]
integer               : ['1', "<type 'int'>", 1]
floating-point number : ['2.5', "<type 'float'>", 2.5]
string                : ['some text', "<type 'str'>", 'some text']
datetime              : ['20080706T16:22:49', "<type 'instance'>", <DateTime '20080706T16:22:49' at a
array                 : ["['a', 'list']", "<type 'list'>", ['a', 'list']]
array                 : ["['a', 'tuple']", "<type 'list'>", ['a', 'tuple']]
structure             : ["{'a': 'dictionary'}", "<type 'dict'>", {'a': 'dictionary'}]
```

And they can be nested to create values of arbitrary complexity:

```
import xmlrpclib
import datetime
import pprint

server = xmlrpclib.ServerProxy('http://localhost:9000')

data = { 'boolean':True,
         'integer': 1,
         'floating-point number': 2.5,
         'string': 'some text',
         'datetime': datetime.datetime.now(),
         'array': ['a', 'list'],
         'array': ('a', 'tuple'),
         'structure': {'a':'dictionary'},
         }
arg = []
for i in range(3):
    d = {}
    d.update(data)
    d['integer'] = i
    arg.append(d)

print 'Before:'
pprint.pprint(arg)

print
print 'After:'
pprint.pprint(server.show_type(arg)[-1])
```

```
$ python xmlrpclib_types_nested.py
Before:
[{'array': ('a', 'tuple'),
  'boolean': True,
  'datetime': datetime.datetime(2008, 7, 6, 16, 24, 52, 348849),
  'floating-point number': 2.5,
  'integer': 0,
  'string': 'some text',
  'structure': {'a': 'dictionary'}},
 {'array': ('a', 'tuple'),
  'boolean': True,
  'datetime': datetime.datetime(2008, 7, 6, 16, 24, 52, 348849),
  'floating-point number': 2.5,
  'integer': 1,
  'string': 'some text',
  'structure': {'a': 'dictionary'}},
 {'array': ('a', 'tuple'),
  'boolean': True,
  'datetime': datetime.datetime(2008, 7, 6, 16, 24, 52, 348849),
  'floating-point number': 2.5,
  'integer': 2,
  'string': 'some text',
  'structure': {'a': 'dictionary'}}]

After:
[{'array': ['a', 'tuple'],
  'boolean': True,
  'datetime': <DateTime '20080706T16:24:52' at a5be18>,
  'floating-point number': 2.5,
  'integer': 0,
  'string': 'some text',
  'structure': {'a': 'dictionary'}},
 {'array': ['a', 'tuple'],
  'boolean': True,
  'datetime': <DateTime '20080706T16:24:52' at a5bf30>,
  'floating-point number': 2.5,
  'integer': 1,
  'string': 'some text',
  'structure': {'a': 'dictionary'}},
 {'array': ['a', 'tuple'],
  'boolean': True,
  'datetime': <DateTime '20080706T16:24:52' at a5bf80>,
  'floating-point number': 2.5,
  'integer': 2,
  'string': 'some text',
  'structure': {'a': 'dictionary'}}]
```

19.16.3 Passing Objects

Instances of Python classes are treated as structures and passed as a dictionary, with the attributes of the object as values in the dictionary.

```
import xmlrpclib

class MyObj:
    def __init__(self, a, b):
        self.a = a
        self.b = b
    def __repr__(self):
        return 'MyObj(%s, %s)' % (repr(self.a), repr(self.b))
```

```
server = xmlrpclib.ServerProxy('http://localhost:9000')

o = MyObj(1, 'b goes here')
print 'o=', o
print server.show_type(o)

o2 = MyObj(2, o)
print 'o2=', o2
print server.show_type(o2)
```

Round-tripping the value gives a dictionary on the client, since there is nothing encoded in the values to tell the server (or client) that it should be instantiated as part of a class.

```
$ python xmlrpclib_types_object.py
o= MyObj(1, 'b goes here')
["{'a': 1, 'b': 'b goes here'}", "<type 'dict'>", {'a': 1, 'b': 'b goes here'}]
o2= MyObj(2, MyObj(1, 'b goes here'))
["{'a': 2, 'b': {'a': 1, 'b': 'b goes here'}}", "<type 'dict'>", {'a': 2, 'b': {'a': 1, 'b': 'b goes
```

19.16.4 Binary Data

All values passed to the server are encoded and escaped automatically. However, some data types may contain characters that are not valid XML. For example, binary image data may include byte values in the ASCII control range 0 to 31. If you need to pass binary data, it is best to use the `Binary` class to encode it for transport.

```
import xmlrpclib

server = xmlrpclib.ServerProxy('http://localhost:9000')

s = 'This is a string with control characters' + '\0'
print 'Local string:', s

data = xmlrpclib.Binary(s)
print 'As binary:', server.send_back_binary(data)

print 'As string:', server.show_type(s)
```

If we pass the string containing a NULL byte to `show_type()`, an exception is raised in the XML parser:

```
$ python xmlrpclib_Binary.py
Local string: This is a string with control characters
As binary: This is a string with control characters
As string:
Traceback (most recent call last):
  File "/Users/dhellmann/Documents/PyMOTW/in_progress/xmlrpclib/xmlrpclib_Binary.py", line 21, in <mo
    print 'As string:', server.show_type(s)
  File "/Library/Frameworks/Python.framework/Versions/2.5/lib/python2.5/xmlrpclib.py", line 1147, in
    return self.__send(self.__name, args)
  File "/Library/Frameworks/Python.framework/Versions/2.5/lib/python2.5/xmlrpclib.py", line 1437, in
    verbose=self.__verbose
  File "/Library/Frameworks/Python.framework/Versions/2.5/lib/python2.5/xmlrpclib.py", line 1201, in
    return self._parse_response(h.getfile(), sock)
  File "/Library/Frameworks/Python.framework/Versions/2.5/lib/python2.5/xmlrpclib.py", line 1340, in
    return u.close()
  File "/Library/Frameworks/Python.framework/Versions/2.5/lib/python2.5/xmlrpclib.py", line 787, in c
    raise Fault(**self._stack[0])
xmlrpclib.Fault: <Fault 1: "<class 'xml.parsers.expat.ExpatError'>:not well-formed (invalid token): l
```

`Binary` objects can also be used to send objects using `pickle`. The normal security issues related to sending what amounts to executable code over the wire apply here (i.e., don't do this unless you're sure your communication channel is secure).

```
import xmlrpclib
import cPickle as pickle

class MyObj:
    def __init__(self, a, b):
        self.a = a
        self.b = b
    def __repr__(self):
        return 'MyObj(%s, %s)' % (repr(self.a), repr(self.b))

server = xmlrpclib.ServerProxy('http://localhost:9000')

o = MyObj(1, 'b goes here')
print 'Local:', o, id(o)

print 'As object:', server.show_type(o)

p = pickle.dumps(o)
b = xmlrpclib.Binary(p)
r = server.send_back_binary(b)

o2 = pickle.loads(r.data)
print 'From pickle:', o2, id(o2)
```

Remember, the data attribute of the `Binary` instance contains the pickled version of the object, so it has to be unpickled before it can be used. That results in a different object (with a new id value).

```
$ python xmlrpclib_Binary_pickle.py
Local: MyObj(1, 'b goes here') 9620936
As object: ["{'a': 1, 'b': 'b goes here'}", "<type 'dict'>", {'a': 1, 'b': 'b goes here'}]
From pickle: MyObj(1, 'b goes here') 11049200
```

19.16.5 Exception Handling

Since the XML-RPC server might be written in any language, exception classes cannot be transmitted directly. Instead, exceptions raised in the server are converted to `Fault` objects and raised as exceptions locally in the client.

```
import xmlrpclib

server = xmlrpclib.ServerProxy('http://localhost:9000')
try:
    server.raises_exception('A message')
except Exception, err:
    print 'Fault code:', err.faultCode
    print 'Message   :', err.faultString
```

```
$ python xmlrpclib_exception.py
Fault code: 1
Message   : <type 'exceptions.RuntimeError'>:A message
```

19.16.6 MultiCall

Multicall is an extension to the XML-RPC protocol to allow more than one call to be sent at the same time, with the responses collected and returned to the caller. The `MultiCall` class was added to `xmlrpclib` in Python 2.4. To use a `MultiCall` instance, invoke the methods on it as with a `ServerProxy`, then call the object with no arguments. The result is an iterator with the results.

```
import xmlrpclib

server = xmlrpclib.ServerProxy('http://localhost:9000')

multicall = xmlrpclib.MultiCall(server)
multicall.ping()
multicall.show_type(1)
multicall.show_type('string')

for i, r in enumerate(multicall()):
    print i, r
```

```
$ python xmlrpclib_MultiCall.py
0 True
1 ['1', "<type 'int'>", 1]
2 ['string', "<type 'str'>", 'string']
```

If one of the calls causes a `Fault` or otherwise raises an exception, the exception is raised when the result is produced from the iterator and no more results are available.

```
import xmlrpclib

server = xmlrpclib.ServerProxy('http://localhost:9000')

multicall = xmlrpclib.MultiCall(server)
multicall.ping()
multicall.show_type(1)
multicall.raises_exception('Next to last call stops execution')
multicall.show_type('string')

for i, r in enumerate(multicall()):
    print i, r
```

```
$ python xmlrpclib_MultiCall_exception.py
0 True
1 ['1', "<type 'int'>", 1]
Traceback (most recent call last):
  File "/Users/dhellmann/Documents/PyMOTW/in_progress/xmlrpclib/xmlrpclib_MultiCall_exception.py", li
    for i, r in enumerate(multicall()):
  File "/Library/Frameworks/Python.framework/Versions/2.5/lib/python2.5/xmlrpclib.py", line 949, in _
    raise Fault(item['faultCode'], item['faultString'])
xmlrpclib.Fault: <Fault 1: "<type 'exceptions.RuntimeError'>:Next to last call stops execution">
```

See also:

xmlrpclib (http://docs.python.org/lib/module-xmlrpclib.html) Standard library documentation for this module.

`SimpleXMLRPCServer` An XML-RPC server implementation.

CHAPTER

TWENTY

STRUCTURED MARKUP PROCESSING TOOLS

20.1 xml.etree.ElementTree – XML Manipulation API

Purpose Generate and parse XML documents

Python Version 2.5 and later

The ElementTree library was contributed to the standard library by Fredrick Lundh. It includes tools for parsing XML using event-based and document-based APIs, searching parsed documents with XPath expressions, and creating new or modifying existing documents.

Note: All of the examples in this section use the Python implementation of ElementTree for simplicity, but there is also a C implementation in `xml.etree.cElementTree`.

20.1.1 Parsing XML Documents

Parsed XML documents are represented in memory by `ElementTree` and `Element` objects connected into a tree structure based on the way the nodes in the XML document are nested.

Parsing an Entire Document

Parsing an entire document with `parse()` returns an `ElementTree` instance. The tree knows about all of the data in the input document, and the nodes of the tree can be searched or manipulated in place. While this flexibility can make working with the parsed document a little easier, it typically takes more memory than an event-based parsing approach since the entire document must be loaded at one time.

The memory footprint of small, simple documents such as this list of podcasts represented as an OPML (http://www.opml.org/) outline is not significant:

```
<?xml version="1.0" encoding="UTF-8"?>
<opml version="1.0">
<head>
        <title>My Podcasts</title>
        <dateCreated>Sun, 07 Mar 2010 15:53:26 GMT</dateCreated>
        <dateModified>Sun, 07 Mar 2010 15:53:26 GMT</dateModified>
</head>
<body>
  <outline text="Science and Tech">
    <outline text="APM: Future Tense" type="rss"
             xmlUrl="http://www.publicradio.org/columns/futuretense/podcast.xml"
             htmlUrl="http://www.publicradio.org/columns/futuretense/" />
        <outline text="Engines Of Our Ingenuity Podcast" type="rss"
```

```
             xmlUrl="http://www.npr.org/rss/podcast.php?id=510030"
             htmlUrl="http://www.uh.edu/engines/engines.htm" />
        <outline text="Science &#38; the City" type="rss"
             xmlUrl="http://www.nyas.org/Podcasts/Atom.axd"
             htmlUrl="http://www.nyas.org/WhatWeDo/SciencetheCity.aspx" />
  </outline>
  <outline text="Books and Fiction">
        <outline text="Podiobooker" type="rss"
             xmlUrl="http://feeds.feedburner.com/podiobooks"
             htmlUrl="http://www.podiobooks.com/blog" />
        <outline text="The Drabblecast" type="rss"
             xmlUrl="http://web.me.com/normsherman/Site/Podcast/rss.xml"
             htmlUrl="http://web.me.com/normsherman/Site/Podcast/Podcast.html" />
        <outline text="tor.com / category / tordotstories" type="rss"
             xmlUrl="http://www.tor.com/rss/category/TorDotStories"
             htmlUrl="http://www.tor.com/" />
  </outline>
  <outline text="Computers and Programming">
        <outline text="MacBreak Weekly" type="rss"
             xmlUrl="http://leo.am/podcasts/mbw"
             htmlUrl="http://twit.tv/mbw" />
        <outline text="FLOSS Weekly" type="rss"
             xmlUrl="http://leo.am/podcasts/floss"
             htmlUrl="http://twit.tv" />
        <outline text="Core Intuition" type="rss"
             xmlUrl="http://www.coreint.org/podcast.xml"
             htmlUrl="http://www.coreint.org/" />
  </outline>
  <outline text="Python">
    <outline text="PyCon Podcast" type="rss"
             xmlUrl="http://advocacy.python.org/podcasts/pycon.rss"
             htmlUrl="http://advocacy.python.org/podcasts/" />
        <outline text="A Little Bit of Python" type="rss"
             xmlUrl="http://advocacy.python.org/podcasts/littlebit.rss"
             htmlUrl="http://advocacy.python.org/podcasts/" />
        <outline text="Django Dose Everything Feed" type="rss"
             xmlUrl="http://djangodose.com/everything/feed/" />
  </outline>
  <outline text="Miscelaneous">
        <outline text="dhellmann's CastSampler Feed" type="rss"
             xmlUrl="http://www.castsampler.com/cast/feed/rss/dhellmann/"
             htmlUrl="http://www.castsampler.com/users/dhellmann/" />
  </outline>
</body>
</opml>
```

To parse the file, pass an open file handle to `parse()`.

```python
from xml.etree import ElementTree

with open('podcasts.opml', 'rt') as f:
    tree = ElementTree.parse(f)

print tree
```

It will read the data, parse the XML, and return an `ElementTree` object.

```
$ python ElementTree_parse_opml.py
```

```
<xml.etree.ElementTree.ElementTree object at 0x10048cfd0>
```

Traversing the Parsed Tree

To visit all of the children in order, use `iter()` to create a generator that iterates over the `ElementTree` instance.

```
from xml.etree import ElementTree

with open('podcasts.opml', 'rt') as f:
    tree = ElementTree.parse(f)

for node in tree.iter():
    print node.tag, node.attrib
```

This example prints the entire tree, one tag at a time.

```
$ python ElementTree_dump_opml.py

opml {'version': '1.0'}
head {}
title {}
dateCreated {}
dateModified {}
body {}
outline {'text': 'Science and Tech'}
outline {'xmlUrl': 'http://www.publicradio.org/columns/futuretense/podcast.xml', 'text': 'APM: Future
outline {'xmlUrl': 'http://www.npr.org/rss/podcast.php?id=510030', 'text': 'Engines Of Our Ingenuity
outline {'xmlUrl': 'http://www.nyas.org/Podcasts/Atom.axd', 'text': 'Science & the City', 'type': 'rs
outline {'text': 'Books and Fiction'}
outline {'xmlUrl': 'http://feeds.feedburner.com/podiobooks', 'text': 'Podiobooker', 'type': 'rss', 'h
outline {'xmlUrl': 'http://web.me.com/normsherman/Site/Podcast/rss.xml', 'text': 'The Drabblecast', '
outline {'xmlUrl': 'http://www.tor.com/rss/category/TorDotStories', 'text': 'tor.com / category / tor
outline {'text': 'Computers and Programming'}
outline {'xmlUrl': 'http://leo.am/podcasts/mbw', 'text': 'MacBreak Weekly', 'type': 'rss', 'htmlUrl':
outline {'xmlUrl': 'http://leo.am/podcasts/floss', 'text': 'FLOSS Weekly', 'type': 'rss', 'htmlUrl':
outline {'xmlUrl': 'http://www.coreint.org/podcast.xml', 'text': 'Core Intuition', 'type': 'rss', 'ht
outline {'text': 'Python'}
outline {'xmlUrl': 'http://advocacy.python.org/podcasts/pycon.rss', 'text': 'PyCon Podcast', 'type':
outline {'xmlUrl': 'http://advocacy.python.org/podcasts/littlebit.rss', 'text': 'A Little Bit of Pyth
outline {'xmlUrl': 'http://djangodose.com/everything/feed/', 'text': 'Django Dose Everything Feed', '
outline {'text': 'Miscelaneous'}
outline {'xmlUrl': 'http://www.castsampler.com/cast/feed/rss/dhellmann/', 'text': "dhellmann's CastSa
```

To print only the groups of names and feed URLs for the podcasts, leaving out of all of the data in the header section by iterating over only the `outline` nodes and print the *text* and *xmlUrl* attributes.

```
from xml.etree import ElementTree

with open('podcasts.opml', 'rt') as f:
    tree = ElementTree.parse(f)

for node in tree.iter('outline'):
    name = node.attrib.get('text')
    url = node.attrib.get('xmlUrl')
    if name and url:
        print '  %s :: %s' % (name, url)
    else:
        print name
```

The 'outline' argument to `iter()` means processing is limited to only nodes with the tag 'outline'.

```
$ python ElementTree_show_feed_urls.py

Science and Tech
  APM: Future Tense :: http://www.publicradio.org/columns/futuretense/podcast.xml
  Engines Of Our Ingenuity Podcast :: http://www.npr.org/rss/podcast.php?id=510030
  Science & the City :: http://www.nyas.org/Podcasts/Atom.axd
Books and Fiction
  Podiobooker :: http://feeds.feedburner.com/podiobooks
  The Drabblecast :: http://web.me.com/normsherman/Site/Podcast/rss.xml
  tor.com / category / tordotstories :: http://www.tor.com/rss/category/TorDotStories
Computers and Programming
  MacBreak Weekly :: http://leo.am/podcasts/mbw
  FLOSS Weekly :: http://leo.am/podcasts/floss
  Core Intuition :: http://www.coreint.org/podcast.xml
Python
  PyCon Podcast :: http://advocacy.python.org/podcasts/pycon.rss
  A Little Bit of Python :: http://advocacy.python.org/podcasts/littlebit.rss
  Django Dose Everything Feed :: http://djangodose.com/everything/feed/
Miscelaneous
  dhellmann's CastSampler Feed :: http://www.castsampler.com/cast/feed/rss/dhellmann/
```

Finding Nodes in a Document

Walking the entire tree like this searching for relevant nodes can be error prone. The example above had to look at each outline node to determine if it was a group (nodes with only a `text` attribute) or podcast (with both `text` and `xmlUrl`). To produce a simple list of the podcast feed URLs, without names or groups, for a podcast downloader application, the logic could be simplified using `findall()` to look for nodes with more descriptive search characteristics.

As a first pass at converting the above example, we can construct an XPath (http://www.w3.org/TR/xpath/) argument to look for all outline nodes.

```python
from xml.etree import ElementTree

with open('podcasts.opml', 'rt') as f:
    tree = ElementTree.parse(f)

for node in tree.findall('.//outline'):
    url = node.attrib.get('xmlUrl')
    if url:
        print url
```

The logic in this version is not substantially different than the version using `getiterator()`. It still has to check for the presence of the URL, except that it does not print the group name when the URL is not found.

```
$ python ElementTree_find_feeds_by_tag.py

http://www.publicradio.org/columns/futuretense/podcast.xml
http://www.npr.org/rss/podcast.php?id=510030
http://www.nyas.org/Podcasts/Atom.axd
http://feeds.feedburner.com/podiobooks
http://web.me.com/normsherman/Site/Podcast/rss.xml
http://www.tor.com/rss/category/TorDotStories
http://leo.am/podcasts/mbw
http://leo.am/podcasts/floss
http://www.coreint.org/podcast.xml
```

```
http://advocacy.python.org/podcasts/pycon.rss
http://advocacy.python.org/podcasts/littlebit.rss
http://djangodose.com/everything/feed/
http://www.castsampler.com/cast/feed/rss/dhellmann/
```

Another version can take advantage of the fact that the outline nodes are only nested two levels deep. Changing the search path to `.//outline/outline` mean the loop will process only the second level of outline nodes.

```
from xml.etree import ElementTree

with open('podcasts.opml', 'rt') as f:
    tree = ElementTree.parse(f)

for node in tree.findall('.//outline/outline'):
    url = node.attrib.get('xmlUrl')
    print url
```

All of those outline nodes nested two levels deep in the input are expected to have the *xmlURL* attribute refering to the podcast feed, so the loop can skip checking for for the attribute before using it.

```
$ python ElementTree_find_feeds_by_structure.py

http://www.publicradio.org/columns/futuretense/podcast.xml
http://www.npr.org/rss/podcast.php?id=510030
http://www.nyas.org/Podcasts/Atom.axd
http://feeds.feedburner.com/podiobooks
http://web.me.com/normsherman/Site/Podcast/rss.xml
http://www.tor.com/rss/category/TorDotStories
http://leo.am/podcasts/mbw
http://leo.am/podcasts/floss
http://www.coreint.org/podcast.xml
http://advocacy.python.org/podcasts/pycon.rss
http://advocacy.python.org/podcasts/littlebit.rss
http://djangodose.com/everything/feed/
http://www.castsampler.com/cast/feed/rss/dhellmann/
```

This version is limited to the existing structure, though, so if the outline nodes are ever rearranged into a deeper tree it will stop working.

Parsed Node Attributes

The items returned by `findall()` and `iter()` are `Element` objects, each representing a node in the XML parse tree. Each `Element` has attributes for accessing data pulled out of the XML. This can be illustrated with a somewhat more contrived example input file, `data.xml`:

```
<?xml version="1.0" encoding="UTF-8"?>
<top>
  <child>This child contains text.</child>
  <child_with_tail>This child has regular text.</child_with_tail>And "tail" text.
  <with_attributes name="value" foo="bar" />
  <entity_expansion attribute="This &#38; That">That &#38; This</entity_expansion>
</top>
```

The "attributes" of a node are available in the `attrib` property, which acts like a dictionary.

```
from xml.etree import ElementTree

with open('data.xml', 'rt') as f:
    tree = ElementTree.parse(f)

node = tree.find('./with_attributes')
print node.tag
for name, value in sorted(node.attrib.items()):
    print '  %-4s = "%s"' % (name, value)
```

The node on line five of the input file has two attributes, `name` and `foo`.

```
$ python ElementTree_node_attributes.py

with_attributes
  foo  = "bar"
  name = "value"
```

The text content of the nodes is available, along with the "tail" text that comes after the end of a close tag.

```
from xml.etree import ElementTree

with open('data.xml', 'rt') as f:
    tree = ElementTree.parse(f)

for path in [ './child', './child_with_tail' ]:
    node = tree.find(path)
    print node.tag
    print '  child node text:', node.text
    print '  and tail text  :', node.tail
```

The `child` node on line three contains embedded text, and the node on line four has text with a tail (including any whitespace).

```
$ python ElementTree_node_text.py

child
  child node text: This child contains text.
  and tail text  :

child_with_tail
  child node text: This child has regular text.
  and tail text  : And "tail" text.
```

XML entity references embedded in the document are conveniently converted to the appropriate characters before values are returned.

```
from xml.etree import ElementTree

with open('data.xml', 'rt') as f:
    tree = ElementTree.parse(f)

node = tree.find('entity_expansion')
print node.tag
print '  in attribute:', node.attrib['attribute']
print '  in text     :', node.text
```

The automatic conversion mean the implementation detail of representing certain characters in an XML document can be ignored.

```
$ python ElementTree_entity_references.py

entity_expansion
```

```
in attribute: This & That
in text      : That & This
```

Watching Events While Parsing

The other API useful for processing XML documents is event-based. The parser generates `start` events for opening tags and `end` events for closing tags. Data can be extracted from the document during the parsing phase by iterating over the event stream, which is convenient if it is not necessary to manipulate the entire document afterwards and there is no need to hold the entire parsed document in memory.

`iterparse()` returns an iterable that produces tuples containing the name of the event and the node triggering the event. Events can be one of:

start A new tag has been encountered. The closing angle bracket of the tag was processed, but not the contents.

end The closing angle bracket of a closing tag has been processed. All of the children were already processed.

start-ns Start a namespace declaration.

end-ns End a namespace declaration.

```
from xml.etree.ElementTree import iterparse

depth = 0
prefix_width = 8
prefix_dots = '.' * prefix_width
line_template = '{prefix:<0.{prefix_len}}{event:<8}{suffix:<{suffix_len}} {node.tag:<12} {node_id}'

for (event, node) in iterparse('podcasts.opml', ['start', 'end', 'start-ns', 'end-ns']):
    if event == 'end':
        depth -= 1

    prefix_len = depth * 2

    print line_template.format(prefix=prefix_dots,
                               prefix_len=prefix_len,
                               suffix='',
                               suffix_len=(prefix_width - prefix_len),
                               node=node,
                               node_id=id(node),
                               event=event,
                               )

    if event == 'start':
        depth += 1
```

By default, only `end` events are generated. To see other events, pass the list of desired event names to `iterparse()`, as in this example:

```
$ python ElementTree_show_all_events.py

start            opml         4299786128
..start          head         4299786192
....start        title        4299786256
....end          title        4299786256
....start        dateCreated  4299786448
....end          dateCreated  4299786448
....start        dateModified 4299786640
....end          dateModified 4299786640
```

```
..end             head        4299786192
..start           body        4299787024
....start         outline     4299787088
......start       outline     4299787152
......end         outline     4299787152
......start       outline     4299787216
......end         outline     4299787216
......start       outline     4299787280
......end         outline     4299787280
....end           outline     4299787088
....start         outline     4299787344
......start       outline     4299787472
......end         outline     4299787472
......start       outline     4299787408
......end         outline     4299787408
......start       outline     4299787536
......end         outline     4299787536
....end           outline     4299787344
....start         outline     4299787600
......start       outline     4299787728
......end         outline     4299787728
......start       outline     4299787920
......end         outline     4299787920
......start       outline     4299787856
......end         outline     4299787856
....end           outline     4299787600
....start         outline     4299788048
......start       outline     4299788112
......end         outline     4299788112
......start       outline     4299788176
......end         outline     4299788176
......start       outline     4299792464
......end         outline     4299792464
....end           outline     4299788048
....start         outline     4299792592
......start       outline     4299792720
......end         outline     4299792720
....end           outline     4299792592
..end             body        4299787024
end               opml        4299786128
```

The event-style of processing is more natural for some operations, such as converting XML input to some other format. This technique can be used to convert list of podcasts from the earlier examples from an XML file to a CSV file, so they can be loaded into a spreadsheet or database application.

```
import csv
from xml.etree.ElementTree import iterparse
import sys

writer = csv.writer(sys.stdout, quoting=csv.QUOTE_NONNUMERIC)

group_name = ''

for (event, node) in iterparse('podcasts.opml', events=['start']):
    if node.tag != 'outline':
        # Ignore anything not part of the outline
        continue
    if not node.attrib.get('xmlUrl'):
        # Remember the current group
        group_name = node.attrib['text']
    else:
        # Output a podcast entry
        writer.writerow( (group_name, node.attrib['text'],
                          node.attrib['xmlUrl'],
                          node.attrib.get('htmlUrl', ''),
                          )
                        )
```

This conversion program does not need to hold the entire parsed input file in memory, and processing each node as it is encountered in the input is more efficient.

```
$ python ElementTree_write_podcast_csv.py

"Science and Tech","APM: Future Tense","http://www.publicradio.org/columns/futuretense/podcast.xml","
"Science and Tech","Engines Of Our Ingenuity Podcast","http://www.npr.org/rss/podcast.php?id=510030",
"Science and Tech","Science & the City","http://www.nyas.org/Podcasts/Atom.axd","http://www.nyas.org/
"Books and Fiction","Podiobooker","http://feeds.feedburner.com/podiobooks","http://www.podiobooks.com
"Books and Fiction","The Drabblecast","http://web.me.com/normsherman/Site/Podcast/rss.xml","http://we
"Books and Fiction","tor.com / category / tordotstories","http://www.tor.com/rss/category/TorDotStori
"Computers and Programming","MacBreak Weekly","http://leo.am/podcasts/mbw","http://twit.tv/mbw"
"Computers and Programming","FLOSS Weekly","http://leo.am/podcasts/floss","http://twit.tv"
"Computers and Programming","Core Intuition","http://www.coreint.org/podcast.xml","http://www.coreint
"Python","PyCon Podcast","http://advocacy.python.org/podcasts/pycon.rss","http://advocacy.python.org/
"Python","A Little Bit of Python","http://advocacy.python.org/podcasts/littlebit.rss","http://advocac
"Python","Django Dose Everything Feed","http://djangodose.com/everything/feed/",""
"Miscelaneous","dhellmann's CastSampler Feed","http://www.castsampler.com/cast/feed/rss/dhellmann/","
```

Creating a Custom Tree Builder

A potentially more efficient means of handling parse events is to replace the standard tree builder behavior with a custom version. The `ElementTree` parser uses an `XMLTreeBuilder` to process the XML and call methods on a target class to save the results. The usual output is an `ElementTree` instance created by the default `TreeBuilder` class. Replacing `TreeBuilder` with another class allows it to receive the events before the `Element` nodes are instantiated, saving that portion of the overhead.

The XML-to-CSV converter from the previous section can be translated to a tree builder.

```
import csv
from xml.etree.ElementTree import XMLTreeBuilder
import sys

class PodcastListToCSV(object):

    def __init__(self, outputFile):
        self.writer = csv.writer(outputFile, quoting=csv.QUOTE_NONNUMERIC)
        self.group_name = ''
        return

    def start(self, tag, attrib):
        if tag != 'outline':
            # Ignore anything not part of the outline
            return
        if not attrib.get('xmlUrl'):
            # Remember the current group
            self.group_name = attrib['text']
        else:
            # Output a podcast entry
            self.writer.writerow( (self.group_name, attrib['text'],
                                   attrib['xmlUrl'],
                                   attrib.get('htmlUrl', ''),
                                   )
                                 )

    def end(self, tag):
        # Ignore closing tags
        pass
    def data(self, data):
        # Ignore data inside nodes
        pass
    def close(self):
        # Nothing special to do here
        return


target = PodcastListToCSV(sys.stdout)
parser = XMLTreeBuilder(target=target)
with open('podcasts.opml', 'rt') as f:
    for line in f:
        parser.feed(line)
parser.close()
```

`PodcastListToCSV` implements the `TreeBuilder` protocol. Each time a new XML tag is encountered, `start()` is called with the tag name and attributes. When a closing tag is seen `end()` is called with the name. In between, `data()` is called when a node has content (the tree builder is expected to keep up with the "current" node). When all of the input is processed, `close()` is called. It can return a value, which will be returned to the user of the `XMLTreeBuilder`.

```
$ python ElementTree_podcast_csv_treebuilder.py

"Science and Tech","APM: Future Tense","http://www.publicradio.org/columns/futuretense/podcast.xml","
"Science and Tech","Engines Of Our Ingenuity Podcast","http://www.npr.org/rss/podcast.php?id=510030",
"Science and Tech","Science & the City","http://www.nyas.org/Podcasts/Atom.axd","http://www.nyas.org
"Books and Fiction","Podiobooker","http://feeds.feedburner.com/podiobooks","http://www.podiobooks.co
"Books and Fiction","The Drabblecast","http://web.me.com/normsherman/Site/Podcast/rss.xml","http://w
"Books and Fiction","tor.com / category / tordotstories","http://www.tor.com/rss/category/TorDotStor
"Computers and Programming","MacBreak Weekly","http://leo.am/podcasts/mbw","http://twit.tv/mbw"
"Computers and Programming","FLOSS Weekly","http://leo.am/podcasts/floss","http://twit.tv"
"Computers and Programming","Core Intuition","http://www.coreint.org/podcast.xml","http://www.corein
"Python","PyCon Podcast","http://advocacy.python.org/podcasts/pycon.rss","http://advocacy.python.org
"Python","A Little Bit of Python","http://advocacy.python.org/podcasts/littlebit.rss","http://advoca
"Python","Django Dose Everything Feed","http://djangodose.com/everything/feed/",""
"Miscelaneous","dhellmann's CastSampler Feed","http://www.castsampler.com/cast/feed/rss/dhellmann/","
```

Parsing Strings

To work with smaller bits of XML text, especially string literals as might be embedded in the source of a program, use `XML()` and the string containing the XML to be parsed as the only argument.

```
from xml.etree.ElementTree import XML

parsed = XML('''
<root>
```

```
  <group>
    <child id="a">This is child "a".</child>
    <child id="b">This is child "b".</child>
  </group>
  <group>
    <child id="c">This is child "c".</child>
  </group>
</root>
''')

print 'parsed =', parsed

for elem in parsed:
    print elem.tag
    if elem.text is not None and elem.text.strip():
        print '  text: "%s"' % elem.text
    if elem.tail is not None and elem.tail.strip():
        print '  tail: "%s"' % elem.tail
    for name, value in sorted(elem.attrib.items()):
        print '  %-4s = "%s"' % (name, value)
    print
```

Notice that unlike with `parse()`, the return value is an `Element` instance instead of an `ElementTree`. An `Element` supports the iterator protocol directly, so there is no need to call `getiterator()`.

```
$ python ElementTree_XML.py

parsed = <Element 'root' at 0x100497710>
group

group
```

For structured XML that uses the `id` attribute to identify unique nodes of interest, `XMLID()` is a convenient way to access the parse results.

```
from xml.etree.ElementTree import XMLID

tree, id_map = XMLID('''
<root>
  <group>
    <child id="a">This is child "a".</child>
    <child id="b">This is child "b".</child>
  </group>
  <group>
    <child id="c">This is child "c".</child>
  </group>
</root>
''')

for key, value in sorted(id_map.items()):
    print '%s = %s' % (key, value)
```

`XMLID()` returns the parsed tree as an `Element` object, along with a dictionary mapping the `id` attribute strings to the individual nodes in the tree.

```
$ python ElementTree_XMLID.py

a = <Element 'child' at 0x100497850>
b = <Element 'child' at 0x100497910>
```

```
c = <Element 'child' at 0x100497b50>
```

See also:

Outline Processor Markup Language, OPML (http://www.opml.org/) Dave Winer's OPML specification and documentation.

XML Path Language, XPath (http://www.w3.org/TR/xpath/) A syntax for identifying parts of an XML document.

XPath Support in ElementTree (http://effbot.org/zone/element-xpath.htm) Part of Fredrick Lundh's original documentation for ElementTree.

csv Read and write comma-separated-value files

20.1.2 Creating XML Documents

In addition to its parsing capabilities, `xml.etree.ElementTree` also supports creating well-formed XML documents from `Element` objects constructed in an application. The `Element` class used when a document is parsed also knows how to generate a serialized form of its contents, which can then be written to a file or other data stream.

Building Element Nodes

There are three helper functions useful for creating a hierarchy of `Element` nodes. `Element()` creates a standard node, `SubElement()` attaches a new node to a parent, and `Comment()` creates a node that serializes using XML's comment syntax.

```
from xml.etree.ElementTree import Element, SubElement, Comment, tostring

top = Element('top')

comment = Comment('Generated for PyMOTW')
top.append(comment)

child = SubElement(top, 'child')
child.text = 'This child contains text.'

child_with_tail = SubElement(top, 'child_with_tail')
child_with_tail.text = 'This child has regular text.'
child_with_tail.tail = 'And "tail" text.'

child_with_entity_ref = SubElement(top, 'child_with_entity_ref')
child_with_entity_ref.text = 'This & that'

print tostring(top)
```

The output contains only the XML nodes in the tree, not the XML declaration with version and encoding.

```
$ python ElementTree_create.py

<top><!--Generated for PyMOTW--><child>This child contains text.</ch
ild><child_with_tail>This child has regular text.</child_with_tail>A
nd "tail" text.<child_with_entity_ref>This &amp; that</child_with_en
tity_ref></top>
```

The `&` character in the text of `child_with_entity_ref` is converted to the entity reference `&amp;` automatically.

Pretty-Printing XML

`ElementTree` makes no effort to "pretty print" the output produced by `tostring()`, since adding extra whitespace changes the contents of the document. To make the output easier to follow for human readers, the rest of the examples below will use a tip I found online (http://renesd.blogspot.com/2007/05/pretty-print-xml-with-python.html) and re-parse the XML with `xml.dom.minidom` then use its `toprettyxml()` method.

```
from xml.etree import ElementTree
from xml.dom import minidom

def prettify(elem):
    """Return a pretty-printed XML string for the Element.
    """
    rough_string = ElementTree.tostring(elem, 'utf-8')
    reparsed = minidom.parseString(rough_string)
    return reparsed.toprettyxml(indent="  ")
```

The updated example now looks like:

```
from xml.etree.ElementTree import Element, SubElement, Comment
from ElementTree_pretty import prettify

top = Element('top')

comment = Comment('Generated for PyMOTW')
top.append(comment)

child = SubElement(top, 'child')
child.text = 'This child contains text.'

child_with_tail = SubElement(top, 'child_with_tail')
child_with_tail.text = 'This child has regular text.'
child_with_tail.tail = 'And "tail" text.'

child_with_entity_ref = SubElement(top, 'child_with_entity_ref')
child_with_entity_ref.text = 'This & that'

print prettify(top)
```

and the output is easier to read:

```
$ python ElementTree_create_pretty.py

<?xml version="1.0" ?>
<top>
  <!--Generated for PyMOTW-->
  <child>
    This child contains text.
  </child>
  <child_with_tail>
    This child has regular text.
  </child_with_tail>
  And &quot;tail&quot; text.
  <child_with_entity_ref>
    This &amp; that
  </child_with_entity_ref>
</top>
```

In addition to the extra whitespace for formatting, the `xml.dom.minidom` pretty-printer also adds an XML declaration to the output.

Setting Element Properties

The previous example created nodes with tags and text content, but did not set any attributes of the nodes. Many of the examples from *Parsing XML Documents* worked with an OPML (http://www.opml.org/) file listing podcasts and their feeds. The `outline` nodes in the tree used attributes for the group names and podcast properties. `ElementTree` can be used to construct a similar XML file from a CSV input file, setting all of the element attributes as the tree is constructed.

```
import csv
from xml.etree.ElementTree import Element, SubElement, Comment, tostring
import datetime
from ElementTree_pretty import prettify

generated_on = str(datetime.datetime.now())

# Configure one attribute with set()
root = Element('opml')
root.set('version', '1.0')

root.append(Comment('Generated by ElementTree_csv_to_xml.py for PyMOTW'))

head = SubElement(root, 'head')
title = SubElement(head, 'title')
title.text = 'My Podcasts'
dc = SubElement(head, 'dateCreated')
dc.text = generated_on
dm = SubElement(head, 'dateModified')
dm.text = generated_on

body = SubElement(root, 'body')

with open('podcasts.csv', 'rt') as f:
    current_group = None
    reader = csv.reader(f)
    for row in reader:
        group_name, podcast_name, xml_url, html_url = row
        if current_group is None or group_name != current_group.text:
            # Start a new group
            current_group = SubElement(body, 'outline', {'text':group_name})
        # Add this podcast to the group,
        # setting all of its attributes at
        # once.
        podcast = SubElement(current_group, 'outline',
                             {'text':podcast_name,
                              'xmlUrl':xml_url,
                              'htmlUrl':html_url,
                              })

print prettify(root)
```

The attribute values can be configured one at a time with `set()` (as with the `root` node), or all at once by passing a dictionary to the node factory (as with each group and podcast node).

```
$ python ElementTree_csv_to_xml.py

<?xml version="1.0" ?>
```

```
<opml version="1.0">
  <!--Generated by ElementTree_csv_to_xml.py for PyMOTW-->
  <head>
    <title>
      My Podcasts
    </title>
    <dateCreated>
      2013-02-21 06:38:01.494066
    </dateCreated>
    <dateModified>
      2013-02-21 06:38:01.494066
    </dateModified>
  </head>
  <body>
    <outline text="Science and Tech">
      <outline htmlUrl="http://www.publicradio.org/columns/futureten
se/" text="APM: Future Tense" xmlUrl="http://www.publicradio.org/col
umns/futuretense/podcast.xml"/>
    </outline>
    <outline text="Science and Tech">
      <outline htmlUrl="http://www.uh.edu/engines/engines.htm" text=
"Engines Of Our Ingenuity Podcast" xmlUrl="http://www.npr.org/rss/po
dcast.php?id=510030"/>
    </outline>
    <outline text="Science and Tech">
      <outline htmlUrl="http://www.nyas.org/WhatWeDo/SciencetheCity.
aspx" text="Science &amp; the City" xmlUrl="http://www.nyas.org/Podc
asts/Atom.axd"/>
    </outline>
    <outline text="Books and Fiction">
      <outline htmlUrl="http://www.podiobooks.com/blog" text="Podiob
ooker" xmlUrl="http://feeds.feedburner.com/podiobooks"/>
    </outline>
    <outline text="Books and Fiction">
      <outline htmlUrl="http://web.me.com/normsherman/Site/Podcast/P
odcast.html" text="The Drabblecast" xmlUrl="http://web.me.com/normsh
erman/Site/Podcast/rss.xml"/>
    </outline>
    <outline text="Books and Fiction">
      <outline htmlUrl="http://www.tor.com/" text="tor.com / categor
y / tordotstories" xmlUrl="http://www.tor.com/rss/category/TorDotSto
ries"/>
    </outline>
    <outline text="Computers and Programming">
      <outline htmlUrl="http://twit.tv/mbw" text="MacBreak Weekly" x
mlUrl="http://leo.am/podcasts/mbw"/>
    </outline>
    <outline text="Computers and Programming">
      <outline htmlUrl="http://twit.tv" text="FLOSS Weekly" xmlUrl="
http://leo.am/podcasts/floss"/>
    </outline>
    <outline text="Computers and Programming">
      <outline htmlUrl="http://www.coreint.org/" text="Core Intuitio
n" xmlUrl="http://www.coreint.org/podcast.xml"/>
    </outline>
    <outline text="Python">
      <outline htmlUrl="http://advocacy.python.org/podcasts/" text="
PyCon Podcast" xmlUrl="http://advocacy.python.org/podcasts/pycon.rss
```

```
"/>
    </outline>
    <outline text="Python">
      <outline htmlUrl="http://advocacy.python.org/podcasts/" text="
A Little Bit of Python" xmlUrl="http://advocacy.python.org/podcasts/
littlebit.rss"/>
    </outline>
    <outline text="Python">
      <outline htmlUrl="" text="Django Dose Everything Feed" xmlUrl=
"http://djangodose.com/everything/feed/"/>
    </outline>
    <outline text="Miscelaneous">
      <outline htmlUrl="http://www.castsampler.com/users/dhellmann/"
 text="dhellmann's CastSampler Feed" xmlUrl="http://www.castsampler.
com/cast/feed/rss/dhellmann/"/>
    </outline>
  </body>
</opml>
```

Building Trees from Lists of Nodes

Multiple children can be added to an `Element` instance with the `extend()` method. The argument to `extend()` is any iterable, including a `list` or another `Element` instance.

```
from xml.etree.ElementTree import Element, tostring
from ElementTree_pretty import prettify

top = Element('top')

children = [
    Element('child', num=str(i))
    for i in xrange(3)
    ]

top.extend(children)

print prettify(top)
```

When a `list` is given, the nodes in the list are added directly to the new parent.

```
$ python ElementTree_extend.py

<?xml version="1.0" ?>
<top>
  <child num="0"/>
  <child num="1"/>
  <child num="2"/>
</top>
```

When another `Element` instance is given, the children of that node are added to the new parent.

```
from xml.etree.ElementTree import Element, SubElement, tostring, XML
from ElementTree_pretty import prettify

top = Element('top')

parent = SubElement(top, 'parent')
```

```
children = XML('''<root><child num="0" /><child num="1" /><child num="2" /></root> ''')
parent.extend(children)

print prettify(top)
```

In this case, the node with tag `root` created by parsing the XML string has three children, which are added to the `parent` node. The `root` node is not part of the output tree.

```
$ python ElementTree_extend_node.py

<?xml version="1.0" ?>
<top>
  <parent>
    <child num="0"/>
    <child num="1"/>
    <child num="2"/>
  </parent>
</top>
```

It is important to understand that `extend()` does not modify any existing parent-child relationships with the nodes. If the values passed to extend exist somewhere in the tree already, they will still be there, and will be repeated in the output.

```
from xml.etree.ElementTree import Element, SubElement, tostring, XML
from ElementTree_pretty import prettify

top = Element('top')

parent_a = SubElement(top, 'parent', id='A')
parent_b = SubElement(top, 'parent', id='B')

# Create children
children = XML('''<root><child num="0" /><child num="1" /><child num="2" /></root> ''')

# Set the id to the Python object id of the node to make duplicates
# easier to spot.
for c in children:
    c.set('id', str(id(c)))

# Add to first parent
parent_a.extend(children)

print 'A:'
print prettify(top)
print

# Copy nodes to second parent
parent_b.extend(children)

print 'B:'
print prettify(top)
print
```

Setting the `id` attribute of these children to the Python unique object identifier exposes the fact that the same node objects appear in the output tree more than once.

```
$ python ElementTree_extend_node_copy.py
```

```
A:
<?xml version="1.0" ?>
<top>
  <parent id="A">
    <child id="4300110224" num="0"/>
    <child id="4300110288" num="1"/>
    <child id="4300110480" num="2"/>
  </parent>
  <parent id="B"/>
</top>


B:
<?xml version="1.0" ?>
<top>
  <parent id="A">
    <child id="4300110224" num="0"/>
    <child id="4300110288" num="1"/>
    <child id="4300110480" num="2"/>
  </parent>
  <parent id="B">
    <child id="4300110224" num="0"/>
    <child id="4300110288" num="1"/>
    <child id="4300110480" num="2"/>
  </parent>
</top>
```

Serializing XML to a Stream

`tostring()` is implemented to write to an in-memory file-like object and then return a string representing the entire element tree. When working with large amounts of data, it will take less memory and make more efficient use of the I/O libraries to write directly to a file handle using the `write()` method of `ElementTree`.

```
import sys
from xml.etree.ElementTree import Element, SubElement, Comment, ElementTree

top = Element('top')

comment = Comment('Generated for PyMOTW')
top.append(comment)

child = SubElement(top, 'child')
child.text = 'This child contains text.'

child_with_tail = SubElement(top, 'child_with_tail')
child_with_tail.text = 'This child has regular text.'
child_with_tail.tail = 'And "tail" text.'

child_with_entity_ref = SubElement(top, 'child_with_entity_ref')
child_with_entity_ref.text = 'This & that'

empty_child = SubElement(top, 'empty_child')

ElementTree(top).write(sys.stdout)
```

The example uses *sys.stdout* to write to the console, but it could also write to an open file or socket.

```
$ python ElementTree_write.py

<top><!--Generated for PyMOTW--><child>This child contains text.</ch
ild><child_with_tail>This child has regular text.</child_with_tail>A
nd "tail" text.<child_with_entity_ref>This &amp; that</child_with_en
tity_ref><empty_child /></top>
```

The last node in the tree contains no text or sub-nodes, so it is written as an empty tag, `<empty_child />`. `write()` takes a *method* argument to control the handling for empty nodes.

```python
import sys
from xml.etree.ElementTree import Element, SubElement, ElementTree

top = Element('top')

child = SubElement(top, 'child')
child.text = 'This child contains text.'

empty_child = SubElement(top, 'empty_child')

for method in [ 'xml', 'html', 'text' ]:
    print method
    ElementTree(top).write(sys.stdout, method=method)
    print '\n'
```

Three methods are supported:

`xml` The default method, produces `<empty_child />`.

`html` Produce the tag pair, as is required in HTML documents (`<empty_child></empty_child>`).

`text` Prints only the text of nodes, and skips empty tags entirely.

```
$ python ElementTree_write_method.py

xml
<top><child>This child contains text.</child><empty_child /></top>

html
<top><child>This child contains text.</child><empty_child></empty_child></top>

text
This child contains text.
```

See also:

Outline Processor Markup Language, OPML (http://www.opml.org/) Dave Winer's OPML specification and documentation.

See also:

xml.etree.ElementTree (http://docs.python.org/library/xml.etree.elementtree.html) The standard library documentation for this module.

ElementTree Overview (http://effbot.org/zone/element-index.htm) Fredrick Lundh's original documentation and links to the development versions of the ElementTree library.

Process XML in Python with ElementTree (http://www.ibm.com/developerworks/library/x-matters28/) IBM DeveloperWorks article by David Mertz.

lxml.etree (http://codespeak.net/lxml/) A separate implementation of the ElementTree API based on libxml2 with more complete XPath support.

CHAPTER

TWENTYONE

INTERNATIONALIZATION

21.1 gettext – Message Catalogs

Purpose Message catalog API for internationalization.

Available In 2.1.3 and later

The `gettext` module provides a pure-Python implementation compatible with the GNU gettext (http://www.gnu.org/software/gettext/) library for message translation and catalog management. The tools available with the Python source distribution enable you to extract messages from your source, build a message catalog containing translations, and use that message catalog to print an appropriate message for the user at runtime.

Message catalogs can be used to provide internationalized interfaces for your program, showing messages in a language appropriate to the user. They can also be used for other message customizations, including "skinning" an interface for different wrappers or partners.

Note: Although the standard library documentation says everything you need is included with Python, I found that `pygettext.py` refused to extract messages wrapped in the `ungettext` call, even when I used what seemed to be the appropriate command line options. I ended up installing the GNU gettext (http://www.gnu.org/software/gettext/) tools from source and using `xgettext` instead.

21.1.1 Translation Workflow Overview

The process for setting up and using translations includes five steps:

1. Mark up literal strings in your code that contain messages to translate.

   Start by identifying the messages within your program source that need to be translated, and marking the literal strings so the extraction program can find them.

2. Extract the messages.

   After you have identified the translatable strings in your program source, use `xgettext` to pull the strings out and create a `.pot` file, or translation template. The template is a text file with copies of all of the strings you identified and placeholders for their translations.

3. Translate the messages.

   Give a copy of the `.pot` file to the translator, changing the extension to `.po`. The `.po` file is an editable source file used as input for the compilation step. The translator should update the header text in the file and provide translations for all of the strings.

4. "Compile" the message catalog from the translation.

When the translator gives you back the completed `.po` file, compile the text file to the binary catalog format using `msgfmt`. The binary format is used by the runtime catalog lookup code.

5. Load and activate the appropriate message catalog at runtime.

   The final step is to add a few lines to your application to configure and load the message catalog and install the translation function. There are a couple of ways to do that, with associated trade-offs, and each is covered below.

Let's go through those steps in a little more detail, starting with the modifications you need to make to your code.

21.1.2 Creating Message Catalogs from Source Code

`gettext` works by finding literal strings embedded in your program in a database of translations, and pulling out the appropriate translated string. There are several variations of the functions for accessing the catalog, depending on whether you are working with Unicode strings or not. The usual pattern is to bind the lookup function you want to use to the name _ so that your code is not cluttered with lots of calls to functions with longer names.

The message extraction program, `xgettext`, looks for messages embedded in calls to the catalog lookup functions. It understands different source languages, and uses an appropriate parser for each. If you use aliases for the lookup functions or need to add extra functions, you can give `xgettext` the names of additional symbols to consider when extracting messages.

Here's a simple script with a single message ready to be translated:

```
import gettext

# Set up message catalog access
t = gettext.translation('gettext_example', 'locale', fallback=True)
_ = t.ugettext

print _('This message is in the script.')
```

In this case I am using the Unicode version of the lookup function, `ugettext()`. The text `"This message is in the script."` is the message to be substituted from the catalog. I've enabled fallback mode, so if we run the script without a message catalog, the in-lined message is printed:

```
$ python gettext_example.py

This message is in the script.
```

The next step is to extract the message(s) and create the `.pot` file, using `pygettext.py`.

```
$ xgettext -d gettext_example -o gettext_example.pot gettext_example.py
```

The output file produced looks like:

```
# SOME DESCRIPTIVE TITLE.
# Copyright (C) YEAR THE PACKAGE'S COPYRIGHT HOLDER
# This file is distributed under the same license as the PACKAGE package.
# FIRST AUTHOR <EMAIL@ADDRESS>, YEAR.
#
#, fuzzy
msgid ""
msgstr ""
"Project-Id-Version: PACKAGE VERSION\n"
"Report-Msgid-Bugs-To: \n"
"POT-Creation-Date: 2014-08-23 17:12-0400\n"
"PO-Revision-Date: YEAR-MO-DA HO:MI+ZONE\n"
```

```
"Last-Translator: FULL NAME <EMAIL@ADDRESS>\n"
"Language-Team: LANGUAGE <LL@li.org>\n"
"Language: \n"
"MIME-Version: 1.0\n"
"Content-Type: text/plain; charset=CHARSET\n"
"Content-Transfer-Encoding: 8bit\n"

#: gettext_example.py:16
msgid "This message is in the script."
msgstr ""
```

Message catalogs are installed into directories organized by *domain* and *language*. The domain is usually a unique value like your application name. In this case, I used `gettext_example`. The language value is provided by the user's environment at runtime, through one of the environment variables `LANGUAGE`, `LC_ALL`, `LC_MESSAGES`, or `LANG`, depending on their configuration and platform. My language is set to `en_US` so that's what I'll be using in all of the examples below.

Now that we have the template, the next step is to create the required directory structure and copy the template in to the right spot. I'm going to use the `locale` directory inside the PyMOTW source tree as the root of my message catalog directory, but you would typically want to use a directory accessible system-wide. The full path to the catalog input source is `$localedir/$language/LC_MESSAGES/$domain.po`, and the actual catalog has the filename extension `.mo`.

For my configuration, I need to copy `gettext_example.pot` to `locale/en_US/LC_MESSAGES/gettext_example.po` and edit it to change the values in the header and add my alternate messages. The result looks like:

```
# Messages from gettext_example.py.
# Copyright (C) 2009 Doug Hellmann
# Doug Hellmann <doug.hellmann@gmail.com>, 2009.
#
msgid ""
msgstr ""
"Project-Id-Version: PyMOTW 1.92\n"
"Report-Msgid-Bugs-To: Doug Hellmann <doug.hellmann@gmail.com>\n"
"POT-Creation-Date: 2009-06-07 10:31+EDT\n"
"PO-Revision-Date: 2009-06-07 10:31+EDT\n"
"Last-Translator: Doug Hellmann <doug.hellmann@gmail.com>\n"
"Language-Team: US English <doug.hellmann@gmail.com>\n"
"MIME-Version: 1.0\n"
"Content-Type: text/plain; charset=UTF-8\n"
"Content-Transfer-Encoding: 8bit\n"


#: gettext_example.py:16
msgid "This message is in the script."
msgstr "This message is in the en_US catalog."
```

The catalog is built from the `.po` file using `msgformat`:

```
$ cd locale/en_US/LC_MESSAGES/; msgfmt -o gettext_example.mo gettext_exa\
mple.po
```

And now when we run the script, the message from the catalog is printed instead of the in-line string:

```
$ python gettext_example.py

This message is in the en_US catalog.
```

21.1.3 Finding Message Catalogs at Runtime

As described above, the *locale directory* containing the message catalogs is organized based on the language with catalogs named for the *domain* of the program. Different operating systems define their own default value, but `gettext` does not know all of these defaults. Iut uses a default locale directory of `sys.prefix + '/share/locale'`, but most of the time it is safer for you to always explicitly give a `localedir` value than to depend on this default being valid.

The language portion of the path is taken from one of several environment variables that can be used to configure localization features (`LANGUAGE`, `LC_ALL`, `LC_MESSAGES`, and `LANG`). The first variable found to be set is used. Multiple languages can be selected by separating the values with a colon (`:`). We can illustrate how that works by creating a second message catalog and running a few experiments.

```
$ cd locale/en_CA/LC_MESSAGES/; msgfmt -o gettext_example.mo gettext_exa\
mple.po
$ python gettext_find.py

Catalogs: ['locale/en_US/LC_MESSAGES/gettext_example.mo']
$ LANGUAGE=en_CA python gettext_find.py

Catalogs: ['locale/en_CA/LC_MESSAGES/gettext_example.mo']
$ LANGUAGE=en_CA:en_US python gettext_find.py

Catalogs: ['locale/en_CA/LC_MESSAGES/gettext_example.mo', 'locale/en_US/LC_MESSAGES/gettext_example.m
$ LANGUAGE=en_US:en_CA python gettext_find.py

Catalogs: ['locale/en_US/LC_MESSAGES/gettext_example.mo', 'locale/en_CA/LC_MESSAGES/gettext_example.m
```

Although `find()` shows the complete list of catalogs, only the first one in the sequence is actually loaded for message lookups.

```
$ python gettext_example.py

This message is in the en_US catalog.
$ LANGUAGE=en_CA python gettext_example.py

This message is in the en_CA catalog.
$ LANGUAGE=en_CA:en_US python gettext_example.py

This message is in the en_CA catalog.
$ LANGUAGE=en_US:en_CA python gettext_example.py

This message is in the en_US catalog.
```

21.1.4 Plural Values

While simple message substitution will handle most of your translation needs, `gettext` treats pluralization as a special case. Depending on the language, the difference between the singular and plural forms of a message may vary only by the ending of a single word, or the entire sentence structure may be different. There may also be different forms depending on the level of plurality (http://www.gnu.org/software/gettext/manual/gettext.html#Plural-forms). To make managing plurals easier (and possible), there is a separate set of functions for asking for the plural form of a message.

```
from gettext import translation
import sys

t = translation('gettext_plural', 'locale', fallback=True)
```

```
num = int(sys.argv[1])
msg = t.ungettext('%(num)d means singular.', '%(num)d means plural.', num)

# Still need to add the values to the message ourself.
print msg % {'num':num}
```

```
$ xgettext -L Python -d gettext_plural -o gettext_plural.pot gettext_plu\
ral.py
```

Since there are alternate forms to be translated, the replacements are listed in an array. Using an array allows translations for languages with multiple plural forms (Polish, for example (http://www.gnu.org/software/gettext/manual/gettext.html#Plural-forms), has different forms indicating the relative quantity).

```
# SOME DESCRIPTIVE TITLE.
# Copyright (C) YEAR THE PACKAGE'S COPYRIGHT HOLDER
# This file is distributed under the same license as the PACKAGE package.
# FIRST AUTHOR <EMAIL@ADDRESS>, YEAR.
#
#, fuzzy
msgid ""
msgstr ""
"Project-Id-Version: PACKAGE VERSION\n"
"Report-Msgid-Bugs-To: \n"
"POT-Creation-Date: 2014-08-23 17:12-0400\n"
"PO-Revision-Date: YEAR-MO-DA HO:MI+ZONE\n"
"Last-Translator: FULL NAME <EMAIL@ADDRESS>\n"
"Language-Team: LANGUAGE <LL@li.org>\n"
"Language: \n"
"MIME-Version: 1.0\n"
"Content-Type: text/plain; charset=CHARSET\n"
"Content-Transfer-Encoding: 8bit\n"
"Plural-Forms: nplurals=INTEGER; plural=EXPRESSION;\n"

#: gettext_plural.py:15
#, python-format
msgid "%(num)d means singular."
msgid_plural "%(num)d means plural."
msgstr[0] ""
msgstr[1] ""
```

In addition to filling in the translation strings, you will also need to describe the way plurals are formed so the library knows how to index into the array for any given count value. The line `"Plural-Forms: nplurals=INTEGER; plural=EXPRESSION;\n"` includes two values to replace manually. `nplurals` is an integer indicating the size of the array (the number of translations used) and `plural` is a C language expression for converting the incoming quantity to an index in the array when looking up the translation. The literal string `n` is replaced with the quantity passed to `ungettext()`.

For example, English includes two plural forms. A quantity of `0` is treated as plural ("0 bananas"). The Plural-Forms entry should look like:

```
Plural-Forms: nplurals=2; plural=n != 1;
```

The singular translation would then go in position 0, and the plural translation in position 1.

```
# Messages from gettext_plural.py
# Copyright (C) 2009 Doug Hellmann
# This file is distributed under the same license as the PyMOTW package.
# Doug Hellmann <doug.hellmann@gmail.com>, 2009.
```

```
#
#, fuzzy
msgid ""
msgstr ""
"Project-Id-Version: PyMOTW 1.92\n"
"Report-Msgid-Bugs-To: Doug Hellmann <doug.hellmann@gmail.com>\n"
"POT-Creation-Date: 2009-06-14 09:29-0400\n"
"PO-Revision-Date: 2009-06-14 09:29-0400\n"
"Last-Translator: Doug Hellmann <doug.hellmann@gmail.com>\n"
"Language-Team: en_US <doug.hellmann@gmail.com>\n"
"MIME-Version: 1.0\n"
"Content-Type: text/plain; charset=UTF-8\n"
"Content-Transfer-Encoding: 8bit\n"
"Plural-Forms: nplurals=2; plural=n != 1;"

#: gettext_plural.py:15
#, python-format
msgid "%(num)d means singular."
msgid_plural "%(num)d means plural."
msgstr[0] "In en_US, %(num)d is singular."
msgstr[1] "In en_US, %(num)d is plural."
```

If we run the test script a few times after the catalog is compiled, you can see how different values of N are converted to indexes for the translation strings.

```
$ cd locale/en_US/LC_MESSAGES/; msgfmt -o gettext_plural.mo gettext_plur\
al.po
$ python gettext_plural.py 0

In en_US, 0 is plural.
$ python gettext_plural.py 1

In en_US, 1 is singular.
$ python gettext_plural.py 2

In en_US, 2 is plural.
```

21.1.5 Application vs. Module Localization

The scope of your translation effort defines how you install and use the `gettext` functions in your code.

Application Localization

For application-wide translations, it would be acceptable to install a function like `ungettext()` globally using the `__builtins__` namespace because you have control over the top-level of the application's code.

```
import gettext
gettext.install('gettext_example', 'locale', unicode=True, names=['ngettext'])

print _('This message is in the script.')
```

The `install()` function binds `gettext()` to the name `_()` in the `__builtins__` namespace. It also adds `ngettext()` and other functions listed in *names*. If *unicode* is true, the Unicode versions of the functions are used instead of the default ASCII versions.

Module Localization

For a library, or individual module, modifying `__builtins__` is not a good idea because you don't know what conflicts you might introduce with an application global value. You can import or re-bind the names of translation functions by hand at the top of your module.

```
import gettext
t = gettext.translation('gettext_example', 'locale', fallback=True)
_ = t.ugettext
ngettext = t.ungettext

print _('This message is in the script.')
```

See also:

gettext (http://docs.python.org/library/gettext.html) The standard library documentation for this module.

`locale` Other localization tools.

GNU gettext (http://www.gnu.org/software/gettext/) The message catalog formats, API, etc. for this module are all based on the original gettext package from GNU. The catalog file formats are compatible, and the command line scripts have similar options (if not identical). The GNU gettext manual (http://www.gnu.org/software/gettext/manual/gettext.html) has a detailed description of the file formats and describes GNU versions of the tools for working with them.

Internationalizing Python (http://www.python.org/workshops/1997-10/proceedings/loewis.html) A paper by Martin von Löwis about techniques for internationalization of Python applications.

Django Internationalization (http://docs.djangoproject.com/en/dev/topics/i18n/) Another good source of information on using gettext, including real-life examples.

21.2 locale – POSIX cultural localization API

Purpose Format and parse values that depend on location or language.

Available In 1.5 and later

The `locale` module is part of Python's internationalization and localization support library. It provides a standard way to handle operations that may depend on the language or location of a user. For example, it handles formatting numbers as currency, comparing strings for sorting, and working with dates. It does not cover translation (see the `gettext` module) or Unicode encoding.

Note: Changing the locale can have application-wide ramifications, so the recommended practice is to avoid changing the value in a library and to let the application set it one time. In the examples below, the locale is changed several times within a short program to highlight the differences in the settings of various locales. It is far more likely that your application will set the locale once at startup and not change it.

21.2.1 Probing the Current Locale

The most common way to let the user change the locale settings for an application is through an environment variable (`LC_ALL`, `LC_CTYPE`, `LANG`, or `LANGUAGE`, depending on the platform). The application then calls `setlocale()` without a hard-coded value, and the environment value is used.

```
import locale
import os
import pprint
import codecs
import sys

sys.stdout = codecs.getwriter('UTF-8')(sys.stdout)

# Default settings based on the user's environment.
locale.setlocale(locale.LC_ALL, '')

print 'Environment settings:'
for env_name in [ 'LC_ALL', 'LC_CTYPE', 'LANG', 'LANGUAGE' ]:
    print '\t%s = %s' % (env_name, os.environ.get(env_name, ''))

# What is the locale?
print
print 'Locale from environment:', locale.getlocale()

template = """
Numeric formatting:

  Decimal point      : "%(decimal_point)s"
  Grouping positions : %(grouping)s
  Thousands separator: "%(thousands_sep)s"

Monetary formatting:

  International currency symbol             : "%(int_curr_symbol)r"
  Local currency symbol                     : %(currency_symbol)r (%(currency_symbol_u)s)
  Symbol precedes positive value            : %(p_cs_precedes)s
  Symbol precedes negative value            : %(n_cs_precedes)s
  Decimal point                             : "%(mon_decimal_point)s"
  Digits in fractional values               : %(frac_digits)s
  Digits in fractional values, international: %(int_frac_digits)s
  Grouping positions                        : %(mon_grouping)s
  Thousands separator                       : "%(mon_thousands_sep)s"
  Positive sign                             : "%(positive_sign)s"
  Positive sign position                    : %(p_sign_posn)s
  Negative sign                             : "%(negative_sign)s"
  Negative sign position                    : %(n_sign_posn)s

"""

sign_positions = {
    0 : 'Surrounded by parentheses',
    1 : 'Before value and symbol',
    2 : 'After value and symbol',
    3 : 'Before value',
    4 : 'After value',
    locale.CHAR_MAX : 'Unspecified',
    }

info = {}
info.update(locale.localeconv())
info['p_sign_posn'] = sign_positions[info['p_sign_posn']]
info['n_sign_posn'] = sign_positions[info['n_sign_posn']]
# convert the currency symbol to unicode
info['currency_symbol_u'] = info['currency_symbol'].decode('utf-8')

print (template % info)
```

The `localeconv()` method returns a dictionary containing the locale's conventions. The full list of value names and definitions is covered in the standard library documentation.

A Mac running OS X 10.6 with all of the variables unset produces this output:

```
$ export LANG=; export LC_CTYPE=; python locale_env_example.py

Environment settings:
        LC_ALL =
        LC_CTYPE =
        LANG =
        LANGUAGE =

Locale from environment: (None, None)

Numeric formatting:

  Decimal point      : "."
  Grouping positions : []
  Thousands separator: ""

Monetary formatting:

  International currency symbol             : "''"
  Local currency symbol                     : '' ()
  Symbol precedes positive value            : 127
  Symbol precedes negative value            : 127
  Decimal point                             : ""
  Digits in fractional values               : 127
  Digits in fractional values, international: 127
  Grouping positions                        : []
  Thousands separator                       : ""
  Positive sign                             : ""
  Positive sign position                    : Unspecified
  Negative sign                             : ""
  Negative sign position                    : Unspecified
```

Running the same script with the `LANG` variable set shows how the locale and default encoding change:

France (`fr_FR`):

```
$ LANG=fr_FR LC_CTYPE=fr_FR LC_ALL=fr_FR python locale_env_example.py

Environment settings:
        LC_ALL = fr_FR
        LC_CTYPE = fr_FR
        LANG = fr_FR
        LANGUAGE =

Locale from environment: ('fr_FR', 'ISO8859-1')

Numeric formatting:

  Decimal point      : ","
  Grouping positions : [127]
  Thousands separator: ""

Monetary formatting:

  International currency symbol             : "'EUR '"
  Local currency symbol                      : 'Eu' (Eu)
  Symbol precedes positive value             : 0
  Symbol precedes negative value             : 0
  Decimal point                              : ","
  Digits in fractional values                : 2
  Digits in fractional values, international: 2
  Grouping positions                         : [3, 3, 0]
  Thousands separator                        : " "
  Positive sign                              : ""
  Positive sign position                     : Before value and symbol
  Negative sign                              : "-"
  Negative sign position                     : After value and symbol
```

Spain (`es_ES`):

```
$ LANG=es_ES LC_CTYPE=es_ES LC_ALL=es_ES python locale_env_example.py

Environment settings:
        LC_ALL = es_ES
        LC_CTYPE = es_ES
        LANG = es_ES
        LANGUAGE =

Locale from environment: ('es_ES', 'ISO8859-1')

Numeric formatting:

  Decimal point      : ","
  Grouping positions : [127]
  Thousands separator: ""

Monetary formatting:

  International currency symbol              : "'EUR '"
  Local currency symbol                      : 'Eu' (Eu)
  Symbol precedes positive value             : 1
  Symbol precedes negative value             : 1
  Decimal point                              : ","
  Digits in fractional values                : 2
  Digits in fractional values, international: 2
  Grouping positions                         : [3, 3, 0]
  Thousands separator                        : "."
  Positive sign                              : ""
  Positive sign position                     : Before value and symbol
  Negative sign                              : "-"
  Negative sign position                     : Before value and symbol
```

Portgual (`pt_PT`):

```
$ LANG=pt_PT LC_CTYPE=pt_PT LC_ALL=pt_PT python locale_env_example.py

Environment settings:
        LC_ALL = pt_PT
        LC_CTYPE = pt_PT
        LANG = pt_PT
        LANGUAGE =

Locale from environment: ('pt_PT', 'ISO8859-1')
```

```
Numeric formatting:

  Decimal point      : ","
  Grouping positions : []
  Thousands separator: " "

Monetary formatting:

  International currency symbol             : "'EUR '"
  Local currency symbol                     : 'Eu' (Eu)
  Symbol precedes positive value            : 0
  Symbol precedes negative value            : 0
  Decimal point                             : "."
  Digits in fractional values               : 2
  Digits in fractional values, international: 2
  Grouping positions                        : [3, 3, 0]
  Thousands separator                       : "."
  Positive sign                             : ""
  Positive sign position                    : Before value and symbol
  Negative sign                             : "-"
  Negative sign position                    : Before value and symbol
```

Poland (`pl_PL`):

```
$ LANG=pl_PL LC_CTYPE=pl_PL LC_ALL=pl_PL python locale_env_example.py

Environment settings:
        LC_ALL = pl_PL
        LC_CTYPE = pl_PL
        LANG = pl_PL
        LANGUAGE =

Locale from environment: ('pl_PL', 'ISO8859-2')

Numeric formatting:

  Decimal point      : ","
  Grouping positions : [3, 3, 0]
  Thousands separator: " "

Monetary formatting:

  International currency symbol             : "'PLN '"
  Local currency symbol                     : 'z\xc5\x82' (zł)
  Symbol precedes positive value            : 1
  Symbol precedes negative value            : 1
  Decimal point                             : ","
  Digits in fractional values               : 2
  Digits in fractional values, international: 2
  Grouping positions                        : [3, 3, 0]
  Thousands separator                       : " "
  Positive sign                             : ""
  Positive sign position                    : After value
  Negative sign                             : "-"
  Negative sign position                    : After value
```

21.2.2 Currency

The example output above shows that changing the locale updates the currency symbol setting and the character to separate whole numbers from decimal fractions. This example loops through several different locales to print a positive and negative currency value formatted for each locale:

```
import locale

sample_locales = [ ('USA',      'en_US'),
                   ('France',   'fr_FR'),
                   ('Spain',    'es_ES'),
                   ('Portugal', 'pt_PT'),
                   ('Poland',   'pl_PL'),
                   ]

for name, loc in sample_locales:
    locale.setlocale(locale.LC_ALL, loc)
    print '%20s: %10s  %10s' % (name, locale.currency(1234.56), locale.currency(-1234.56))
```

The output is this small table:

```
$ python locale_currency_example.py

                 USA:   $1234.56   -$1234.56
              France: 1234,56 Eu  1234,56 Eu-
               Spain: Eu 1234,56  -Eu 1234,56
            Portugal: 1234.56 Eu  -1234.56 Eu
              Poland: zł 1234,56  zł 1234,56-
```

21.2.3 Formatting Numbers

Numbers not related to currency are also formatted differently depending on the locale. In particular, the *grouping* character used to separate large numbers into readable chunks is changed:

```
import locale

sample_locales = [ ('USA',      'en_US'),
                   ('France',   'fr_FR'),
                   ('Spain',    'es_ES'),
                   ('Portugal', 'pt_PT'),
                   ('Poland',   'pl_PL'),
                   ]

print '%20s %15s %20s' % ('Locale', 'Integer', 'Float')
for name, loc in sample_locales:
    locale.setlocale(locale.LC_ALL, loc)

    print '%20s' % name,
    print locale.format('%15d', 123456, grouping=True),
    print locale.format('%20.2f', 123456.78, grouping=True)
```

To format numbers without the currency symbol, use `format()` instead of `currency()`.

```
$ python locale_grouping.py

              Locale         Integer                Float
                 USA         123,456           123,456.78
              France          123456            123456,78
```

```
       Spain          123456            123456,78
    Portugal          123456            123456,78
      Poland         123 456           123 456,78
```

21.2.4 Parsing Numbers

Besides generating output in different formats, the `locale` module helps with parsing input. It includes `atoi()` and `atof()` functions for converting the strings to integer and floating point values based on the locale's numerical formatting conventions.

```
import locale

sample_data = [ ('USA',      'en_US', '1,234.56'),
                ('France',   'fr_FR', '1234,56'),
                ('Spain',    'es_ES', '1234,56'),
                ('Portugal', 'pt_PT', '1234.56'),
                ('Poland',   'pl_PL', '1 234,56'),
                ]

for name, loc, a in sample_data:
    locale.setlocale(locale.LC_ALL, loc)
    f = locale.atof(a)
    print '%20s: %9s => %f' % (name, a, f)
```

The grouping and decimal separator values

```
$ python locale_atof_example.py

                 USA:  1,234.56 => 1234.560000
              France:   1234,56 => 1234.560000
               Spain:   1234,56 => 1234.560000
            Portugal:   1234.56 => 1234.560000
              Poland:  1 234,56 => 1234.560000
```

21.2.5 Dates and Times

Another important aspect of localization is date and time formatting:

```
import locale
import time

sample_locales = [ ('USA',      'en_US'),
                   ('France',   'fr_FR'),
                   ('Spain',    'es_ES'),
                   ('Portugal', 'pt_PT'),
                   ('Poland',   'pl_PL'),
                   ]

for name, loc in sample_locales:
    locale.setlocale(locale.LC_ALL, loc)
    print '%20s: %s' % (name, time.strftime(locale.nl_langinfo(locale.D_T_FMT)))
```

```
$ python locale_date_example.py

                 USA: Thu Feb 21 06:35:54 2013
```

```
   France: Jeu 21 fév 06:35:54 2013
    Spain: jue 21 feb 06:35:54 2013
 Portugal: Qui 21 Fev 06:35:54 2013
   Poland: czw 21 lut 06:35:54 2013
```

This discussion only covers some of the high-level functions in the `locale` module. There are others which are lower level (`format_string()`) or which relate to managing the locale for your application (`resetlocale()`).

See also:

locale (http://docs.python.org/library/locale.html) The standard library documentation for this module.

`gettext` Message catalogs for translations.

CHAPTER

TWENTYTWO

PROGRAM FRAMEWORKS

22.1 cmd – Create line-oriented command processors

Purpose Create line-oriented command processors.

Available In 1.4 and later, with some additions in 2.3

The cmd module contains one public class, Cmd, designed to be used as a base class for command processors such as interactive shells and other command interpreters. By default it uses readline for interactive prompt handling, command line editing, and command completion.

22.1.1 Processing Commands

The interpreter uses a loop to read all lines from its input, parse them, and then dispatch the command to an appropriate command handler. Input lines are parsed into two parts. The command, and any other text on the line. If the user enters a command foo bar, and your class includes a method named do_foo(), it is called with "bar" as the only argument.

The end-of-file marker is dispatched to do_EOF(). If a command handler returns a true value, the program will exit cleanly. So to give a clean way to exit your interpreter, make sure to implement do_EOF() and have it return True.

This simple example program supports the "greet" command:

```
import cmd

class HelloWorld(cmd.Cmd):
    """Simple command processor example."""

    def do_greet(self, line):
        print "hello"

    def do_EOF(self, line):
        return True

if __name__ == '__main__':
    HelloWorld().cmdloop()
```

By running it interactively, we can demonstrate how commands are dispatched as well as show of some of the features included in Cmd for free.

```
$ python cmd_simple.py
(Cmd)
```

The first thing to notice is the command prompt, (Cmd). The prompt can be configured through the attribute prompt. If the prompt changes as the result of a command processor, the new value is used to query for the next command.

```
(Cmd) help

Undocumented commands:
======================
EOF  greet  help
```

The help command is built into Cmd. With no arguments, it shows the list of commands available. If you include a command you want help on, the output is more verbose and restricted to details of that command, when available.

If we use the greet command, do_greet() is invoked to handle it:

```
(Cmd) greet
hello
```

If your class does not include a specific command processor for a command, the method default() is called with the entire input line as an argument. The built-in implementation of default() reports an error.

```
(Cmd) foo *** Unknown syntax: foo
```

Since do_EOF() returns True, typing Ctrl-D will drop us out of the interpreter.

```
(Cmd) ^D$
```

Notice that no newline is printed, so the results are a little messy.

22.1.2 Command Arguments

This version of the example includes a few enhancements to eliminate some of the annoyances and add help for the greet command.

```
import cmd

class HelloWorld(cmd.Cmd):
    """Simple command processor example."""

    def do_greet(self, person):
        """greet [person]
        Greet the named person"""
        if person:
            print "hi,", person
        else:
            print 'hi'

    def do_EOF(self, line):
        return True

    def postloop(self):
        print

if __name__ == '__main__':
    HelloWorld().cmdloop()
```

First, let's look at the help. The docstring added to do_greet() becomes the help text for the command:

```
$ python cmd_arguments.py
(Cmd) help

Documented commands (type help ):
```

```
========================================
greet

Undocumented commands:
======================
EOF  help

(Cmd) help greet
greet [person]
        Greet the named person
```

The output shows one optional argument to the greet command, *person*. Although the argument is optional to the command, there is a distinction between the command and the callback method. The method always takes the argument, but sometimes the value is an empty string. It is left up to the command processor to determine if an empty argument is valid, or do any further parsing and processing of the command. In this example, if a person's name is provided then the greeting is personalized.

```
(Cmd) greet Alice
hi, Alice
(Cmd) greet
hi
```

Whether an argument is given by the user or not, the value passed to the command processor does not include the command itself. That simplifies parsing in the command processor, if multiple arguments are needed.

22.1.3 Live Help

In the previous example, the formatting of the help text leaves something to be desired. Since it comes from the docstring, it retains the indentation from our source. We could edit the source to remove the extra white-space, but that would leave our application looking poorly formatted. An alternative solution is to implement a help handler for the greet command, named `help_greet()`. When present, the help handler is called on to produce help text for the named command.

```python
import cmd

class HelloWorld(cmd.Cmd):
    """Simple command processor example."""

    def do_greet(self, person):
        if person:
            print "hi,", person
        else:
            print 'hi'

    def help_greet(self):
        print '\n'.join([ 'greet [person]',
                          'Greet the named person',
                          ])

    def do_EOF(self, line):
        return True

if __name__ == '__main__':
    HelloWorld().cmdloop()
```

In this simple example, the text is static but formatted more nicely. It would also be possible to use previous command state to tailor the contents of the help text to the current context.

```
$ python cmd_do_help.py
(Cmd) help greet
greet [person]
Greet the named person
```

It is up to the help handler to actually output the help message, and not simply return the help text for handling elsewhere.

22.1.4 Auto-Completion

`Cmd` includes support for command completion based on the names of the commands with processor methods. The user triggers completion by hitting the tab key at an input prompt. When multiple completions are possible, pressing tab twice prints a list of the options.

```
$ python cmd_do_help.py
(Cmd) <tab><tab>
EOF    greet  help
(Cmd) h<tab>
(Cmd) help
```

Once the command is known, argument completion is handled by methods with the prefix `complete_`. This allows you to assemble a list of possible completions using your own criteria (query a database, look at at a file or directory on the filesystem, etc.). In this case, the program has a hard-coded set of "friends" who receive a less formal greeting than named or anonymous strangers. A real program would probably save the list somewhere, and either read it once and cache the contents to be scanned as needed.

```
import cmd

class HelloWorld(cmd.Cmd):
    """Simple command processor example."""

    FRIENDS = [ 'Alice', 'Adam', 'Barbara', 'Bob' ]

    def do_greet(self, person):
        "Greet the person"
        if person and person in self.FRIENDS:
            greeting = 'hi, %s!' % person
        elif person:
            greeting = "hello, " + person
        else:
            greeting = 'hello'
        print greeting

    def complete_greet(self, text, line, begidx, endidx):
        if not text:
            completions = self.FRIENDS[:]
        else:
            completions = [ f
                            for f in self.FRIENDS
                            if f.startswith(text)
                            ]
        return completions

    def do_EOF(self, line):
        return True
```

```
if __name__ == '__main__':
    HelloWorld().cmdloop()
```

When there is input text, `complete_greet()` returns a list of friends that match. Otherwise, the full list of friends is returned.

```
$ python cmd_arg_completion.py
(Cmd) greet <tab><tab>
Adam      Alice     Barbara   Bob
(Cmd) greet A<tab><tab>
Adam    Alice
(Cmd) greet Ad<tab>
(Cmd) greet Adam
hi, Adam!
```

If the name given is not in the list of friends, the formal greeting is given.

```
(Cmd) greet Joe
hello, Joe
```

22.1.5 Overriding Base Class Methods

Cmd includes several methods that can be overridden as hooks for taking actions or altering the base class behavior. This example is not exhaustive, but contains many of the methods commonly useful.

```
import cmd

class Illustrate(cmd.Cmd):
    "Illustrate the base class method use."

    def cmdloop(self, intro=None):
        print 'cmdloop(%s)' % intro
        return cmd.Cmd.cmdloop(self, intro)

    def preloop(self):
        print 'preloop()'

    def postloop(self):
        print 'postloop()'

    def parseline(self, line):
        print 'parseline(%s) =>' % line,
        ret = cmd.Cmd.parseline(self, line)
        print ret
        return ret

    def onecmd(self, s):
        print 'onecmd(%s)' % s
        return cmd.Cmd.onecmd(self, s)

    def emptyline(self):
        print 'emptyline()'
        return cmd.Cmd.emptyline(self)

    def default(self, line):
        print 'default(%s)' % line
        return cmd.Cmd.default(self, line)
    def precmd(self, line):
        print 'precmd(%s)' % line
        return cmd.Cmd.precmd(self, line)

    def postcmd(self, stop, line):
        print 'postcmd(%s, %s)' % (stop, line)
        return cmd.Cmd.postcmd(self, stop, line)

    def do_greet(self, line):
        print 'hello,', line

    def do_EOF(self, line):
        "Exit"
        return True

if __name__ == '__main__':
    Illustrate().cmdloop('Illustrating the methods of cmd.Cmd')
```

`cmdloop()` is the main processing loop of the interpreter. You can override it, but it is usually not necessary, since the `preloop()` and `postloop()` hooks are available.

Each iteration through `cmdloop()` calls `onecmd()` to dispatch the command to its processor. The actual input line is parsed with `parseline()` to create a tuple containing the command, and the remaining portion of the line.

If the line is empty, `emptyline()` is called. The default implementation runs the previous command again. If the line contains a command, first `precmd()` is called then the processor is looked up and invoked. If none is found, `default()` is called instead. Finally postcmd() is called.

Here's an example session with `print` statements added:

```
$ python cmd_illustrate_methods.py
cmdloop(Illustrating the methods of cmd.Cmd)
preloop()
Illustrating the methods of cmd.Cmd
(Cmd) greet Bob
precmd(greet Bob)
onecmd(greet Bob)
parseline(greet Bob) => ('greet', 'Bob', 'greet Bob')
hello, Bob
postcmd(None, greet Bob)
(Cmd) ^Dprecmd(EOF)
onecmd(EOF)
parseline(EOF) => ('EOF', '', 'EOF')
postcmd(True, EOF)
postloop()
```

22.1.6 Configuring Cmd Through Attributes

In addition to the methods described above, there are several attributes for controlling command interpreters.

`prompt` can be set to a string to be printed each time the user is asked for a new command.

`intro` is the "welcome" message printed at the start of the program. cmdloop() takes an argument for this value, or you can set it on the class directly.

When printing help, the `doc_header`, `misc_header`, `undoc_header`, and `ruler` attributes are used to format the output.

This example class shows a command processor to let the user control the prompt for the interactive session.

```
import cmd

class HelloWorld(cmd.Cmd):
    """Simple command processor example."""

    prompt = 'prompt: '
    intro = "Simple command processor example."

    doc_header = 'doc_header'
    misc_header = 'misc_header'
    undoc_header = 'undoc_header'

    ruler = '-'

    def do_prompt(self, line):
        "Change the interactive prompt"
        self.prompt = line + ': '

    def do_EOF(self, line):
        return True

if __name__ == '__main__':
    HelloWorld().cmdloop()
```

```
$ python cmd_attributes.py
Simple command processor example.
prompt: prompt hello
hello: help

doc_header
----------
prompt

undoc_header
------------
EOF  help

hello:
```

22.1.7 Shelling Out

To supplement the standard command processing, `Cmd` includes 2 special command prefixes. A question mark (`?`) is equivalent to the built-in help command, and can be used in the same way. An exclamation point (`!`) maps to `do_shell()`, and is intended for shelling out to run other commands, as in this example.

```
import cmd
import os

class ShellEnabled(cmd.Cmd):

    last_output = ''

    def do_shell(self, line):
        "Run a shell command"
        print "running shell command:", line
        output = os.popen(line).read()
        print output
        self.last_output = output

    def do_echo(self, line):
        "Print the input, replacing '$out' with the output of the last shell command"
        # Obviously not robust
        print line.replace('$out', self.last_output)

    def do_EOF(self, line):
        return True

if __name__ == '__main__':
    ShellEnabled().cmdloop()
```

```
$ python cmd_do_shell.py
(Cmd) ?

Documented commands (type help ):
========================================
echo  shell

Undocumented commands:
======================
EOF  help

(Cmd) ? shell
Run a shell command
(Cmd) ? echo
Print the input, replacing '$out' with the output of the last shell command
(Cmd) shell pwd
running shell command: pwd
/Users/dhellmann/Documents/PyMOTW/in_progress/cmd

(Cmd) ! pwd
running shell command: pwd
/Users/dhellmann/Documents/PyMOTW/in_progress/cmd

(Cmd) echo $out
/Users/dhellmann/Documents/PyMOTW/in_progress/cmd

(Cmd)
```

22.1.8 Alternative Inputs

While the default mode for `Cmd()` is to interact with the user through the `readline` library, it is also possible to pass a series of commands in to standard input using standard Unix shell redirection.

```
$ echo help | python cmd_do_help.py
(Cmd)
Documented commands (type help ):
========================================
greet

Undocumented commands:
======================
EOF  help

(Cmd)
```

If you would rather have your program read the script file directly, a few other changes may be needed. Since readline interacts with the terminal/tty device, rather than the standard input stream, you should disable it if you know your script is going to be reading from a file. Also, to avoid printing superfluous prompts, you can set the prompt to an empty string. This example shows how to open a file and pass it as input to a modified version of the HelloWorld example.

```
import cmd

class HelloWorld(cmd.Cmd):
    """Simple command processor example."""

    # Disable rawinput module use
    use_rawinput = False

    # Do not show a prompt after each command read
    prompt = ''

    def do_greet(self, line):
        print "hello,", line

    def do_EOF(self, line):
        return True

if __name__ == '__main__':
    import sys
    input = open(sys.argv[1], 'rt')
    try:
        HelloWorld(stdin=input).cmdloop()
    finally:
        input.close()
```

With *use_rawinput* set to False and *prompt* set to an empty string, we can call the script on this input file:

```
greet
greet Alice and Bob
```

to produce output like:

```
$ python cmd_file.py cmd_file.txt
hello,
hello, Alice and Bob
```

22.1.9 Commands from sys.argv

You can also process command line arguments to the program as a command for your interpreter class, instead of reading commands from stdin or a file. To use the command line arguments, you can call `onecmd()` directly, as in this example.

```
import cmd

class InteractiveOrCommandLine(cmd.Cmd):
    """Accepts commands via the normal interactive prompt or on the command line."""

    def do_greet(self, line):
        print 'hello,', line

    def do_EOF(self, line):
        return True
```

```
if __name__ == '__main__':
    import sys
    if len(sys.argv) > 1:
        InteractiveOrCommandLine().onecmd(' '.join(sys.argv[1:]))
    else:
        InteractiveOrCommandLine().cmdloop()
```

Since `onecmd()` takes a single string as input, the arguments to the program need to be joined together before being passed in.

```
$ python cmd_argv.py greet Command Line User
hello, Command Line User
$ python cmd_argv.py
(Cmd) greet Interactive User
hello, Interactive User
(Cmd)
```

See also:

cmd (http://docs.python.org/library/cmd.html) The standard library documentation for this module.

cmd2 (http://pypi.python.org/pypi/cmd2) Drop-in replacement for cmd with additional features.

GNU readline (http://tiswww.case.edu/php/chet/readline/rltop.html) The GNU Readline library provides functions that allow users to edit input lines as they are typed.

`readline` The Python standard library interface to readline.

22.2 shlex – Lexical analysis of shell-style syntaxes.

Purpose Lexical analysis of shell-style syntaxes.

Available In 1.5.2, with additions in later versions

The shlex module implements a class for parsing simple shell-like syntaxes. It can be used for writing your own domain specific language, or for parsing quoted strings (a task that is more complex than it seems, at first).

22.2.1 Quoted Strings

A common problem when working with input text is to identify a sequence of quoted words as a single entity. Splitting the text on quotes does not always work as expected, especially if there are nested levels of quotes. Take the following text:

```
This string has embedded "double quotes" and 'single quotes' in it,
and even "a 'nested example'".
```

A naive approach might attempt to construct a regular expression to find the parts of the text outside the quotes to separate them from the text inside the quotes, or vice versa. Such an approach would be unnecessarily complex and prone to errors resulting from edge cases like apostrophes or even typos. A better solution is to use a true parser, such as the one provided by the `shlex` module. Here is a simple example that prints the tokens identified in the input file:

```
import shlex
import sys

if len(sys.argv) != 2:
    print 'Please specify one filename on the command line.'
    sys.exit(1)
```

```
filename = sys.argv[1]
body = file(filename, 'rt').read()
print 'ORIGINAL:', repr(body)
print

print 'TOKENS:'
lexer = shlex.shlex(body)
for token in lexer:
    print repr(token)
```

When run on data with embedded quotes, the parser produces the list of tokens we expect:

```
$ python shlex_example.py quotes.txt

ORIGINAL: 'This string has embedded "double quotes" and \'single quotes\' in it,\nand even "a \'neste

TOKENS:
'This'
'string'
'has'
'embedded'
'"double quotes"'
'and'
"'single quotes'"
'in'
'it'
','
'and'
'even'
'"a \'nested example\'"'
'.'
```

Isolated quotes such as apostrophes are also handled. Given this input file:

```
This string has an embedded apostrophe, doesn't it?
```

The token with the embedded apostrophe is no problem:

```
$ python shlex_example.py apostrophe.txt

ORIGINAL: "This string has an embedded apostrophe, doesn't it?"

TOKENS:
'This'
'string'
'has'
'an'
'embedded'
'apostrophe'
','
"doesn't"
'it'
'?'
```

22.2.2 Embedded Comments

Since the parser is intended to be used with command languages, it needs to handle comments. By default, any text following a # is considered part of a comment, and ignored. Due to the nature of the parser, only single character comment prefixes are supported. The set of comment characters used can be configured through the commenters property.

```
$ python shlex_example.py comments.txt

ORIGINAL: 'This line is recognized.\n# But this line is ignored.\nAnd this line is processed.'

TOKENS:
'This'
'line'
'is'
'recognized'
'.'
'And'
'this'
'line'
'is'
'processed'
'.'
```

22.2.3 Split

If you just need to split an existing string into component tokens, the convenience function `split()` is a simple wrapper around the parser.

```
import shlex

text = """This text has "quoted parts" inside it."""
print 'ORIGINAL:', repr(text)
print

print 'TOKENS:'
print shlex.split(text)
```

The result is a list:

```
$ python shlex_split.py

ORIGINAL: 'This text has "quoted parts" inside it.'

TOKENS:
['This', 'text', 'has', 'quoted parts', 'inside', 'it.']
```

22.2.4 Including Other Sources of Tokens

The `shlex` class includes several configuration properties which allow us to control its behavior. The *source* property enables a feature for code (or configuration) re-use by allowing one token stream to include another. This is similar to the Bourne shell `source` operator, hence the name.

```
import shlex

text = """This text says to source quotes.txt before continuing."""
```

```
print 'ORIGINAL:', repr(text)
print

lexer = shlex.shlex(text)
lexer.wordchars += '.'
lexer.source = 'source'

print 'TOKENS:'
for token in lexer:
    print repr(token)
```

Notice the string `source quotes.txt` embedded in the original text. Since the source property of the lexer is set to "source", when the keyword is encountered the filename appearing in the next title is automatically included. In order to cause the filename to appear as a single token, the `.` character needs to be added to the list of characters that are included in words (otherwise "`quotes.txt`" becomes three tokens, "`quotes`", "`.`", "`txt`"). The output looks like:

```
$ python shlex_source.py

ORIGINAL: 'This text says to source quotes.txt before continuing.'

TOKENS:
'This'
'text'
'says'
'to'
'This'
'string'
'has'
'embedded'
'"double quotes"'
'and'
"'single quotes'"
'in'
'it'
','
'and'
'even'
'"a \'nested example\'"'
'.'
'before'
'continuing.'
```

The "source" feature uses a method called `sourcehook()` to load the additional input source, so you can subclass `shlex` to provide your own implementation to load data from anywhere.

22.2.5 Controlling the Parser

I have already given an example changing the *wordchars* value to control which characters are included in words. It is also possible to set the *quotes* character to use additional or alternative quotes. Each quote must be a single character, so it is not possible to have different open and close quotes (no parsing on parentheses, for example).

```
import shlex

text = """|Col 1||Col 2||Col 3|"""
print 'ORIGINAL:', repr(text)
print
```

```
lexer = shlex.shlex(text)
lexer.quotes = '|'

print 'TOKENS:'
for token in lexer:
    print repr(token)
```

In this example, each table cell is wrapped in vertical bars:

```
$ python shlex_table.py

ORIGINAL: '|Col 1||Col 2||Col 3|'

TOKENS:
'|Col 1|'
'|Col 2|'
'|Col 3|'
```

It is also possible to control the whitespace characters used to split words. If we modify the example in shlex_example.py to include period and comma, as follows:

```
import shlex
import sys

if len(sys.argv) != 2:
    print 'Please specify one filename on the command line.'
    sys.exit(1)

filename = sys.argv[1]
body = file(filename, 'rt').read()
print 'ORIGINAL:', repr(body)
print

print 'TOKENS:'
lexer = shlex.shlex(body)
lexer.whitespace += '.,'
for token in lexer:
    print repr(token)
```

The results change to:

```
$ python shlex_whitespace.py quotes.txt

ORIGINAL: 'This string has embedded "double quotes" and \'single quotes\' in it,\nand even "a \'neste

TOKENS:
'This'
'string'
'has'
'embedded'
'"double quotes"'
'and'
"'single quotes'"
'in'
'it'
'and'
'even'
'"a \'nested example\'"'
```

22.2.6 Error Handling

When the parser encounters the end of its input before all quoted strings are closed, it raises *ValueError*. When that happens, it is useful to examine some of the properties of the parser maintained as it processes the input. For example, *infile* refers to the name of the file being processed (which might be different from the original file, if one file sources another). The *lineno* reports the line when the error is discovered. The *lineno* is typically the end of the file, which may be far away from the first quote. The *token* attribute contains the buffer of text not already included in a valid token. The `error_leader()` method produces a message prefix in a style similar to Unix compilers, which enables editors such as emacs to parse the error and take the user directly to the invalid line.

```
import shlex

text = """This line is ok.
This line has an "unfinished quote.
This line is ok, too.
"""

print 'ORIGINAL:', repr(text)
print

lexer = shlex.shlex(text)

print 'TOKENS:'
try:
    for token in lexer:
        print repr(token)
except ValueError, err:
    first_line_of_error = lexer.token.splitlines()[0]
    print 'ERROR:', lexer.error_leader(), str(err), 'following "' + first_line_of_error + '"'
```

The example above produces this output:

```
$ python shlex_errors.py

ORIGINAL: 'This line is ok.\nThis line has an "unfinished quote.\nThis line is ok, too.\n'

TOKENS:
'This'
'line'
'is'
'ok'
'.'
'This'
'line'
'has'
'an'
ERROR: "None", line 4:  No closing quotation following ""unfinished quote."
```

22.2.7 POSIX vs. Non-POSIX Parsing

The default behavior for the parser is to use a backwards-compatible style which is not POSIX-compliant. For POSIX behavior, set the posix argument when constructing the parser.

```
import shlex

for s in [ 'Do"Not"Separate',
           '"Do"Separate',
            'Escaped \e Character not in quotes',
            'Escaped "\e" Character in double quotes',
            "Escaped '\e' Character in single quotes",
            r"Escaped '\'' \"\'\" single quote",
            r'Escaped "\"" \'\"\' double quote',
            "\"'Strip extra layer of quotes'\"",
            ]:
    print 'ORIGINAL :', repr(s)
    print 'non-POSIX:',

    non_posix_lexer = shlex.shlex(s, posix=False)
    try:
        print repr(list(non_posix_lexer))
    except ValueError, err:
        print 'error(%s)' % err


    print 'POSIX    :',
    posix_lexer = shlex.shlex(s, posix=True)
    try:
        print repr(list(posix_lexer))
    except ValueError, err:
        print 'error(%s)' % err

    print
```

Here are a few examples of the differences in parsing behavior:

```
$ python shlex_posix.py

ORIGINAL : 'Do"Not"Separate'
non-POSIX: ['Do"Not"Separate']
POSIX    : ['DoNotSeparate']

ORIGINAL : '"Do"Separate'
non-POSIX: ['"Do"', 'Separate']
POSIX    : ['DoSeparate']

ORIGINAL : 'Escaped \\e Character not in quotes'
non-POSIX: ['Escaped', '\\', 'e', 'Character', 'not', 'in', 'quotes']
POSIX    : ['Escaped', 'e', 'Character', 'not', 'in', 'quotes']

ORIGINAL : 'Escaped "\\e" Character in double quotes'
non-POSIX: ['Escaped', '"\\e"', 'Character', 'in', 'double', 'quotes']
POSIX    : ['Escaped', '\\e', 'Character', 'in', 'double', 'quotes']

ORIGINAL : "Escaped '\\e' Character in single quotes"
non-POSIX: ['Escaped', "'\\e'", 'Character', 'in', 'single', 'quotes']
POSIX    : ['Escaped', '\\e', 'Character', 'in', 'single', 'quotes']

ORIGINAL : 'Escaped \'\\\'\' \\"\\\'\\" single quote'
non-POSIX: error(No closing quotation)
POSIX    : ['Escaped', '\\ \\"\\"', 'single', 'quote']

ORIGINAL : 'Escaped "\\"" \\\'\\"\\\' double quote'
non-POSIX: error(No closing quotation)
POSIX    : ['Escaped', '"', '\'"\'', 'double', 'quote']
```

```
ORIGINAL : '"\'Strip extra layer of quotes\'"'
non-POSIX: ['"\'Strip extra layer of quotes\'"']
POSIX    : ["'Strip extra layer of quotes'"]
```

See also:

shlex **(http://docs.python.org/lib/module-shlex.html)** Standard library documentation for this module.

`cmd` Tools for building interactive command interpreters.

`optparse` Command line option parsing.

`getopt` Command line option parsing.

CHAPTER TWENTYTHREE

DEVELOPMENT TOOLS

23.1 doctest – Testing through documentation

Purpose Write automated tests as part of the documentation for a module.

Available In 2.1

doctest lets you test your code by running examples embedded in the documentation and verifying that they produce the expected results. It works by parsing the help text to find examples, running them, then comparing the output text against the expected value. Many developers find doctest easier than unittest because in its simplest form, there is no API to learn before using it. However, as the examples become more complex the lack of fixture management can make writing doctest tests more cumbersome than using unittest.

23.1.1 Getting Started

The first step to setting up doctests is to use the interactive interpreter to create examples and then copy and paste them into the docstrings in your module. Here, `my_function()` has two examples given:

```
def my_function(a, b):
    """
    >>> my_function(2, 3)
    6
    >>> my_function('a', 3)
    'aaa'
    """
    return a * b
```

To run the tests, use doctest as the main program via the `-m` option to the interpreter. Usually no output is produced while the tests are running, so the example below includes the `-v` option to make the output more verbose.

```
$ python -m doctest -v doctest_simple.py

Trying:
    my_function(2, 3)
Expecting:
    6
ok
Trying:
    my_function('a', 3)
Expecting:
    'aaa'
ok
1 items had no tests:
    doctest_simple
```

```
1 items passed all tests:
   2 tests in doctest_simple.my_function
2 tests in 2 items.
2 passed and 0 failed.
Test passed.
```

Examples cannot usually stand on their own as explanations of a function, so `doctest` also lets you keep the surrounding text you would normally include in the documentation. It looks for lines beginning with the interpreter prompt, >>>, to find the beginning of a test case. The case is ended by a blank line, or by the next interpreter prompt. Intervening text is ignored, and can have any format as long as it does not look like a test case.

```
def my_function(a, b):
    """Returns a * b.

    Works with numbers:

    >>> my_function(2, 3)
    6

    and strings:

    >>> my_function('a', 3)
    'aaa'
    """
    return a * b
```

The surrounding text in the updated docstring makes it more useful to a human reader, and is ignored by `doctest`, and the results are the same.

```
$ python -m doctest -v doctest_simple_with_docs.py

Trying:
    my_function(2, 3)
Expecting:
    6
ok
Trying:
    my_function('a', 3)
Expecting:
    'aaa'
ok
1 items had no tests:
    doctest_simple_with_docs
1 items passed all tests:
   2 tests in doctest_simple_with_docs.my_function
2 tests in 2 items.
2 passed and 0 failed.
Test passed.
```

23.1.2 Handling Unpredictable Output

There are other cases where the exact output may not be predictable, but should still be testable. Local date and time values and object ids change on every test run. The default precision used in the representation of floating point values depend on compiler options. Object string representations may not be deterministic. Although these conditions are outside of your control, there are techniques for dealing with them.

For example, in CPython, object identifiers are based on the memory address of the data structure holding the object.

```
class MyClass(object):
    pass

def unpredictable(obj):
    """Returns a new list containing obj.

    >>> unpredictable(MyClass())
    [<doctest_unpredictable.MyClass object at 0x10055a2d0>]
    """
    return [obj]
```

These id values change each time a program runs, because it is loaded into a different part of memory.

```
$ python -m doctest -v doctest_unpredictable.py

Trying:
    unpredictable(MyClass())
Expecting:
    [<doctest_unpredictable.MyClass object at 0x10055a2d0>]
**********************************************************************
File "doctest_unpredictable.py", line 16, in doctest_unpredictable.unpredictable
Failed example:
    unpredictable(MyClass())
Expected:
    [<doctest_unpredictable.MyClass object at 0x10055a2d0>]
Got:
    [<doctest_unpredictable.MyClass object at 0x10051df90>]
2 items had no tests:
    doctest_unpredictable
    doctest_unpredictable.MyClass
**********************************************************************
1 items had failures:
   1 of   1 in doctest_unpredictable.unpredictable
1 tests in 3 items.
0 passed and 1 failed.
***Test Failed*** 1 failures.
```

When the tests include values that are likely to change in unpredictable ways, and where the actual value is not important to the test results, you can use the `ELLIPSIS` option to tell `doctest` to ignore portions of the verification value.

```
class MyClass(object):
    pass

def unpredictable(obj):
    """Returns a new list containing obj.

    >>> unpredictable(MyClass()) #doctest: +ELLIPSIS
    [<doctest_ellipsis.MyClass object at 0x...>]
    """
    return [obj]
```

The comment after the call to `unpredictable()` (`#doctest:  +ELLIPSIS`) tells `doctest` to turn on the `ELLIPSIS` option for that test. The `...` replaces the memory address in the object id, so that portion of the expected value is ignored and the actual output matches and the test passes.

```
$ python -m doctest -v doctest_ellipsis.py

Trying:
    unpredictable(MyClass()) #doctest: +ELLIPSIS
Expecting:
    [<doctest_ellipsis.MyClass object at 0x...>]
ok
2 items had no tests:
    doctest_ellipsis
    doctest_ellipsis.MyClass
1 items passed all tests:
   1 tests in doctest_ellipsis.unpredictable
1 tests in 3 items.
1 passed and 0 failed.
Test passed.
```

There are cases where you cannot ignore the unpredictable value, because that would obviate the test. For example, simple tests quickly become more complex when dealing with data types whose string representations are inconsistent. The string form of a dictionary, for example, may change based on the order the keys are added.

```
keys = [ 'a', 'aa', 'aaa' ]

d1 = dict( (k,len(k)) for k in keys )
d2 = dict( (k,len(k)) for k in reversed(keys) )

print
print 'd1:', d1
print 'd2:', d2
print 'd1 == d2:', d1 == d2

s1 = set(keys)
s2 = set(reversed(keys))

print
print 's1:', s1
print 's2:', s2
print 's1 == s2:', s1 == s2
```

Because of cache collision, the internal key list order is different for the two dictionaries, even though they contain the same values and are considered to be equal. Sets use the same hashing algorithm, and exhibit the same behavior.

```
$ python doctest_hashed_values.py


d1: {'a': 1, 'aa': 2, 'aaa': 3}
d2: {'aa': 2, 'a': 1, 'aaa': 3}
d1 == d2: True

s1: set(['a', 'aa', 'aaa'])
s2: set(['aa', 'a', 'aaa'])
s1 == s2: True
```

The best way to deal with these potential discrepancies is to create tests that produce values that are not likely to change. In the case of dictionaries and sets, that might mean looking for specific keys individually, generating a sorted list of the contents of the data structure, or comparing against a literal value for equality instead of depending on the string representation.

```
def group_by_length(words):
    """Returns a dictionary grouping words into sets by length.

    >>> grouped = group_by_length([ 'python', 'module', 'of', 'the', 'week' ])
    >>> grouped == { 2:set(['of']),
    ...                 3:set(['the']),
    ...                 4:set(['week']),
    ...                 6:set(['python', 'module']),
    ...                 }
    True

    """
    d = {}
    for word in words:
        s = d.setdefault(len(word), set())
        s.add(word)
    return d
```

Notice that the single example is actually interpreted as two separate tests, with the first expecting no console output and the second expecting the boolean result of the comparison operation.

```
$ python -m doctest -v doctest_hashed_values_tests.py

Trying:
    grouped = group_by_length([ 'python', 'module', 'of', 'the', 'week' ])
Expecting nothing
ok
Trying:
    grouped == { 2:set(['of']),
                 3:set(['the']),
                 4:set(['week']),
                 6:set(['python', 'module']),
                 }
Expecting:
    True
ok
1 items had no tests:
    doctest_hashed_values_tests
1 items passed all tests:
   2 tests in doctest_hashed_values_tests.group_by_length
2 tests in 2 items.
2 passed and 0 failed.
Test passed.
```

23.1.3 Tracebacks

Tracebacks are a special case of changing data. Since the paths in a traceback depend on the location where a module is installed on the filesystem on a given system, it would be impossible to write portable tests if they were treated the same as other output.

```
def this_raises():
    """This function always raises an exception.

    >>> this_raises()
    Traceback (most recent call last):
      File "<stdin>", line 1, in <module>
      File "/no/such/path/doctest_tracebacks.py", line 14, in this_raises
        raise RuntimeError('here is the error')
    RuntimeError: here is the error
    """
    raise RuntimeError('here is the error')
```

doctest makes a special effort to recognize tracebacks, and ignore the parts that might change from system to system.

```
$ python -m doctest -v doctest_tracebacks.py

Trying:
    this_raises()
Expecting:
    Traceback (most recent call last):
      File "<stdin>", line 1, in <module>
      File "/no/such/path/doctest_tracebacks.py", line 14, in this_raises
        raise RuntimeError('here is the error')
    RuntimeError: here is the error
ok
1 items had no tests:
    doctest_tracebacks
1 items passed all tests:
   1 tests in doctest_tracebacks.this_raises
1 tests in 2 items.
1 passed and 0 failed.
Test passed.
```

In fact, the entire body of the traceback is ignored and can be omitted.

```
def this_raises():
    """This function always raises an exception.

    >>> this_raises()
    Traceback (most recent call last):
    RuntimeError: here is the error
    """
    raise RuntimeError('here is the error')
```

When doctest sees a traceback header line (either `Traceback (most recent call last):` or `Traceback (innermost last):`, depending on the version of Python you are running), it skips ahead to find the exception type and message, ignoring the intervening lines entirely.

```
$ python -m doctest -v doctest_tracebacks_no_body.py

Trying:
    this_raises()
Expecting:
    Traceback (most recent call last):
    RuntimeError: here is the error
ok
1 items had no tests:
    doctest_tracebacks_no_body
1 items passed all tests:
   1 tests in doctest_tracebacks_no_body.this_raises
1 tests in 2 items.
1 passed and 0 failed.
Test passed.
```

23.1.4 Working Around Whitespace

In real world applications, output usually includes whitespace such as blank lines, tabs, and extra spacing to make it more readable. Blank lines, in particular, cause issues with doctest because they are used to delimit tests.

```
def double_space(lines):
    """Prints a list of lines double-spaced.

    >>> double_space(['Line one.', 'Line two.'])
    Line one.

    Line two.

    """
    for l in lines:
        print l
        print
    return
```

`double_space()` takes a list of input lines, and prints them double-spaced with blank lines between.

```
$ python -m doctest doctest_blankline_fail.py

**********************************************************************
File "doctest_blankline_fail.py", line 13, in doctest_blankline_fail.double_space
Failed example:
    double_space(['Line one.', 'Line two.'])
Expected:
    Line one.
Got:
    Line one.
    <BLANKLINE>
    Line two.
    <BLANKLINE>
**********************************************************************
1 items had failures:
   1 of   1 in doctest_blankline_fail.double_space
***Test Failed*** 1 failures.
```

The test fails, because it interprets the blank line after `Line one.` in the docstring as the end of the sample output. To match the blank lines, replace them in the sample input with the string `<BLANKLINE>`.

```
def double_space(lines):
    """Prints a list of lines double-spaced.

    >>> double_space(['Line one.', 'Line two.'])
    Line one.
    <BLANKLINE>
    Line two.
    <BLANKLINE>
    """
    for l in lines:
        print l
        print
    return
```

`doctest` replaces actual blank lines with the same literal before performing the comparison, so now the actual and expected values match and the test passes.

```
$ python -m doctest -v doctest_blankline.py

Trying:
    double_space(['Line one.', 'Line two.'])
Expecting:
    Line one.
    <BLANKLINE>
    Line two.
    <BLANKLINE>
ok
1 items had no tests:
    doctest_blankline
1 items passed all tests:
   1 tests in doctest_blankline.double_space
1 tests in 2 items.
1 passed and 0 failed.
Test passed.
```

Another pitfall of using text comparisons for tests is that embedded whitespace can also cause tricky problems with tests. This example has a single extra space after the 6.

```
def my_function(a, b):
    """
    >>> my_function(2, 3)
    6 
    >>> my_function('a', 3)
    'aaa'
    """
    return a * b
```

Extra spaces can find their way into your code via copy-and-paste errors, but since they come at the end of the line, they can go unnoticed in the source file and be invisible in the test failure report as well.

```
$ python -m doctest -v doctest_extra_space.py

Trying:
    my_function(2, 3)
Expecting:
    6 
**********************************************************************
File "doctest_extra_space.py", line 12, in doctest_extra_space.my_function
Failed example:
    my_function(2, 3)
Expected:
    6 
Got:
    6
Trying:
    my_function('a', 3)
Expecting:
    'aaa'
ok
1 items had no tests:
    doctest_extra_space
**********************************************************************
1 items had failures:
   1 of   2 in doctest_extra_space.my_function
2 tests in 2 items.
1 passed and 1 failed.
***Test Failed*** 1 failures.
```

Using one of the diff-based reporting options, such as REPORT_NDIFF, shows the difference between the actual and expected values with more detail, and the extra space becomes visible.

```
def my_function(a, b):
    """
    >>> my_function(2, 3) #doctest: +REPORT_NDIFF
    6
    >>> my_function('a', 3)
    'aaa'
    """
    return a * b
```

Unified (REPORT_UDIFF) and context (REPORT_CDIFF) diffs are also available, for output where those formats are more readable.

```
$ python -m doctest -v doctest_ndiff.py

Trying:
    my_function(2, 3) #doctest: +REPORT_NDIFF
Expecting:
    6
**********************************************************************
File "doctest_ndiff.py", line 12, in doctest_ndiff.my_function
Failed example:
    my_function(2, 3) #doctest: +REPORT_NDIFF
Differences (ndiff with -expected +actual):
    - 6
    ?  -
    + 6
Trying:
    my_function('a', 3)
Expecting:
    'aaa'
ok
1 items had no tests:
    doctest_ndiff
**********************************************************************
1 items had failures:
   1 of   2 in doctest_ndiff.my_function
2 tests in 2 items.
1 passed and 1 failed.
***Test Failed*** 1 failures.
```

There are cases where it is beneficial to add extra whitespace in the sample output for the test, and have doctest ignore it. For example, data structures can be easier to read when spread across several lines, even if their representation would fit on a single line.

```
def my_function(a, b):
    """Returns a * b.

    >>> my_function(['A', 'B', 'C'], 3) #doctest: +NORMALIZE_WHITESPACE
    ['A', 'B', 'C',
     'A', 'B', 'C',
     'A', 'B', 'C']

    This does not match because of the extra space after the [ in the list

    >>> my_function(['A', 'B', 'C'], 2) #doctest: +NORMALIZE_WHITESPACE
    [ 'A', 'B', 'C',
      'A', 'B', 'C' ]
    """
    return a * b
```

When NORMALIZE_WHITESPACE is turned on, any whitespace in the actual and expected values is considered a match. You cannot add whitespace to the expected value where none exists in the output, but the length of the whitespace sequence and actual whitespace characters do not need to match. The first test example gets this rule correct, and passes, even though there are extra spaces and newlines. The second has extra whitespace after [and before], so it fails.

```
$ python -m doctest -v doctest_normalize_whitespace.py

Trying:
    my_function(['A', 'B', 'C'], 3) #doctest: +NORMALIZE_WHITESPACE
Expecting:
    ['A', 'B', 'C',
     'A', 'B', 'C',
     'A', 'B', 'C']
ok
Trying:
    my_function(['A', 'B', 'C'], 2) #doctest: +NORMALIZE_WHITESPACE
Expecting:
    [ 'A', 'B', 'C',
      'A', 'B', 'C' ]
**********************************************************************
File "doctest_normalize_whitespace.py", line 20, in doctest_normalize_whitespace.my_function
Failed example:
    my_function(['A', 'B', 'C'], 2) #doctest: +NORMALIZE_WHITESPACE
Expected:
    [ 'A', 'B', 'C',
      'A', 'B', 'C' ]
Got:
    ['A', 'B', 'C', 'A', 'B', 'C']
1 items had no tests:
    doctest_normalize_whitespace
**********************************************************************
1 items had failures:
   1 of   2 in doctest_normalize_whitespace.my_function
2 tests in 2 items.
1 passed and 1 failed.
***Test Failed*** 1 failures.
```

23.1.5 Test Locations

All of the tests in the examples so far have been written in the docstrings of the functions they are testing. That is convenient for users who examine the docstrings for help using the funcion (especially with pydoc), but doctest looks for tests in other places, too. The obvious location for additional tests is in the docstrings elsewhere in the module.

```
#!/usr/bin/env python
# encoding: utf-8

"""Tests can appear in any docstring within the module.

Module-level tests cross class and function boundaries.

>>> A('a') == B('b')
False
"""

class A(object):
    """Simple class.

    >>> A('instance_name').name
    'instance_name'
    """
    def __init__(self, name):
        self.name = name
    def method(self):
        """Returns an unusual value.

        >>> A('name').method()
        'eman'
        """
        return ''.join(reversed(list(self.name)))

class B(A):
    """Another simple class.

    >>> B('different_name').name
    'different_name'
    """
```

Every docstring can contain tests at the module, class and function level.

```
$ python -m doctest -v doctest_docstrings.py

Trying:
    A('a') == B('b')
Expecting:
    False
ok
Trying:
    A('instance_name').name
Expecting:
    'instance_name'
ok
Trying:
    A('name').method()
Expecting:
    'eman'
ok
Trying:
    B('different_name').name
Expecting:
    'different_name'
ok
1 items had no tests:
    doctest_docstrings.A.__init__
4 items passed all tests:
   1 tests in doctest_docstrings
   1 tests in doctest_docstrings.A
   1 tests in doctest_docstrings.A.method
   1 tests in doctest_docstrings.B
4 tests in 5 items.
4 passed and 0 failed.
Test passed.
```

In cases where you have tests that you want to include with your source code, but do not want to have appear in the help for your module, you need to put them somewhere other than the docstrings. `doctest` also looks for a module-level variable called `__test__` and uses it to locate other tests. `__test__` should be a dictionary mapping test set names (as strings) to strings, modules, classes, or functions.

```
import doctest_private_tests_external

__test__ = {
    'numbers':"""
>>> my_function(2, 3)
6

>>> my_function(2.0, 3)
6.0
""",

    'strings':"""
>>> my_function('a', 3)
'aaa'

>>> my_function(3, 'a')
'aaa'
""",

    'external':doctest_private_tests_external,

    }

def my_function(a, b):
    """Returns a * b
    """
    return a * b
```

If the value associated with a key is a string, it is treated as a docstring and scanned for tests. If the value is a class or function, `doctest` searchs them recursively for docstrings, which are then scanned for tests. In this example, the module `doctest_private_tests_external` has a single test in its docstring.

```
#!/usr/bin/env python
# encoding: utf-8
#
# Copyright (c) 2010 Doug Hellmann.  All rights reserved.
#
"""External tests associated with doctest_private_tests.py.

>>> my_function(['A', 'B', 'C'], 2)
['A', 'B', 'C', 'A', 'B', 'C']
"""
```

`doctest` finds a total of five tests to run.

```
$ python -m doctest -v doctest_private_tests.py

Trying:
    my_function(['A', 'B', 'C'], 2)
Expecting:
    ['A', 'B', 'C', 'A', 'B', 'C']
ok
Trying:
    my_function(2, 3)
Expecting:
    6
```

```
ok
Trying:
    my_function(2.0, 3)
Expecting:
    6.0
ok
Trying:
    my_function('a', 3)
Expecting:
    'aaa'
ok
Trying:
    my_function(3, 'a')
Expecting:
    'aaa'
ok
2 items had no tests:
    doctest_private_tests
    doctest_private_tests.my_function
3 items passed all tests:
   1 tests in doctest_private_tests.__test__.external
   2 tests in doctest_private_tests.__test__.numbers
   2 tests in doctest_private_tests.__test__.strings
5 tests in 5 items.
5 passed and 0 failed.
Test passed.
```

23.1.6 External Documentation

Mixing tests in with your code isn't the only way to use doctest. Examples embedded in external project documentation files, such as reStructuredText files, can be used as well.

```
def my_function(a, b):
    """Returns a*b
    """
    return a * b
```

The help for doctest_in_help is saved to a separate file, doctest_in_help.rst. The examples illustrating how to use the module are included with the help text, and doctest can be used to find and run them.

```
===============================
 How to Use doctest_in_help.py
===============================

This library is very simple, since it only has one function called
``my_function()``.

Numbers
=======

``my_function()`` returns the product of its arguments.  For numbers,
that value is equivalent to using the ``*`` operator.

::

    >>> from doctest_in_help import my_function
    >>> my_function(2, 3)
    6

It also works with floating point values.

::

    >>> my_function(2.0, 3)
    6.0

Non-Numbers
===========

Because ``*`` is also defined on data types other than numbers,
``my_function()`` works just as well if one of the arguments is a
string, list, or tuple.

::

    >>> my_function('a', 3)
    'aaa'

    >>> my_function(['A', 'B', 'C'], 2)
    ['A', 'B', 'C', 'A', 'B', 'C']
```

The tests in the text file can be run from the command line, just as with the Python source modules.

```
$ python -m doctest -v doctest_in_help.rst

Trying:
    from doctest_in_help import my_function
Expecting nothing
ok
Trying:
    my_function(2, 3)
Expecting:
    6
ok
Trying:
    my_function(2.0, 3)
Expecting:
    6.0
ok
Trying:
    my_function('a', 3)
Expecting:
    'aaa'
ok
Trying:
    my_function(['A', 'B', 'C'], 2)
Expecting:
    ['A', 'B', 'C', 'A', 'B', 'C']
ok
1 items passed all tests:
   5 tests in doctest_in_help.rst
5 tests in 1 items.
5 passed and 0 failed.
Test passed.
```

Normally `doctest` sets up the test execution environment to include the members of the module being tested, so your tests don't need to import the module explicitly. In this case, however, the tests aren't defined in a Python module, doctest does not know how to set up the global namespace, so the examples need to do the import work themselves. All of the tests in a given file share the same execution context, so importing the module once at the top of the file is enough.

23.1.7 Running Tests

The previous examples all use the command line test runner built into doctest. It is easy and convenient for a single module, but will quickly become tedious as your package spreads out into multiple files. There are several alternative approaches.

By Module

You can include instructions to run doctest against your source at the bottom of your modules. Use testmod() without any arguments to test the current module.

```
def my_function(a, b):
    """
    >>> my_function(2, 3)
    6
    >>> my_function('a', 3)
    'aaa'
    """
    return a * b

if __name__ == '__main__':
    import doctest
    doctest.testmod()
```

Ensure the tests are only run when the module is called as a main program by invoking testmod() only if the current module name is __main__.

```
$ python doctest_testmod.py -v

Trying:
    my_function(2, 3)
Expecting:
    6
ok
Trying:
    my_function('a', 3)
Expecting:
    'aaa'
ok
1 items had no tests:
    __main__
1 items passed all tests:
   2 tests in __main__.my_function
2 tests in 2 items.
2 passed and 0 failed.
Test passed.
```

The first argument to testmod() is a module containing code to be scanned for tests. This feature lets you create a separate test script that imports your real code and runs the tests in each module one after another.

```
import doctest_simple

if __name__ == '__main__':
    import doctest
    doctest.testmod(doctest_simple)
```

You can build a test suite for your project by importing each module and running its tests.

```
$ python doctest_testmod_other_module.py -v

Trying:
    my_function(2, 3)
Expecting:
    6
ok
Trying:
    my_function('a', 3)
Expecting:
    'aaa'
ok
1 items had no tests:
    doctest_simple
1 items passed all tests:
   2 tests in doctest_simple.my_function
2 tests in 2 items.
2 passed and 0 failed.
Test passed.
```

By File

`testfile()` works in a way similar to `testmod()`, allowing you to explicitly invoke the tests in an external file from within your test program.

```
import doctest

if __name__ == '__main__':
    doctest.testfile('doctest_in_help.rst')
```

```
$ python doctest_testfile.py -v

Trying:
    from doctest_in_help import my_function
Expecting nothing
ok
Trying:
    my_function(2, 3)
Expecting:
    6
ok
Trying:
    my_function(2.0, 3)
Expecting:
    6.0
ok
Trying:
    my_function('a', 3)
Expecting:
    'aaa'
ok
Trying:
    my_function(['A', 'B', 'C'], 2)
Expecting:
    ['A', 'B', 'C', 'A', 'B', 'C']
ok
1 items passed all tests:
   5 tests in doctest_in_help.rst
5 tests in 1 items.
5 passed and 0 failed.
Test passed.
```

Both `testmod()` and `testfile()` include optional parameters to let you control the behavior of the tests through the `doctest` options, global namespace for the tests, etc. Refer to the standard library documentation for more details if you need those features – most of the time you won't need them.

Unittest Suite

If you use both `unittest` and `doctest` for testing the same code in different situations, you may find the `unittest` integration in `doctest` useful for running the tests together. Two classes, `DocTestSuite` and `DocFileSuite` create test suites compatible with the test-runner API of `unittest`.

```python
import doctest
import unittest

import doctest_simple

suite = unittest.TestSuite()
suite.addTest(doctest.DocTestSuite(doctest_simple))
suite.addTest(doctest.DocFileSuite('doctest_in_help.rst'))

runner = unittest.TextTestRunner(verbosity=2)
runner.run(suite)
```

The tests from each source are collapsed into a single outcome, instead of being reported individually.

```
$ python doctest_unittest.py

my_function (doctest_simple)
Doctest: doctest_simple.my_function ... ok
doctest_in_help.rst
Doctest: doctest_in_help.rst ... ok

----------------------------------------------------------------------
Ran 2 tests in 0.003s

OK
```

23.1.8 Test Context

The execution context created by `doctest` as it runs tests contains a copy of the module-level globals for the module containing your code. This isolates the tests from each other somewhat, so they are less likely to interfere with one another. Each test source (function, class, module) has its own set of global values.

```
class TestGlobals(object):

    def one(self):
        """
        >>> var = 'value'
        >>> 'var' in globals()
        True
        """

    def two(self):
        """
        >>> 'var' in globals()
        False
        """
```

`TestGlobals` has two methods, `one()` and `two()`. The tests in the docstring for `one()` set a global variable, and the test for `two()` looks for it (expecting not to find it).

```
$ python -m doctest -v doctest_test_globals.py

Trying:
    var = 'value'
Expecting nothing
ok
Trying:
    'var' in globals()
Expecting:
    True
ok
Trying:
    'var' in globals()
Expecting:
    False
ok
2 items had no tests:
    doctest_test_globals
    doctest_test_globals.TestGlobals
2 items passed all tests:
   2 tests in doctest_test_globals.TestGlobals.one
   1 tests in doctest_test_globals.TestGlobals.two
3 tests in 4 items.
3 passed and 0 failed.
Test passed.
```

That does not mean the tests *cannot* interfere with each other, though, if they change the contents of mutable variables defined in the module.

```
_module_data = {}

class TestGlobals(object):

    def one(self):
        """
        >>> TestGlobals().one()
        >>> 'var' in _module_data
        True
        """
        _module_data['var'] = 'value'
    def two(self):
        """
        >>> 'var' in _module_data
        False
        """
```

The module varabile `_module_data` is changed by the tests for `one()`, causing the test for `two()` to fail.

```
$ python -m doctest -v doctest_mutable_globals.py

Trying:
    TestGlobals().one()
Expecting nothing
ok
Trying:
    'var' in _module_data
Expecting:
    True
ok
Trying:
    'var' in _module_data
Expecting:
    False
**********************************************************************
File "doctest_mutable_globals.py", line 24, in doctest_mutable_globals.TestGlobals.two
Failed example:
    'var' in _module_data
Expected:
    False
Got:
    True
2 items had no tests:
    doctest_mutable_globals
    doctest_mutable_globals.TestGlobals
1 items passed all tests:
   2 tests in doctest_mutable_globals.TestGlobals.one
**********************************************************************
1 items had failures:
   1 of   1 in doctest_mutable_globals.TestGlobals.two
3 tests in 4 items.
2 passed and 1 failed.
***Test Failed*** 1 failures.
```

If you need to set global values for the tests, to parameterize them for an environment for example, you can pass values to `testmod()` and `testfile()` and have the context set up using data you control.

See also:

doctest (http://docs.python.org/library/doctest.html) The standard library documentation for this module.

The Mighty Dictionary (http://blip.tv/file/3332763) Presentation by Brandon Rhodes at PyCon 2010 about the internal operations of the `dict`.

`difflib` Python's sequence difference computation library, used to produce the ndiff output.

Sphinx (http://sphinx.pocoo.org/) As well as being the documentation processing tool for Python's standard library, Sphinx has been adopted by many third-party projects because it is easy to use and produces clean output in several digital and print formats. Sphinx includes an extension for running doctests as is processes your documentation, so you know your examples are always accurate.

nose (http://somethingaboutorange.com/mrl/projects/nose/) Third-party test runner with `doctest` support.

py.test (http://codespeak.net/py/dist/test/) Third-party test runner with `doctest` support.

Manuel (http://packages.python.org/manuel/) Third-party documentation-based test runner with more advanced test case extraction and integration with Sphinx.

23.2 pydoc – Online help for Python modules

Purpose Generates help for Python modules and classes from the code.

Available In 2.1 and later

The `pydoc` module imports a Python module and uses the contents to generate help text at runtime. The output includes docstrings for any objects that have them, and all of the documentable contents of the module are described.

23.2.1 Plain Text Help

Running:

```
$ pydoc atexit
```

Produces plaintext help on the console, using your pager if one is configured.

23.2.2 HTML Help

You can also cause `pydoc` to generate HTML output, either writing a static file to a local directory or starting a web server to browse documentation online.

```
$ pydoc -w atexit
```

Creates `atexit.html` in the current directory.

```
$ pydoc -p 5000
```

Starts a web server listening at http://localhost:5000/. The server generates documentation as you browse through the available modules.

23.2.3 Interactive Help

pydoc also adds a function `help()` to the `__builtins__` so you can access the same information from the Python interpreter prompt.

```
$ python
Python 2.6.2 (r262:71600, Apr 16 2009, 09:17:39)
[GCC 4.0.1 (Apple Computer, Inc. build 5250)] on darwin
Type "help", "copyright", "credits" or "license" for more information.
>>> help('atexit')
Help on module atexit:

NAME
    atexit

FILE
    /Library/Frameworks/Python.framework/Versions/2.6/lib/python2.6/atexit.py
...
```

See also:

pydoc **(http://docs.python.org/library/pydoc.html)** The standard library documentation for this module.

motw-cli Accessing the Module of the Week articles from the command line.

motw-interactive Accessing the Module of the Week articles from the interactive interpreter.

23.3 unittest – Automated testing framework

Purpose Automated testing framework

Available In 2.1

Python's `unittest` module, sometimes referred to as PyUnit, is based on the XUnit framework design by Kent Beck and Erich Gamma. The same pattern is repeated in many other languages, including C, perl, Java, and Smalltalk. The framework implemented by `unittest` supports fixtures, test suites, and a test runner to enable automated testing for your code.

23.3.1 Basic Test Structure

Tests, as defined by `unittest`, have two parts: code to manage test "fixtures", and the test itself. Individual tests are created by subclassing `TestCase` and overriding or adding appropriate methods. For example,

```
import unittest

class SimplisticTest(unittest.TestCase):

    def test(self):
        self.failUnless(True)

if __name__ == '__main__':
    unittest.main()
```

In this case, the `SimplisticTest` has a single `test()` method, which would fail if True is ever False.

23.3.2 Running Tests

The easiest way to run unittest tests is to include:

```
if __name__ == '__main__':
    unittest.main()
```

at the bottom of each test file, then simply run the script directly from the command line:

```
$ python unittest_simple.py

.
----------------------------------------------------------------------
Ran 1 test in 0.000s

OK
```

This abbreviated output includes the amount of time the tests took, along with a status indicator for each test (the "." on the first line of output means that a test passed). For more detailed test results, include the -v option:

```
$ python unittest_simple.py -v

test (__main__.SimplisticTest) ... ok

----------------------------------------------------------------------
Ran 1 test in 0.000s

OK
```

23.3.3 Test Outcomes

Tests have 3 possible outcomes:

ok The test passes.

FAIL The test does not pass, and raises an AssertionError exception.

ERROR The test raises an exception other than AssertionError.

There is no explicit way to cause a test to "pass", so a test's status depends on the presence (or absence) of an exception.

```
import unittest

class OutcomesTest(unittest.TestCase):

    def testPass(self):
        return

    def testFail(self):
        self.failIf(True)

    def testError(self):
        raise RuntimeError('Test error!')

if __name__ == '__main__':
    unittest.main()
```

When a test fails or generates an error, the traceback is included in the output.

```
$ python unittest_outcomes.py

EF.
======================================================================
ERROR: testError (__main__.OutcomesTest)
----------------------------------------------------------------------
Traceback (most recent call last):
  File "unittest_outcomes.py", line 42, in testError
    raise RuntimeError('Test error!')
RuntimeError: Test error!

======================================================================
FAIL: testFail (__main__.OutcomesTest)
----------------------------------------------------------------------
Traceback (most recent call last):
  File "unittest_outcomes.py", line 39, in testFail
    self.failIf(True)
AssertionError: True is not false

----------------------------------------------------------------------
```

```
Ran 3 tests in 0.000s

FAILED (failures=1, errors=1)
```

In the example above, `testFail()` fails and the traceback shows the line with the failure code. It is up to the person reading the test output to look at the code to figure out the semantic meaning of the failed test, though. To make it easier to understand the nature of a test failure, the `fail*()` and `assert*()` methods all accept an argument *msg*, which can be used to produce a more detailed error message.

```
import unittest

class FailureMessageTest(unittest.TestCase):

    def testFail(self):
        self.failIf(True, 'failure message goes here')

if __name__ == '__main__':
    unittest.main()
```

```
$ python unittest_failwithmessage.py -v

testFail (__main__.FailureMessageTest) ... FAIL

======================================================================
FAIL: testFail (__main__.FailureMessageTest)
----------------------------------------------------------------------
Traceback (most recent call last):
  File "unittest_failwithmessage.py", line 36, in testFail
    self.failIf(True, 'failure message goes here')
AssertionError: failure message goes here

----------------------------------------------------------------------
Ran 1 test in 0.000s

FAILED (failures=1)
```

23.3.4 Asserting Truth

Most tests assert the truth of some condition. There are a few different ways to write truth-checking tests, depending on the perspective of the test author and the desired outcome of the code being tested. If the code produces a value which can be evaluated as true, the methods `failUnless()` and `assertTrue()` should be used. If the code produces a false value, the methods `failIf()` and `assertFalse()` make more sense.

```
import unittest

class TruthTest(unittest.TestCase):

    def testFailUnless(self):
        self.failUnless(True)

    def testAssertTrue(self):
        self.assertTrue(True)

    def testFailIf(self):
        self.failIf(False)

    def testAssertFalse(self):
        self.assertFalse(False)

if __name__ == '__main__':
    unittest.main()
```

```
$ python unittest_truth.py -v

testAssertFalse (__main__.TruthTest) ... ok
testAssertTrue (__main__.TruthTest) ... ok
testFailIf (__main__.TruthTest) ... ok
testFailUnless (__main__.TruthTest) ... ok

----------------------------------------------------------------------
Ran 4 tests in 0.000s

OK
```

23.3.5 Testing Equality

As a special case, `unittest` includes methods for testing the equality of two values.

```
import unittest

class EqualityTest(unittest.TestCase):

    def testEqual(self):
        self.failUnlessEqual(1, 3-2)

    def testNotEqual(self):
        self.failIfEqual(2, 3-2)

if __name__ == '__main__':
    unittest.main()
```

```
$ python unittest_equality.py -v

testEqual (__main__.EqualityTest) ... ok
testNotEqual (__main__.EqualityTest) ... ok

----------------------------------------------------------------------
Ran 2 tests in 0.000s

OK
```

These special tests are handy, since the values being compared appear in the failure message when a test fails.

```
import unittest

class InequalityTest(unittest.TestCase):

    def testEqual(self):
        self.failIfEqual(1, 3-2)

    def testNotEqual(self):
        self.failUnlessEqual(2, 3-2)
```

```
if __name__ == '__main__':
    unittest.main()
```

And when these tests are run:

```
$ python unittest_notequal.py -v

testEqual (__main__.InequalityTest) ... FAIL
testNotEqual (__main__.InequalityTest) ... FAIL

======================================================================
FAIL: testEqual (__main__.InequalityTest)
----------------------------------------------------------------------
Traceback (most recent call last):
  File "unittest_notequal.py", line 36, in testEqual
    self.failIfEqual(1, 3-2)
AssertionError: 1 == 1

======================================================================
FAIL: testNotEqual (__main__.InequalityTest)
----------------------------------------------------------------------
Traceback (most recent call last):
  File "unittest_notequal.py", line 39, in testNotEqual
    self.failUnlessEqual(2, 3-2)
AssertionError: 2 != 1

----------------------------------------------------------------------
Ran 2 tests in 0.000s

FAILED (failures=2)
```

23.3.6 Almost Equal?

In addition to strict equality, it is possible to test for near equality of floating point numbers using `failIfAlmostEqual()` and `failUnlessAlmostEqual()`.

```
import unittest

class AlmostEqualTest(unittest.TestCase):

    def testNotAlmostEqual(self):
        self.failIfAlmostEqual(1.1, 3.3-2.0, places=1)

    def testAlmostEqual(self):
        self.failUnlessAlmostEqual(1.1, 3.3-2.0, places=0)

if __name__ == '__main__':
    unittest.main()
```

The arguments are the values to be compared, and the number of decimal places to use for the test.

```
$ python unittest_almostequal.py

..
----------------------------------------------------------------------
Ran 2 tests in 0.000s
```

```
OK
```

23.3.7 Testing for Exceptions

As previously mentioned, if a test raises an exception other than *AssertionError* it is treated as an error. This is very useful for uncovering mistakes while you are modifying code which has existing test coverage. There are circumstances, however, in which you want the test to verify that some code does produce an exception. For example, if an invalid value is given to an attribute of an object. In such cases, `failUnlessRaises()` makes the code more clear than trapping the exception yourself. Compare these two tests:

```
import unittest

def raises_error(*args, **kwds):
    print args, kwds
    raise ValueError('Invalid value: ' + str(args) + str(kwds))

class ExceptionTest(unittest.TestCase):

    def testTrapLocally(self):
        try:
            raises_error('a', b='c')
        except ValueError:
            pass
        else:
            self.fail('Did not see ValueError')

    def testFailUnlessRaises(self):
        self.failUnlessRaises(ValueError, raises_error, 'a', b='c')

if __name__ == '__main__':
    unittest.main()
```

The results for both are the same, but the second test using `failUnlessRaises()` is more succinct.

```
$ python unittest_exception.py -v

testFailUnlessRaises (__main__.ExceptionTest) ... ok
testTrapLocally (__main__.ExceptionTest) ... ok

----------------------------------------------------------------------
Ran 2 tests in 0.000s

OK
('a',) {'b': 'c'}
('a',) {'b': 'c'}
```

23.3.8 Test Fixtures

Fixtures are resources needed by a test. For example, if you are writing several tests for the same class, those tests all need an instance of that class to use for testing. Other test fixtures include database connections and temporary files (many people would argue that using external resources makes such tests not "unit" tests, but they are still tests and still useful). `TestCase` includes a special hook to configure and clean up any fixtures needed by your tests. To configure the fixtures, override `setUp()`. To clean up, override `tearDown()`.

```
import unittest

class FixturesTest(unittest.TestCase):

    def setUp(self):
        print 'In setUp()'
        self.fixture = range(1, 10)

    def tearDown(self):
        print 'In tearDown()'
        del self.fixture

    def test(self):
        print 'in test()'
        self.failUnlessEqual(self.fixture, range(1, 10))

if __name__ == '__main__':
    unittest.main()
```

When this sample test is run, you can see the order of execution of the fixture and test methods:

```
$ python unittest_fixtures.py

.
----------------------------------------------------------------------
Ran 1 test in 0.000s

OK
In setUp()
in test()
In tearDown()
```

23.3.9 Test Suites

The standard library documentation describes how to organize test suites manually. I generally do not use test suites directly, because I prefer to build the suites automatically (these are automated tests, after all). Automating the construction of test suites is especially useful for large code bases, in which related tests are not all in the same place. Tools such as nose make it easier to manage tests when they are spread over multiple files and directories.

See also:

unittest (http://docs.python.org/lib/module-unittest.html) Standard library documentation for this module.

doctest An alternate means of running tests embedded in docstrings or external documentation files.

nose (http://somethingaboutorange.com/mrl/projects/nose/) A more sophisticated test manager.

unittest2 (http://pypi.python.org/pypi/unittest2) Ongoing improvements to `unittest`

23.4 pdb – Interactive Debugger

Purpose Python's Interactive Debugger

Available In 1.4 and later

pdb implements an interactive debugging environment for Python programs. It includes features to let you pause your program, look at the values of variables, and watch program execution step-by-step, so you can understand what your program actually does and find bugs in the logic.

23.4.1 Starting the Debugger

The first step to using pdb is causing the interpreter to enter the debugger when you want it to. There are a few different ways to do that, depending on your starting conditions and what you need to debug.

From the Command Line

The most straightforward way to use the debugger is to run it from the command line, giving it your own program as input so it knows what to run.

```
1  #!/usr/bin/env python
2  # encoding: utf-8
3  #
4  # Copyright (c) 2010 Doug Hellmann.  All rights reserved.
5  #
6  
7  class MyObj(object):
8  
9      def __init__(self, num_loops):
10         self.count = num_loops
11 
12     def go(self):
13         for i in range(self.count):
14             print i
15         return
16 
17 if __name__ == '__main__':
18     MyObj(5).go()
```

Running the debugger from the command line causes it to load your source file and stop execution on the first statement it finds. In this case, it stops before evaluating the definition of the class MyObj on line 7.

```
$ python -m pdb pdb_script.py
> .../pdb_script.py(7)<module>()
-> """
(Pdb)
```

Note: Normally pdb includes the full path to each module in the output when printing a filename. In order to maintain clear examples, the sample output in this section replaces the path with ....

Within the Interpreter

Many Python developers work with the interactive interpreter while developing early versions of modules because it lets them experiment more iteratively without the save/run/repeat cycle needed when creating standalone scripts. To run the debugger from within an interactive interpreter, use run() or runeval().

```
$ python
Python 2.7 (r27:82508, Jul  3 2010, 21:12:11)
[GCC 4.0.1 (Apple Inc. build 5493)] on darwin
Type "help", "copyright", "credits" or "license" for more information.
```

```
>>> import pdb_script
>>> import pdb
>>> pdb.run('pdb_script.MyObj(5).go()')
> <string>(1)<module>()
(Pdb)
```

The argument to `run()` is a string expression that can be evaluated by the Python interpreter. The debugger will parse it, then pause execution just before the first expression evaluates. You can use the debugger commands described below to navigate and control the execution.

From Within Your Program

Both of the previous examples assume you want to start the debugger at the beginning of your program. For a long-running process where the problem appears much later in the program execution, it will be more convenient to start the debugger from inside your program using `set_trace()`.

```
1  #!/usr/bin/env python
2  # encoding: utf-8
3  #
4  # Copyright (c) 2010 Doug Hellmann.  All rights reserved.
5  #
6
7  import pdb
8
9  class MyObj(object):
10
11     def __init__(self, num_loops):
12         self.count = num_loops
13
14     def go(self):
15         for i in range(self.count):
16             pdb.set_trace()
17             print i
18         return
19
20 if __name__ == '__main__':
21     MyObj(5).go()
```

Line 16 of the sample script triggers the debugger at that point in execution.

```
$ python ./pdb_set_trace.py
> .../pdb_set_trace.py(17)go()
-> print i
(Pdb)
```

`set_trace()` is just a Python function, so you can call it at any point in your program. This lets you enter the debugger based on conditions inside your program, including from an exception handler or via a specific branch of a control statement.

After a Failure

Debugging a failure after a program terminates is called *post-mortem* debugging. `pdb` supports post-mortem debugging through the `pm()` and `post_mortem()` functions.

```
#!/usr/bin/env python
# encoding: utf-8
```

```
3  #
4  # Copyright (c) 2010 Doug Hellmann.  All rights reserved.
5  #
6
7  class MyObj(object):
8
9      def __init__(self, num_loops):
10         self.count = num_loops
11
12     def go(self):
13         for i in range(self.num_loops):
14             print i
15         return
```

Here the incorrect attribute name on line 13 triggers an *AttributeError* exception, causing execution to stop. `pm()` looks for the active traceback and starts the debugger at the point in the call stack where the exception occurred.

```
$ python
Python 2.7 (r27:82508, Jul  3 2010, 21:12:11)
[GCC 4.0.1 (Apple Inc. build 5493)] on darwin
Type "help", "copyright", "credits" or "license" for more information.
>>> from pdb_post_mortem import MyObj
>>> MyObj(5).go()
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
  File "pdb_post_mortem.py", line 13, in go
    for i in range(self.num_loops):
AttributeError: 'MyObj' object has no attribute 'num_loops'
>>> import pdb
>>> pdb.pm()
> .../pdb_post_mortem.py(13)go()
-> for i in range(self.num_loops):
(Pdb)
```

23.4.2 Controlling the Debugger

You interact with the debugger using a small command language that lets you move around the call stack, examine and change the values of variables, and control how the debugger executes your program. The interactive debugger uses `readline` to accept commands. Entering a blank line re-runs the previous command again, unless it was a **list** operation.

Navigating the Execution Stack

At any point while the debugger is running you can use **where** (abbreviated **w**) to find out exactly what line is being executed and where on the call stack you are. In this case, the module `pdb_set_trace.py` line 17 in the `go()` method.

```
$ python pdb_set_trace.py
> .../pdb_set_trace.py(17)go()
-> print i
(Pdb) where
  .../pdb_set_trace.py(21)<module>()
-> MyObj(5).go()
> .../pdb_set_trace.py(17)go()
-> print i
```

To add more context around the current location, use **list** (**l**).

```
(Pdb) list
 12             self.count = num_loops
 13
 14         def go(self):
 15             for i in range(self.count):
 16                 pdb.set_trace()
 17  ->             print i
 18             return
 19
 20     if __name__ == '__main__':
 21         MyObj(5).go()
[EOF]
(Pdb)
```

The default is to list 11 lines around the current line (five before and five after). Using **list** with a single numerical argument lists 11 lines around that line instead of the current line.

```
(Pdb) list 14
  9     class MyObj(object):
 10
 11         def __init__(self, num_loops):
 12             self.count = num_loops
 13
 14         def go(self):
 15             for i in range(self.count):
 16                 pdb.set_trace()
 17  ->             print i
 18             return
 19
```

If **list** receives two arguments, it interprets them as the first and last lines to include in its output.

```
(Pdb) list 5, 19
  5     #
  6
  7     import pdb
  8
  9     class MyObj(object):
 10
 11         def __init__(self, num_loops):
 12             self.count = num_loops
 13
 14         def go(self):
 15             for i in range(self.count):
 16                 pdb.set_trace()
 17  ->             print i
 18             return
 19
```

Move between frames within the current call stack using **up** and down. **up** (abbreviated **u**) moves towards older frames on the stack. **down** (abbreviated **d**) moves towards newer frames.

```
(Pdb) up
> .../pdb_set_trace.py(21)<module>()
-> MyObj(5).go()

(Pdb) down
> .../pdb_set_trace.py(17)go()
```

```
-> print i
```

Each time you move up or down the debugger prints the current location in the same format as produced by **where**.

Examining Variables on the Stack

Each frame on the stack maintains a set of variables, including values local to the function being executed and global state information. pdb provides several ways to examine the contents of those variables.

```python
#!/usr/bin/env python
# encoding: utf-8
#
# Copyright (c) 2010 Doug Hellmann.  All rights reserved.
#

import pdb

def recursive_function(n=5, output='to be printed'):
    if n > 0:
        recursive_function(n-1)
    else:
        pdb.set_trace()
        print output
    return

if __name__ == '__main__':
    recursive_function()
```

The **args** command (abbreviated **a**) prints all of the arguments to the function active in the current frame. This example also uses a recursive function to show what a deeper stack looks like when printed by **where**.

```
$ python pdb_function_arguments.py
> .../pdb_function_arguments.py(14)recursive_function()
-> return
(Pdb) where
  .../pdb_function_arguments.py(17)<module>()
-> recursive_function()
  .../pdb_function_arguments.py(11)recursive_function()
-> recursive_function(n-1)
  .../pdb_function_arguments.py(11)recursive_function()
-> recursive_function(n-1)
  .../pdb_function_arguments.py(11)recursive_function()
-> recursive_function(n-1)
  .../pdb_function_arguments.py(11)recursive_function()
-> recursive_function(n-1)
  .../pdb_function_arguments.py(11)recursive_function()
-> recursive_function(n-1)
> .../pdb_function_arguments.py(14)recursive_function()
-> return

(Pdb) args
n = 0
output = to be printed

(Pdb) up
> .../pdb_function_arguments.py(11)recursive_function()
-> recursive_function(n-1)
```

```
(Pdb) args
n = 1
output = to be printed

(Pdb)
```

The **p** command evaluates an expression given as argument and prints the result. You can also use Python's `print` statement, but that is passed through to the interpreter to be executed rather than running as a command in the debugger.

```
(Pdb) p n
1

(Pdb) print n
1
```

Similarly, prefixing an expression with **!** passes it to the Python interpreter to be evaluated. You can use this feature to execute arbitrary Python statements, including modifying variables. This example changes the value of *output* before letting the debugger continue running the program. The next statement after the call to `set_trace()` prints the value of *output*, showing the modified value.

```
$ python pdb_function_arguments.py
> .../pdb_function_arguments.py(14)recursive_function()
-> print output

(Pdb) !output
'to be printed'

(Pdb) !output='changed value'

(Pdb) continue
changed value
```

For more complicated values such as nested or large data structures, use **pp** to "pretty print" them. This program reads several lines of text from a file.

```
#!/usr/bin/env python
# encoding: utf-8
#
# Copyright (c) 2010 Doug Hellmann.  All rights reserved.
#

import pdb

with open('lorem.txt', 'rt') as f:
    lines = f.readlines()

pdb.set_trace()
```

Printing the variable `lines` with **p** results in output that is difficult to read because it wraps awkwardly. **pp** uses `pprint` to format the value for clean printing.

```
$ python pdb_pp.py
--Return--
> .../pdb_pp.py(12)<module>()->None
-> pdb.set_trace()
(Pdb) p lines
['Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Donec\n', 'egestas, enim
et consectetuer ullamcorper, lectus ligula rutrum leo, a\n', 'elementum elit tortor
eu quam.\n']
```

```
(Pdb) pp lines
['Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Donec\n',
 'egestas, enim et consectetuer ullamcorper, lectus ligula rutrum leo, a\n',
 'elementum elit tortor eu quam.\n']

(Pdb)
```

Stepping Through Your Program

In addition to navigating up and down the call stack when the program is paused, you can also step through execution of the program past the point where it enters the debugger.

```
#!/usr/bin/env python
# encoding: utf-8
#
# Copyright (c) 2010 Doug Hellmann.  All rights reserved.
#

import pdb

def f(n):
    for i in range(n):
        j = i * n
        print i, j
    return

if __name__ == '__main__':
    pdb.set_trace()
    f(5)
```

Use **step** to execute the current line and then stop at the next execution point – either the first statement inside a function being called or the next line of the current function.

```
$ python pdb_step.py
> /Users/dhellmann/Documents/PyMOTW/src.pdb/PyMOTW/pdb/pdb_step.py(17)<module>()
-> f(5)
```

The interpreter pauses at the call to `set_trace()` and gives control to the debugger. The first step causes the execution to enter `f()`.

```
(Pdb) step
--Call--
> .../pdb_step.py(9)f()
-> def f(n):
```

One more step moves execution to the first line of `f()` and starts the loop.

```
(Pdb) step
> /Users/dhellmann/Documents/PyMOTW/src.pdb/PyMOTW/pdb/pdb_step.py(10)f()
-> for i in range(n):
```

Stepping again moves to the first line inside the loop where `j` is defined.

```
(Pdb) step
> /Users/dhellmann/Documents/PyMOTW/src.pdb/PyMOTW/pdb/pdb_step.py(11)f()
-> j = i * n
(Pdb) p i
0
```

The value of i is 0, so after one more step the value of j should also be 0.

```
(Pdb) step
> /Users/dhellmann/Documents/PyMOTW/src.pdb/PyMOTW/pdb/pdb_step.py(12)f()
-> print i, j

(Pdb) p j
0

(Pdb)
```

Stepping one line at a time like this can become tedious if there is a lot of code to cover before the point where the error occurs, or if the same function is called repeatedly.

```
#!/usr/bin/env python
# encoding: utf-8
#
# Copyright (c) 2010 Doug Hellmann.  All rights reserved.
#

import pdb

def calc(i, n):
    j = i * n
    return j

def f(n):
    for i in range(n):
        j = calc(i, n)
        print i, j
    return

if __name__ == '__main__':
    pdb.set_trace()
    f(5)
```

In this example, there is nothing wrong with calc(), so stepping through it each time it is called in the loop in f() obscures the useful output by showing all of the lines of calc() as they are executed.

```
$ python pdb_next.py
> .../pdb_next.py(21)<module>()
-> f(5)
(Pdb) step
--Call--
> .../pdb_next.py(13)f()
-> def f(n):

(Pdb) step
> .../pdb_next.py(14)f()
-> for i in range(n):

(Pdb) step
> .../pdb_next.py(15)f()
-> j = calc(i, n)

(Pdb) step
--Call--
> .../pdb_next.py(9)calc()
-> def calc(i, n):
```

```
(Pdb) step
> .../pdb_next.py(10)calc()
-> j = i * n

(Pdb) step
> .../pdb_next.py(11)calc()
-> return j

(Pdb) step
--Return--
> .../pdb_next.py(11)calc()->0
-> return j

(Pdb) step
> .../pdb_next.py(16)f()
-> print i, j

(Pdb) step
0 0
```

The **next** command is like step, but does not enter functions called from the statement being executed. In effect, it steps all the way through the function call to the next statement in the current function in a single operation.

```
> .../pdb_next.py(14)f()
-> for i in range(n):
(Pdb) step
> .../pdb_next.py(15)f()
-> j = calc(i, n)

(Pdb) next
> .../pdb_next.py(16)f()
-> print i, j

(Pdb)
```

The **until** command is like **next**, except it explicitly continues until execution reaches a line in the same function with a line number higher than the current value. That means, for example, that **until** can be used to step past the end of a loop.

```
$ python pdb_next.py
> .../pdb_next.py(21)<module>()
-> f(5)
(Pdb) step
--Call--
> .../pdb_next.py(13)f()
-> def f(n):

(Pdb) step
> .../pdb_next.py(14)f()
-> for i in range(n):

(Pdb) step
> .../pdb_next.py(15)f()
-> j = calc(i, n)

(Pdb) next
> .../pdb_next.py(16)f()
-> print i, j
```

```
(Pdb) until
0 0
1 5
2 10
3 15
4 20
> .../pdb_next.py(17)f()
-> return

(Pdb)
```

Before **until** was run, the current line was 16, the last line of the loop. After **until** ran, execution was on line 17, and the loop had been exhausted.

return is another short-cut for bypassing parts of a function. It continues executing until the function is about to execute a `return` statement, and then it pauses. This gives you time to look at the return value before the function returns.

```
$ python pdb_next.py
> .../pdb_next.py(21)<module>()
-> f(5)
(Pdb) step
--Call--
> .../pdb_next.py(13)f()
-> def f(n):

(Pdb) step
> .../pdb_next.py(14)f()
-> for i in range(n):

(Pdb) return
0 0
1 5
2 10
3 15
4 20
--Return--
> .../pdb_next.py(17)f()->None
-> return

(Pdb)
```

23.4.3 Breakpoints

As programs grow even longer, even using **next** and **until** will become slow and cumbersome. Instead of stepping through the program by hand, a better solution is to let it run normally until it reaches a point where you want the debugger to interrupt it. You could use `set_trace()` to start the debugger, but that only works if there is only one point you want to pause the program. It is more convenient to run the program through the debugger, but tell the debugger where to stop in advance using *breakpoints*. The debugger monitors your program, and when it reaches the location described by a breakpoint the program is paused before the line is executed.

```
#!/usr/bin/env python
# encoding: utf-8
#
# Copyright (c) 2010 Doug Hellmann.  All rights reserved.
#
```

```

def calc(i, n):
    j = i * n
    print 'j =', j
    if j > 0:
        print 'Positive!'
    return j

def f(n):
    for i in range(n):
        print 'i =', i
        j = calc(i, n)
    return

if __name__ == '__main__':
    f(5)
```

There are several options to the **break** command used for setting break points. You can specify the line number, file, and function where processing should pause. To set a breakpoint on a specific line of the current file, use `break lineno`:

```
$ python -m pdb pdb_break.py
> .../pdb_break.py(7)<module>()
-> def calc(i, n):
(Pdb) break 11
Breakpoint 1 at .../pdb_break.py:11

(Pdb) continue
i = 0
j = 0
i = 1
j = 5
> .../pdb_break.py(11)calc()
-> print 'Positive!'

(Pdb)
```

The command **continue** tells the debugger to keep running your program until the next breakpoint. In this case, it runs through the first iteration of the `for` loop in `f()` and stops inside `calc()` during the second iteration.

Breakpoints can also be set to the first line of a function by specifying the function name instead of a line number. This example shows what happens if a breakpoint is added for the `calc()` function.

```
$ python -m pdb pdb_break.py
> .../pdb_break.py(7)<module>()
-> def calc(i, n):
(Pdb) break calc
Breakpoint 1 at .../pdb_break.py:7

(Pdb) continue
i = 0
> .../pdb_break.py(8)calc()
-> j = i * n

(Pdb) where
  .../pdb_break.py(21)<module>()
-> f(5)
  .../pdb_break.py(17)f()
-> j = calc(i, n)
```

```
> .../pdb_break.py(8)calc()
-> j = i * n

(Pdb)
```

To specify a breakpoint in another file, prefix the line or function argument with a filename.

```
#!/usr/bin/env python
# encoding: utf-8
#
# Copyright (c) 2010 Doug Hellmann.  All rights reserved.
#

from pdb_break import f

f(5)
```

Here a breakpoint is set for line 11 of `pdb_break.py` after starting the main program `pdb_break_remote.py`.

```
$ python -m pdb pdb_break_remote.py
> .../pdb_break_remote.py(7)<module>()
-> from pdb_break import f
(Pdb) break pdb_break.py:11
Breakpoint 1 at .../pdb_break.py:11

(Pdb) continue
i = 0
j = 0
i = 1
j = 5
> .../pdb_break.py(11)calc()
-> print 'Positive!'

(Pdb)
```

The filename can be a full path to the source file, or a relative path to a file available on `sys.path`.

To list the breakpoints currently set, use **break** without any arguments. The output includes the file and line number of each break point, as well as information about how many times it has been encountered.

```
$ python -m pdb pdb_break.py
> .../pdb_break.py(7)<module>()
-> def calc(i, n):
(Pdb) break 11
Breakpoint 1 at .../pdb_break.py:11

(Pdb) break
Num Type         Disp Enb   Where
1   breakpoint   keep yes   at .../pdb_break.py:11

(Pdb) continue
i = 0
j = 0
i = 1
j = 5
> .../pdb/pdb_break.py(11)calc()
-> print 'Positive!'

(Pdb) continue
```

```
Positive!
i = 2
j = 10
> .../pdb_break.py(11)calc()
-> print 'Positive!'

(Pdb) break
Num Type         Disp Enb   Where
1   breakpoint   keep yes   at .../pdb_break.py:11
        breakpoint already hit 2 times

(Pdb)
```

Managing Breakpoints

As each new breakpoint is added, it is assigned a numerical identifier. These ID numbers are used to enable, disable, and remove the breakpoints interactively.

Turning off a breakpoint with **disable** tells the debugger not to stop when that line is reached. The breakpoint is remembered, but ignored.

```
$ python -m pdb pdb_break.py
> .../pdb_break.py(7)<module>()
-> def calc(i, n):
(Pdb) break calc
Breakpoint 1 at .../pdb_break.py:7

(Pdb) break 11
Breakpoint 2 at .../pdb_break.py:11

(Pdb) break
Num Type         Disp Enb   Where
1   breakpoint   keep yes   at .../pdb_break.py:7
2   breakpoint   keep yes   at .../pdb_break.py:11

(Pdb) disable 1

(Pdb) break
Num Type         Disp Enb   Where
1   breakpoint   keep no    at .../pdb_break.py:7
2   breakpoint   keep yes   at .../pdb_break.py:11

(Pdb) continue
i = 0
j = 0
i = 1
j = 5
> .../pdb_break.py(11)calc()
-> print 'Positive!'

(Pdb)
```

The debugging session below sets two breakpoints in the program, then disables one. The program is run until the remaining breakpoint is encountered, and then the other breakpoint is turned back on with **enable** before execution continues.

```
$ python -m pdb pdb_break.py
> .../pdb_break.py(7)<module>()
-> def calc(i, n):
(Pdb) break calc
Breakpoint 1 at .../pdb_break.py:7

(Pdb) break 16
Breakpoint 2 at .../pdb_break.py:16

(Pdb) disable 1

(Pdb) continue
> .../pdb_break.py(16)f()
-> print ’i =’, i

(Pdb) list
 11             print ’Positive!’
 12         return j
 13
 14     def f(n):
 15         for i in range(n):
 16 B->         print ’i =’, i
 17             j = calc(i, n)
 18         return
 19
 20     if __name__ == ’__main__’:
 21         f(5)

(Pdb) continue
i = 0
j = 0
> .../pdb_break.py(16)f()
-> print ’i =’, i

(Pdb) list
 11             print ’Positive!’
 12         return j
 13
 14     def f(n):
 15         for i in range(n):
 16 B->         print ’i =’, i
 17             j = calc(i, n)
 18         return
 19
 20     if __name__ == ’__main__’:
 21         f(5)

(Pdb) p i
1

(Pdb) enable 1

(Pdb) continue
i = 1
> .../pdb_break.py(8)calc()
-> j = i * n

(Pdb) list
```

```
  3     #
  4     # Copyright (c) 2010 Doug Hellmann.  All rights reserved.
  5     #
  6
  7 B   def calc(i, n):
  8  ->     j = i * n
  9         print 'j =', j
 10         if j > 0:
 11             print 'Positive!'
 12         return j
 13

(Pdb)
```

The lines prefixed with `B` in the output from **list** show where the breakpoints are set in the program (lines 9 and 18).

Use **clear** to delete a breakpoint entirely.

```
$ python -m pdb pdb_break.py
> .../pdb_break.py(7)<module>()
-> def calc(i, n):
(Pdb) break calc
Breakpoint 1 at .../pdb_break.py:7

(Pdb) break 11
Breakpoint 2 at .../pdb_break.py:11

(Pdb) break 16
Breakpoint 3 at .../pdb_break.py:16

(Pdb) break
Num Type         Disp Enb   Where
1   breakpoint   keep yes   at .../pdb_break.py:7
2   breakpoint   keep yes   at .../pdb_break.py:11
3   breakpoint   keep yes   at .../pdb_break.py:16

(Pdb) clear 2
Deleted breakpoint 2

(Pdb) break
Num Type         Disp Enb   Where
1   breakpoint   keep yes   at .../pdb_break.py:7
3   breakpoint   keep yes   at .../pdb_break.py:16

(Pdb)
```

The other breakpoints retain their original identifiers and are not renumbered.

Temporary Breakpoints

A temporary breakpoint is automatically cleared the first time program execution hits it. Using a temporary breakpoint lets you reach a particular spot in the program flow quickly, just as with a regular breakpoint, but since it is cleared immediately it does not interfere with subsequent progress if that part of the program is run repeatedly.

```
$ python -m pdb pdb_break.py
> .../pdb_break.py(7)<module>()
-> def calc(i, n):
(Pdb) tbreak 11
```

```
Breakpoint 1 at .../pdb_break.py:11

(Pdb) continue
i = 0
j = 0
i = 1
j = 5
Deleted breakpoint 1
> .../pdb_break.py(11)calc()
-> print 'Positive!'

(Pdb) break

(Pdb) continue
Positive!
i = 2
j = 10
Positive!
i = 3
j = 15
Positive!
i = 4
j = 20
Positive!
The program finished and will be restarted
> .../pdb_break.py(7)<module>()
-> def calc(i, n):

(Pdb)
```

After the program reaches line 11 the first time, the breakpoint is removed and execution does not stop again until the program finishes.

Conditional Breakpoints

Rules can be applied to breakpoints so that execution only stops when the conditions are met. Using conditional breakpoints gives you finer control over how the debugger pauses your program than manually enabling and disabling breakpoints yourself.

Conditional breakpoints can be set in two ways. The first is to specify the condition when the breakpoint is set using **break**.

```
$ python -m pdb pdb_break.py
> .../pdb_break.py(7)<module>()
-> def calc(i, n):
(Pdb) break 9, j>0
Breakpoint 1 at .../pdb_break.py:9

(Pdb) break
Num Type         Disp Enb   Where
1   breakpoint   keep yes   at .../pdb_break.py:9
        stop only if j>0

(Pdb) continue
i = 0
j = 0
i = 1
```

```
> .../pdb_break.py(9)calc()
-> print 'j =', j

(Pdb)
```

The condition argument must be an expression using values visible in the stack frame where the breakpoint is defined. If the expression evaluates as true, execution stops at the breakpoint.

A condition can also be applied to an existing breakpoint using the **condition** command. The arguments are the breakpoint ID and the expression.

```
$ python -m pdb pdb_break.py
> .../pdb_break.py(7)<module>()
-> def calc(i, n):
(Pdb) break 9
Breakpoint 1 at .../pdb_break.py:9

(Pdb) break
Num Type         Disp Enb   Where
1   breakpoint   keep yes   at .../pdb_break.py:9

(Pdb) condition 1 j>0

(Pdb) break
Num Type         Disp Enb   Where
1   breakpoint   keep yes   at .../pdb_break.py:9
        stop only if j>0

(Pdb)
```

Ignoring Breakpoints

Programs with a lot of looping or recursive calls to the same function are often easier to debug by "skipping ahead" in the execution, instead of watching every call or breakpoint. The **ignore** command tells the debugger to pass over a breakpoint without stopping. Each time processing encounteres the breakpoint, it decrements the ignore counter. When the counter is zero, the breakpoint is re-activated.

```
$ python -m pdb pdb_break.py
> .../pdb_break.py(7)<module>()
-> def calc(i, n):
(Pdb) break 17
Breakpoint 1 at .../pdb_break.py:17

(Pdb) continue
i = 0
> .../pdb_break.py(17)f()
-> j = calc(i, n)

(Pdb) next
j = 0
> .../pdb_break.py(15)f()
-> for i in range(n):

(Pdb) ignore 1 2
Will ignore next 2 crossings of breakpoint 1.

(Pdb) break
```

```
Num Type         Disp Enb   Where
1   breakpoint   keep yes   at .../pdb_break.py:17
        ignore next 2 hits
        breakpoint already hit 1 time

(Pdb) continue
i = 1
j = 5
Positive!
i = 2
j = 10
Positive!
i = 3
> .../pdb_break.py(17)f()
-> j = calc(i, n)

(Pdb) break
Num Type         Disp Enb   Where
1   breakpoint   keep yes   at .../pdb_break.py:17
        breakpoint already hit 4 times
```

Explicitly resetting the ignore count to zero re-enables the breakpoint immediately.

```
$ python -m pdb pdb_break.py
> .../pdb_break.py(7)<module>()
-> def calc(i, n):
(Pdb) break 17
Breakpoint 1 at .../pdb_break.py:17

(Pdb) ignore 1 2
Will ignore next 2 crossings of breakpoint 1.

(Pdb) break
Num Type         Disp Enb   Where
1   breakpoint   keep yes   at .../pdb_break.py:17
        ignore next 2 hits

(Pdb) ignore 1 0
Will stop next time breakpoint 1 is reached.

(Pdb) break
Num Type         Disp Enb   Where
1   breakpoint   keep yes   at .../pdb_break.py:17
```

Triggering Actions on a Breakpoint

In addition to the purely interactive mode, `pdb` supports basic scripting. Using **commands**, you can define a series of interpreter commands, including Python statements, to be executed when a specific breakpoint is encountered. After running **commands** with the breakpoint number as argument, the debugger prompt changes to `(com)`. Enter commands one a time, and finish the list with `end` to save the script and return to the main debugger prompt.

```
$ python -m pdb pdb_break.py
> .../pdb_break.py(7)<module>()
-> def calc(i, n):
(Pdb) break 9
Breakpoint 1 at .../pdb_break.py:9
```

```
(Pdb) commands 1
(com) print 'debug i =', i
(com) print 'debug j =', j
(com) print 'debug n =', n
(com) end

(Pdb) continue
i = 0
debug i = 0
debug j = 0
debug n = 5
> .../pdb_break.py(9)calc()
-> print 'j =', j

(Pdb) continue
j = 0
i = 1
debug i = 1
debug j = 5
debug n = 5
> .../pdb_break.py(9)calc()
-> print 'j =', j

(Pdb)
```

This feature is especially useful for debugging code that uses a lot of data structures or variables, since you can have the debugger print out all of the values automatically, instead of doing it manually each time the breakpoint is encountered.

23.4.4 Changing Execution Flow

The **jump** command lets you alter the flow of your program at runtime, without modifying the code. You can skip forwards to avoid running some code, or backwards to run it again. This sample program generates a list of numbers.

```
#!/usr/bin/env python
# encoding: utf-8
#
# Copyright (c) 2010 Doug Hellmann.  All rights reserved.
#

def f(n):
    result = []
    j = 0
    for i in range(n):
        j = i * n + j
        j += n
        result.append(j)
    return result

if __name__ == '__main__':
    print f(5)
```

When run without interference the output is a sequence of increasing numbers divisible by 5.

```
$ python pdb_jump.py

[5, 15, 30, 50, 75]
```

Jump Ahead

Jumping ahead moves the point of execution past the current location without evaluating any of the statements in between. By skipping over line 13 in the example below, the value of `j` is not incremented and all of the subsequent values that depend on it are a little smaller.

```
$ python -m pdb pdb_jump.py
> .../pdb_jump.py(7)<module>()
-> def f(n):
(Pdb) break 12
Breakpoint 1 at .../pdb_jump.py:12

(Pdb) continue
> .../pdb_jump.py(12)f()
-> j += n

(Pdb) p j
0

(Pdb) step
> .../pdb_jump.py(13)f()
-> result.append(j)

(Pdb) p j
5

(Pdb) continue
> .../pdb_jump.py(12)f()
-> j += n

(Pdb) jump 13
> .../pdb_jump.py(13)f()
-> result.append(j)

(Pdb) p j
10

(Pdb) disable 1

(Pdb) continue
[5, 10, 25, 45, 70]

The program finished and will be restarted
> .../pdb_jump.py(7)<module>()
-> def f(n):
(Pdb)
```

Jump Back

Jumps can also move the program execution to a statement that has already been executed, to run it again. Here, the value of `j` is incremented an extra time, so the numbers in the result sequence are all larger than they would otherwise be.

```
$ python -m pdb pdb_jump.py
> .../pdb_jump.py(7)<module>()
-> def f(n):
(Pdb) break 13
```

```
Breakpoint 1 at .../pdb_jump.py:13

(Pdb) continue
> .../pdb_jump.py(13)f()
-> result.append(j)

(Pdb) p j
5

(Pdb) jump 12
> .../pdb_jump.py(12)f()
-> j += n

(Pdb) continue
> .../pdb_jump.py(13)f()
-> result.append(j)

(Pdb) p j
10

(Pdb) disable 1

(Pdb) continue
[10, 20, 35, 55, 80]

The program finished and will be restarted
> .../pdb_jump.py(7)<module>()
-> def f(n):
(Pdb)
```

Illegal Jumps

Jumping in and out of certain flow control statements is dangerous or undefined, and therefore prevented by the debugger.

```python
#!/usr/bin/env python
# encoding: utf-8
#
# Copyright (c) 2010 Doug Hellmann.  All rights reserved.
#

def f(n):
    if n < 0:
        raise ValueError('Invalid n: %s' % n)
    result = []
    j = 0
    for i in range(n):
        j = i * n + j
        j += n
        result.append(j)
    return result


if __name__ == '__main__':
    try:
        print f(5)
    finally:
```

```
23          print 'Always printed'
24
25      try:
26          print f(-5)
27      except:
28          print 'There was an error'
29      else:
30          print 'There was no error'
31
32      print 'Last statement'
```

You can jump into a function, but if you do the arguments are not defined and the code is unlikely to work.

```
$ python -m pdb pdb_no_jump.py
> .../pdb_no_jump.py(7)<module>()
-> def f(n):
(Pdb) break 21
Breakpoint 1 at .../pdb_no_jump.py:21

(Pdb) jump 8
> .../pdb_no_jump.py(8)<module>()
-> if n < 0:

(Pdb) p n
*** NameError: NameError("name 'n' is not defined",)

(Pdb) args

(Pdb)
```

You cannot jump into the middle of a block such as a `for` loop or `try:except` statement.

```
$ python -m pdb pdb_no_jump.py
> .../pdb_no_jump.py(7)<module>()
-> def f(n):
(Pdb) break 21
Breakpoint 1 at .../pdb_no_jump.py:21

(Pdb) continue
> .../pdb_no_jump.py(21)<module>()
-> print f(5)

(Pdb) jump 26
*** Jump failed: can't jump into the middle of a block

(Pdb)
```

The code in a `finally` block must all be executed, so you cannot jump out of the block.

```
$ python -m pdb pdb_no_jump.py
> .../pdb_no_jump.py(7)<module>()
-> def f(n):
(Pdb) break 23
Breakpoint 1 at .../pdb_no_jump.py:23

(Pdb) continue
[5, 15, 30, 50, 75]
> .../pdb_no_jump.py(23)<module>()
-> print 'Always printed'
```

```
(Pdb) jump 25
*** Jump failed: can't jump into or out of a 'finally' block

(Pdb)
```

And the most basic restriction is that jumping is constrained to the bottom frame on the call stack. If you move up the stack to examine variables, you cannot change the execution flow at that point.

```
$ python -m pdb pdb_no_jump.py
> .../pdb_no_jump.py(7)<module>()
-> def f(n):
(Pdb) break 11
Breakpoint 1 at .../pdb_no_jump.py:11

(Pdb) continue
> .../pdb_no_jump.py(11)f()
-> j = 0

(Pdb) where
  /Library/Frameworks/Python.framework/Versions/2.7/lib/python2.7/bdb.py(379)run()
-> exec cmd in globals, locals
  <string>(1)<module>()
  .../pdb_no_jump.py(21)<module>()
-> print f(5)
> .../pdb_no_jump.py(11)f()
-> j = 0

(Pdb) up
> .../pdb_no_jump.py(21)<module>()
-> print f(5)

(Pdb) jump 25
*** You can only jump within the bottom frame

(Pdb)
```

Restarting Your Program

When the debugger reaches the end of your program, it automatically starts it over, but you can also restart it explicitly without leaving the debugger and losing your breakpoints or other settings.

```python
#!/usr/bin/env python
# encoding: utf-8
#
# Copyright (c) 2010 Doug Hellmann.  All rights reserved.
#

import sys

def f():
    print 'Command line args:', sys.argv
    return

if __name__ == '__main__':
    f()
```

Running the above program to completion within the debugger prints the name of the script file, since no other arguments were given on the command line.

```
$ python -m pdb pdb_run.py
> .../pdb_run.py(7)<module>()
-> import sys
(Pdb) continue

Command line args: ['pdb_run.py']
The program finished and will be restarted
> .../pdb_run.py(7)<module>()
-> import sys

(Pdb)
```

The program can be restarted using **run**. Arguments passed to **run** are parsed with `shlex` and passed to the program as though they were command line arguments, so you can restart the program with different settings.

```
(Pdb) run a b c "this is a long value"
Restarting pdb_run.py with arguments:
        a b c this is a long value
> .../pdb_run.py(7)<module>()
-> import sys

(Pdb) continue
Command line args: ['pdb_run.py', 'a', 'b', 'c', 'this is a long value']
The program finished and will be restarted
> .../pdb_run.py(7)<module>()
-> import sys

(Pdb)
```

run can also be used at any other point in processing to restart the program.

```
$ python -m pdb pdb_run.py
> .../pdb_run.py(7)<module>()
-> import sys
(Pdb) break 10
Breakpoint 1 at .../pdb_run.py:10

(Pdb) continue
> .../pdb_run.py(10)f()
-> print 'Command line args:', sys.argv

(Pdb) run one two three
Restarting pdb_run.py with arguments:
        one two three
> .../pdb_run.py(7)<module>()
-> import sys

(Pdb)
```

23.4.5 Customizing the Debugger with Aliases

You can avoid typing complex commands repeatedly by using **alias** to define a shortcut. Alias expansion is applied to the first word of each command. The body of the alias can consist of any command that is legal to type at the debugger prompt, including other debugger commands and pure Python expressions. Recursion is allowed in alias definitions, so one alias can even invoke another.

```
$ python -m pdb pdb_function_arguments.py
> .../pdb_function_arguments.py(7)<module>()
-> import pdb
(Pdb) break 10
Breakpoint 1 at .../pdb_function_arguments.py:10

(Pdb) continue
> .../pdb_function_arguments.py(10)recursive_function()
-> if n > 0:

(Pdb) pp locals().keys()
['output', 'n']

(Pdb) alias pl pp locals().keys()

(Pdb) pl
['output', 'n']
```

Running **alias** without any arguments shows the list of defined aliases. A single argument is assumed to be the name of an alias, and its definition is printed.

```
(Pdb) alias
pl = pp locals().keys()

(Pdb) alias pl
pl = pp locals().keys()
(Pdb)
```

Arguments to the alias are referenced using `%n` where *n* is replaced with a number indicating the position of the argument, starting with `1`. To consume all of the arguments, use `%*`.

```
$ python -m pdb pdb_function_arguments.py
> .../pdb_function_arguments.py(7)<module>()
-> import pdb
(Pdb) alias ph !help(%1)

(Pdb) ph locals
Help on built-in function locals in module __builtin__:

locals(...)
    locals() -> dictionary

    Update and return a dictionary containing the current scope's local variables.
```

Clear the definition of an alias with **unalias**.

```
(Pdb) unalias ph

(Pdb) ph locals
*** SyntaxError: invalid syntax (<stdin>, line 1)

(Pdb)
```

23.4.6 Saving Configuration Settings

Debugging a program involves a lot of repetition; running the code, observing the output, adjusting the code or inputs, and running it again. `pdb` attempts to cut down on the amount of repetition you need to use to control the debugging experience, to let you concentrate on your code instead of the debugger. To help reduce the number of times you issue the same commands to the debugger, `pdb` lets you save configuration using text files read and interpreted on startup.

The file `~/.pdbrc` is read first, allowing you to set global personal preferences for all of your debugging sessions. Then `./.pdbrc` is read from the current working directory, so you can set local preferences for a particular project.

```
$ cat ~/.pdbrc
# Show python help
alias ph !help(%1)
# Overridden alias
alias redefined p 'home definition'

$ cat .pdbrc
# Breakpoints
break 10
# Overridden alias
alias redefined p 'local definition'

$ python -m pdb pdb_function_arguments.py
Breakpoint 1 at .../pdb_function_arguments.py:10
> .../pdb_function_arguments.py(7)<module>()
-> import pdb
(Pdb) alias
ph = !help(%1)
redefined = p 'local definition'

(Pdb) break
Num Type         Disp Enb   Where
1   breakpoint   keep yes   at .../pdb_function_arguments.py:10

(Pdb)
```

Any configuration commands that can be typed at the debugger prompt can be saved in one of the startup files, but most commands that control the execution (**continue**, **jump**, etc.) cannot. The exception is **run**, which means you can set the command line arguments for a debugging session in `./.pdbrc` so they are consistent across several runs.

See also:

pdb (http://docs.python.org/library/pdb.html) The standard library documentation for this module.

`readline` Interactive prompt editing library.

`cmd` Build interactive programs.

`shlex` Shell command line parsing.

CHAPTER

TWENTYFOUR

DEBUGGING AND PROFILING

24.1 profile, cProfile, and pstats – Performance analysis of Python programs.

Purpose Performance analysis of Python programs.

Available In 1.4 and later, these examples are for Python 2.5

The `profile` and `cProfile` modules provide APIs for collecting and analyzing statistics about how Python source consumes processor resources.

24.1.1 run()

The most basic starting point in the profile module is `run()`. It takes a string statement as argument, and creates a report of the time spent executing different lines of code while running the statement.

```
import profile

def fib(n):
    # from http://en.literateprograms.org/Fibonacci_numbers_(Python)
    if n == 0:
        return 0
    elif n == 1:
        return 1
    else:
        return fib(n-1) + fib(n-2)

def fib_seq(n):
    seq = [ ]
    if n > 0:
        seq.extend(fib_seq(n-1))
    seq.append(fib(n))
    return seq

print 'RAW'
print '=' * 80
profile.run('print fib_seq(20); print')
```

This recursive version of a fibonacci sequence calculator [1] is especially useful for demonstrating the profile because we can improve the performance so much. The standard report format shows a summary and then details for each function executed.

[1] Fibonacci numbers (Python) - LiteratePrograms (http://en.literateprograms.org/Fibonacci_numbers_(Python))

```
$ python profile_fibonacci_raw.py
RAW
================================================================================
[0, 1, 1, 2, 3, 5, 8, 13, 21, 34, 55, 89, 144, 233, 377, 610, 987, 1597, 2584, 4181, 6765]

         57356 function calls (66 primitive calls) in 0.746 CPU seconds

   Ordered by: standard name

   ncalls  tottime  percall  cumtime  percall filename:lineno(function)
       21    0.000    0.000    0.000    0.000 :0(append)
       20    0.000    0.000    0.000    0.000 :0(extend)
        1    0.001    0.001    0.001    0.001 :0(setprofile)
        1    0.000    0.000    0.744    0.744 <string>:1(<module>)
        1    0.000    0.000    0.746    0.746 profile:0(print fib_seq(20); print)
        0    0.000             0.000          profile:0(profiler)
 57291/21    0.743    0.000    0.743    0.035 profile_fibonacci_raw.py:13(fib)
     21/1    0.001    0.000    0.744    0.744 profile_fibonacci_raw.py:22(fib_seq)
```

As you can see, it takes 57356 separate function calls and 3/4 of a second to run. Since there are only 66 *primitive* calls, we know that the vast majority of those 57k calls were recursive. The details about where time was spent are broken out by function in the listing showing the number of calls, total time spent in the function, time per call (tottime/ncalls), cumulative time spent in a function, and the ratio of cumulative time to primitive calls.

Not surprisingly, most of the time here is spent calling `fib()` repeatedly. We can add a memoize decorator [2] to reduce the number of recursive calls and have a big impact on the performance of this function.

```
import profile

class memoize:
    # from http://avinashv.net/2008/04/python-decorators-syntactic-sugar/
    def __init__(self, function):
        self.function = function
        self.memoized = {}

    def __call__(self, *args):
        try:
            return self.memoized[args]
        except KeyError:
            self.memoized[args] = self.function(*args)
            return self.memoized[args]

@memoize
def fib(n):
    # from http://en.literateprograms.org/Fibonacci_numbers_(Python)
    if n == 0:
        return 0
    elif n == 1:
        return 1
    else:
        return fib(n-1) + fib(n-2)

def fib_seq(n):
    seq = [ ]
    if n > 0:
        seq.extend(fib_seq(n-1))
    seq.append(fib(n))
```

[2] Python Decorators: Syntactic Sugar | avinash.vora (http://avinashv.net/2008/04/python-decorators-syntactic-sugar/)

```
    return seq

if __name__ == '__main__':
    print 'MEMOIZED'
    print '=' * 80
    profile.run('print fib_seq(20); print')
```

By remembering the Fibonacci value at each level we can avoid most of the recursion and drop down to 145 calls that only take 0.003 seconds. Also notice that the ncalls count for `fib()` shows that it *never* recurses.

```
$ python profile_fibonacci_memoized.py
MEMOIZED
================================================================================
[0, 1, 1, 2, 3, 5, 8, 13, 21, 34, 55, 89, 144, 233, 377, 610, 987, 1597, 2584, 4181, 6765]

         145 function calls (87 primitive calls) in 0.003 CPU seconds

   Ordered by: standard name

   ncalls  tottime  percall  cumtime  percall filename:lineno(function)
       21    0.000    0.000    0.000    0.000 :0(append)
       20    0.000    0.000    0.000    0.000 :0(extend)
        1    0.001    0.001    0.001    0.001 :0(setprofile)
        1    0.000    0.000    0.002    0.002 <string>:1(<module>)
        1    0.000    0.000    0.003    0.003 profile:0(print fib_seq(20); print)
        0    0.000             0.000          profile:0(profiler)
    59/21    0.001    0.000    0.001    0.000 profile_fibonacci_memoized.py:19(__call__)
       21    0.000    0.000    0.001    0.000 profile_fibonacci_memoized.py:26(fib)
     21/1    0.001    0.000    0.002    0.002 profile_fibonacci_memoized.py:36(fib_seq)
```

24.1.2 runctx()

Sometimes, instead of constructing a complex expression for `run()`, it is easier to build a simple expression and pass it parameters through a context, using `runctx()`.

```
import profile
from profile_fibonacci_memoized import fib, fib_seq

if __name__ == '__main__':
    profile.runctx('print fib_seq(n); print', globals(), {'n':20})
```

In this example, the value of "n" is passed through the local variable context instead of being embedded directly in the statement passed to `runctx()`.

```
$ python profile_runctx.py
[0, 1, 1, 2, 3, 5, 8, 13, 21, 34, 55, 89, 144, 233, 377, 610, 987, 1597, 2584, 4181, 6765]

         145 function calls (87 primitive calls) in 0.003 CPU seconds

   Ordered by: standard name

   ncalls  tottime  percall  cumtime  percall filename:lineno(function)
       21    0.000    0.000    0.000    0.000 :0(append)
       20    0.000    0.000    0.000    0.000 :0(extend)
        1    0.001    0.001    0.001    0.001 :0(setprofile)
        1    0.000    0.000    0.002    0.002 <string>:1(<module>)
        1    0.000    0.000    0.003    0.003 profile:0(print fib_seq(n); print)
        0    0.000             0.000           profile:0(profiler)
    59/21    0.001    0.000    0.001    0.000 profile_fibonacci_memoized.py:19(__call__)
       21    0.000    0.000    0.001    0.000 profile_fibonacci_memoized.py:26(fib)
     21/1    0.001    0.000    0.002    0.002 profile_fibonacci_memoized.py:36(fib_seq)
```

24.1.3 pstats: Saving and Working With Statistics

The standard report created by the `profile` functions is not very flexible. If it doesn't meet your needs, you can produce your own reports by saving the raw profiling data from `run()` and `runctx()` and processing it separately with the **Stats** class from `pstats`.

For example, to run several iterations of the same test and combine the results, you could do something like this:

```python
import profile
import pstats
from profile_fibonacci_memoized import fib, fib_seq

# Create 5 set of stats
filenames = []
for i in range(5):
    filename = 'profile_stats_%d.stats' % i
    profile.run('print %d, fib_seq(20)' % i, filename)

# Read all 5 stats files into a single object
stats = pstats.Stats('profile_stats_0.stats')
for i in range(1, 5):
    stats.add('profile_stats_%d.stats' % i)

# Clean up filenames for the report
stats.strip_dirs()

# Sort the statistics by the cumulative time spent in the function
stats.sort_stats('cumulative')

stats.print_stats()
```

The output report is sorted in descending order of cumulative time spent in the function and the directory names are removed from the printed filenames to conserve horizontal space.

```
$ python profile_stats.py
0 [0, 1, 1, 2, 3, 5, 8, 13, 21, 34, 55, 89, 144, 233, 377, 610, 987, 1597, 2584, 4181, 6765]
1 [0, 1, 1, 2, 3, 5, 8, 13, 21, 34, 55, 89, 144, 233, 377, 610, 987, 1597, 2584, 4181, 6765]
2 [0, 1, 1, 2, 3, 5, 8, 13, 21, 34, 55, 89, 144, 233, 377, 610, 987, 1597, 2584, 4181, 6765]
3 [0, 1, 1, 2, 3, 5, 8, 13, 21, 34, 55, 89, 144, 233, 377, 610, 987, 1597, 2584, 4181, 6765]
4 [0, 1, 1, 2, 3, 5, 8, 13, 21, 34, 55, 89, 144, 233, 377, 610, 987, 1597, 2584, 4181, 6765]
Sun Aug 31 11:29:36 2008    profile_stats_0.stats
Sun Aug 31 11:29:36 2008    profile_stats_1.stats
Sun Aug 31 11:29:36 2008    profile_stats_2.stats
Sun Aug 31 11:29:36 2008    profile_stats_3.stats
Sun Aug 31 11:29:36 2008    profile_stats_4.stats

         489 function calls (351 primitive calls) in 0.008 CPU seconds

   Ordered by: cumulative time

   ncalls  tottime  percall  cumtime  percall filename:lineno(function)
        5    0.000    0.000    0.007    0.001 <string>:1(<module>)
```

```
  105/5    0.004    0.000    0.007    0.001 profile_fibonacci_memoized.py:36(fib_seq)
      1    0.000    0.000    0.003    0.003 profile:0(print 0, fib_seq(20))
143/105    0.001    0.000    0.002    0.000 profile_fibonacci_memoized.py:19(__call__)
      1    0.000    0.000    0.001    0.001 profile:0(print 4, fib_seq(20))
      1    0.000    0.000    0.001    0.001 profile:0(print 1, fib_seq(20))
      1    0.000    0.000    0.001    0.001 profile:0(print 2, fib_seq(20))
      1    0.000    0.000    0.001    0.001 profile:0(print 3, fib_seq(20))
     21    0.000    0.000    0.001    0.000 profile_fibonacci_memoized.py:26(fib)
    100    0.001    0.000    0.001    0.000 :0(extend)
    105    0.001    0.000    0.001    0.000 :0(append)
      5    0.001    0.000    0.001    0.000 :0(setprofile)
      0    0.000             0.000          profile:0(profiler)
```

24.1.4 Limiting Report Contents

Since we are studying the performance of `fib()` and `fib_seq()`, we can also restrict the output report to only include those functions using a regular expression to match the `filename:lineno(function)` values we want.

```
import profile
import pstats
from profile_fibonacci_memoized import fib, fib_seq

# Read all 5 stats files into a single object
stats = pstats.Stats('profile_stats_0.stats')
for i in range(1, 5):
    stats.add('profile_stats_%d.stats' % i)
stats.strip_dirs()
stats.sort_stats('cumulative')

# limit output to lines with "(fib" in them
stats.print_stats('\(fib')
```

The regular expression includes a literal left paren (`(`) to match against the function name portion of the location value.

```
$ python profile_stats_restricted.py
Sun Aug 31 11:29:36 2008    profile_stats_0.stats
Sun Aug 31 11:29:36 2008    profile_stats_1.stats
Sun Aug 31 11:29:36 2008    profile_stats_2.stats
Sun Aug 31 11:29:36 2008    profile_stats_3.stats
Sun Aug 31 11:29:36 2008    profile_stats_4.stats

         489 function calls (351 primitive calls) in 0.008 CPU seconds

   Ordered by: cumulative time
   List reduced from 13 to 2 due to restriction <'\\(fib'>

   ncalls  tottime  percall  cumtime  percall filename:lineno(function)
    105/5    0.004    0.000    0.007    0.001 profile_fibonacci_memoized.py:36(fib_seq)
       21    0.000    0.000    0.001    0.000 profile_fibonacci_memoized.py:26(fib)
```

24.1.5 Caller / Callee Graphs

Stats also includes methods for printing the callers and callees of functions.

```
import profile
import pstats
from profile_fibonacci_memoized import fib, fib_seq

# Read all 5 stats files into a single object
stats = pstats.Stats('profile_stats_0.stats')
for i in range(1, 5):
    stats.add('profile_stats_%d.stats' % i)
stats.strip_dirs()
stats.sort_stats('cumulative')

print 'INCOMING CALLERS:'
stats.print_callers('\(fib')

print 'OUTGOING CALLEES:'
stats.print_callees('\(fib')
```

The arguments to `print_callers()` and `print_callees()` work the same as the restriction arguments to `print_stats()`. The output shows the caller, callee, and cumulative time.

```
$ python profile_stats_callers.py
INCOMING CALLERS:
   Ordered by: cumulative time
   List reduced from 13 to 2 due to restriction <'\\(fib'>

Function                                   was called by...
profile_fibonacci_memoized.py:36(fib_seq)  <- <string>:1(<module>)(5)    0.007
                                              profile_fibonacci_memoized.py:36(fib_seq)(100)    0.007
profile_fibonacci_memoized.py:26(fib)      <- profile_fibonacci_memoized.py:19(__call__)(21)    0.002


OUTGOING CALLEES:
   Ordered by: cumulative time
   List reduced from 13 to 2 due to restriction <'\\(fib'>

Function                                   called...
profile_fibonacci_memoized.py:36(fib_seq)  -> :0(append)(105)    0.001
                                              :0(extend)(100)    0.001
                                              profile_fibonacci_memoized.py:19(__call__)(105)    0.00
                                              profile_fibonacci_memoized.py:36(fib_seq)(100)    0.007
profile_fibonacci_memoized.py:26(fib)      -> profile_fibonacci_memoized.py:19(__call__)(38)    0.002
```

See also:

profile and cProfile (https://docs.python.org/2.7/library/profile.html) Standard library documentation for this module.

pstats (https://docs.python.org/2.7/library/profile.html#the-stats-class) Standard library documentation for pstats.

Gprof2Dot (http://code.google.com/p/jrfonseca/wiki/Gprof2Dot) Visualization tool for profile output data.

24.2 timeit – Time the execution of small bits of Python code.

Purpose Time the execution of small bits of Python code.

Available In 2.3

The `timeit` module provides a simple interface for determining the execution time of small bits of Python code. It uses a platform-specific time function to provide the most accurate time calculation possible. It reduces the impact of startup or shutdown costs on the time calculation by executing the code repeatedly.

24.2.1 Module Contents

`timeit` defines a single public class, `Timer`. The constructor for `Timer` takes a statement to be timed, and a setup statement (to initialize variables, for example). The Python statements should be strings and can include embedded newlines.

The `timeit()` method runs the setup statement one time, then executes the primary statement repeatedly and returns the amount of time which passes. The argument to timeit() controls how many times to run the statement; the default is 1,000,000.

24.2.2 Basic Example

To illustrate how the various arguments to `Timer` are used, here is a simple example which prints an identifying value when each statement is executed:

```python
import timeit

# using setitem
t = timeit.Timer("print 'main statement'", "print 'setup'")

print 'TIMEIT:'
print t.timeit(2)

print 'REPEAT:'
print t.repeat(3, 2)
```

When run, the output is:

```
$ python timeit_example.py

TIMEIT:
setup
main statement
main statement
1.90734863281e-06
REPEAT:
setup
main statement
main statement
setup
main statement
main statement
setup
main statement
main statement
[9.5367431640625e-07, 9.5367431640625e-07, 1.1920928955078125e-06]
```

When called, `timeit()` runs the setup statement one time, then calls the main statement count times. It returns a single floating point value representing the amount of time it took to run the main statement count times.

When `repeat()` is used, it calls `timeit()` severeal times (3 in this case) and all of the responses are returned in a list.

24.2.3 Storing Values in a Dictionary

For a more complex example, let's compare the amount of time it takes to populate a dictionary with a large number of values using a variety of methods. First, a few constants are needed to configure the `Timer`. We'll be using a list of tuples containing strings and integers. The `Timer` will be storing the integers in a dictionary using the strings as keys.

```
# {{{cog include('timeit/timeit_dictionary.py', 'header')}}}
import timeit
import sys

# A few constants
range_size=1000
count=1000
setup_statement="l = [ (str(x), x) for x in range(%d) ]; d = {}" % range_size
# {{{end}}}
```

Next, we can define a short utility function to print the results in a useful format. The `timeit()` method returns the amount of time it takes to execute the statement repeatedly. The output of `show_results()` converts that into the amount of time it takes per iteration, and then further reduces the value to the amount of time it takes to store one item in the dictionary (as averages, of course).

```
# {{{cog include('timeit/timeit_dictionary.py', 'show_results')}}}
def show_results(result):
    "Print results in terms of microseconds per pass and per item."
    global count, range_size
    per_pass = 1000000 * (result / count)
    print '%.2f usec/pass' % per_pass,
    per_item = per_pass / range_size
    print '%.2f usec/item' % per_item

print "%d items" % range_size
print "%d iterations" % count
print
# {{{end}}}
```

To establish a baseline, the first configuration tested will use `__setitem__()`. All of the other variations avoid overwriting values already in the dictionary, so this simple version should be the fastest.

Notice that the first argument to `Timer` is a multi-line string, with indention preserved to ensure that it parses correctly when run. The second argument is a constant established above to initialize the list of values and the dictionary.

```
# {{{cog include('timeit/timeit_dictionary.py', 'setitem')}}}
# Using __setitem__ without checking for existing values first
print '__setitem__:\t',
sys.stdout.flush()
# using setitem
t = timeit.Timer("""
for s, i in l:
    d[s] = i
""",
setup_statement)
show_results(t.timeit(number=count))
# {{{end}}}
```

The next variation uses `setdefault()` to ensure that values already in the dictionary are not overwritten.

```
# {{{cog include('timeit/timeit_dictionary.py', 'setdefault')}}}
# Using setdefault
```

```
print 'setdefault:\t',
sys.stdout.flush()
t = timeit.Timer("""
for s, i in l:
    d.setdefault(s, i)
""",
setup_statement)
show_results(t.timeit(number=count))
# {{{end}}}
```

Another way to avoid overwriting existing values is to use `has_key()` to check the contents of the dictionary explicitly.

```
# {{{cog include('timeit/timeit_dictionary.py', 'has_key')}}}
# Using has_key
print 'has_key:\t',
sys.stdout.flush()
# using setitem
t = timeit.Timer("""
for s, i in l:
    if not d.has_key(s):
        d[s] = i
""",
setup_statement)
show_results(t.timeit(number=count))
# {{{end}}}
```

Or by adding the value only if we receive a *KeyError* exception when looking for the existing value.

```
# {{{cog include('timeit/timeit_dictionary.py', 'exception')}}}
# Using exceptions
print 'KeyError:\t',
sys.stdout.flush()
# using setitem
t = timeit.Timer("""
for s, i in l:
    try:
        existing = d[s]
    except KeyError:
        d[s] = i
""",
setup_statement)
show_results(t.timeit(number=count))
# {{{end}}}
```

And the last method we will test is the (relatively) new form using "`in`" to determine if a dictionary has a particular key.

```
# {{{cog include('timeit/timeit_dictionary.py', 'in')}}}
# Using "in"
print '"not in":\t',
sys.stdout.flush()
# using setitem
t = timeit.Timer("""
for s, i in l:
    if s not in d:
        d[s] = i
""",
setup_statement)
```

```
show_results(t.timeit(number=count))
# {{{end}}}
```

When run, the script produces output similar to this:

```
$ python timeit_dictionary.py

1000 items
1000 iterations

__setitem__:    107.40 usec/pass 0.11 usec/item
setdefault:     228.97 usec/pass 0.23 usec/item
has_key:        183.76 usec/pass 0.18 usec/item
KeyError:       120.74 usec/pass 0.12 usec/item
"not in":       92.42 usec/pass 0.09 usec/item
```

Those times are for a MacBook Pro running Python 2.6. Your times will be different. Experiment with the *range_size* and *count* variables, since different combinations will produce different results.

24.2.4 From the Command Line

In addition to the programmatic interface, timeit provides a command line interface for testing modules without instrumentation.

To run the module, use the new *-m* option to find the module and treat it as the main program:

```
$ python -m timeit
```

For example, to get help:

```
$ python -m timeit -h

Tool for measuring execution time of small code snippets.

This module avoids a number of common traps for measuring execution
times.  See also Tim Peters' introduction to the Algorithms chapter in
the Python Cookbook, published by O'Reilly.

Library usage: see the Timer class.

Command line usage:
    python timeit.py [-n N] [-r N] [-s S] [-t] [-c] [-h] [--] [statement]

Options:
  -n/--number N: how many times to execute 'statement' (default: see below)
  -r/--repeat N: how many times to repeat the timer (default 3)
  -s/--setup S: statement to be executed once initially (default 'pass')
  -t/--time: use time.time() (default on Unix)
  -c/--clock: use time.clock() (default on Windows)
  -v/--verbose: print raw timing results; repeat for more digits precision
  -h/--help: print this usage message and exit
  --: separate options from statement, use when statement starts with -
  statement: statement to be timed (default 'pass')

A multi-line statement may be given by specifying each line as a
separate argument; indented lines are possible by enclosing an
argument in quotes and using leading spaces.  Multiple -s options are
treated similarly.
```

```
If -n is not given, a suitable number of loops is calculated by trying
successive powers of 10 until the total time is at least 0.2 seconds.

The difference in default timer function is because on Windows,
clock() has microsecond granularity but time()'s granularity is 1/60th
of a second; on Unix, clock() has 1/100th of a second granularity and
time() is much more precise.  On either platform, the default timer
functions measure wall clock time, not the CPU time.  This means that
other processes running on the same computer may interfere with the
timing.  The best thing to do when accurate timing is necessary is to
repeat the timing a few times and use the best time.  The -r option is
good for this; the default of 3 repetitions is probably enough in most
cases.  On Unix, you can use clock() to measure CPU time.

Note: there is a certain baseline overhead associated with executing a
pass statement.  The code here doesn't try to hide it, but you should
be aware of it.  The baseline overhead can be measured by invoking the
program without arguments.

The baseline overhead differs between Python versions!  Also, to
fairly compare older Python versions to Python 2.3, you may want to
use python -O for the older versions to avoid timing SET_LINENO
instructions.
```

The statement argument works a little differently than the argument to `Timer`. Instead of one long string, you pass each line of the instructions as a separate command line argument. To indent lines (such as inside a loop), embed spaces in the string by enclosing the whole thing in quotes. For example:

```
$ python -m timeit -s "d={}" "for i in range(1000):" "  d[str(i)] = i"

1000 loops, best of 3: 289 usec per loop
```

It is also possible to define a function with more complex code, then import the module and call the function from the command line:

```
def test_setitem(range_size=1000):
    l = [ (str(x), x) for x in range(range_size) ]
    d = {}
    for s, i in l:
        d[s] = i
```

Then to run the test:

```
$ python -m timeit "import timeit_setitem; timeit_setitem.test_setitem()\
"

1000 loops, best of 3: 417 usec per loop
```

See also:

timeit (http://docs.python.org/lib/module-timeit.html) Standard library documentation for this module.

`profile` The profile module is also useful for performance analysis.

24.3 trace – Follow Python statements as they are executed

Purpose Monitor which statements and functions are executed as a program runs to produce coverage and call-graph information.

Available In 2.3 and later

The `trace` module helps you understand the way your program runs. You can trace the statements executed, produce coverage reports, and investigate the relationships between functions that call each other.

24.3.1 Command Line Interface

It is easy use `trace` directly from the command line. Given the following Python scripts as input:

```
from recurse import recurse

def main():
    print 'This is the main program.'
    recurse(2)
    return

if __name__ == '__main__':
    main()

def recurse(level):
    print 'recurse(%s)' % level
    if level:
        recurse(level-1)
    return

def not_called():
    print 'This function is never called.'
```

Tracing Execution

We can see which statements are being executed as the program runs using the *--trace* option.

```
$ python -m trace --trace trace_example/main.py

 --- modulename: main, funcname: <module>
main.py(7): """
main.py(12): from recurse import recurse
 --- modulename: recurse, funcname: <module>
recurse.py(7): """
recurse.py(12): def recurse(level):
recurse.py(18): def not_called():
main.py(14): def main():
main.py(19): if __name__ == '__main__':
main.py(20):     main()
 --- modulename: main, funcname: main
main.py(15):     print 'This is the main program.'
This is the main program.
main.py(16):     recurse(2)
 --- modulename: recurse, funcname: recurse
recurse.py(13):     print 'recurse(%s)' % level
recurse(2)
```

```
recurse.py(14):     if level:
recurse.py(15):         recurse(level-1)
 --- modulename: recurse, funcname: recurse
recurse.py(13):     print 'recurse(%s)' % level
recurse(1)
recurse.py(14):     if level:
recurse.py(15):         recurse(level-1)
 --- modulename: recurse, funcname: recurse
recurse.py(13):     print 'recurse(%s)' % level
recurse(0)
recurse.py(14):     if level:
recurse.py(16):     return
recurse.py(16):     return
recurse.py(16):     return
main.py(17):     return
 --- modulename: trace, funcname: _unsettrace
trace.py(80):         sys.settrace(None)
```

The first part of the output shows some setup operations performed by `trace`. The rest of the output shows the entry into each function, including the module where the function is located, and then the lines of the source file as they are executed. You can see that `recurse()` is entered three times, as you would expect from the way it is called in `main()`.

Code Coverage

Running `trace` from the command line with the *--count* option will produce code coverage report information, so you can see which lines are run and which are skipped. Since your program is usually made up of multiple files, a separate coverage report is produced for each. By default the coverage report files are written to the same directory as the module, named after the module but with a `.cover` extension instead of `.py`.

```
$ python -m trace --count trace_example/main.py

This is the main program.
recurse(2)
recurse(1)
recurse(0)
```

And two output files, `trace_example/main.cover`:

```
    1: from recurse import recurse

    1: def main():
    1:     print 'This is the main program.'
    1:     recurse(2)
    1:     return

    1: if __name__ == '__main__':
    1:     main()
```

and `trace_example/recurse.cover`:

```
    1: def recurse(level):
    3:     print 'recurse(%s)' % level
    3:     if level:
    2:         recurse(level-1)
    3:     return
    1: def not_called():
           print 'This function is never called.'
```

Note: Although the line `def recurse(level):` has a count of `1`, that does not mean the function was only run once. It means the function *definition* was only executed once.

It is also possible to run the program several times, perhaps with different options, to save the coverage data and produce a combined report.

```
$ python -m trace --coverdir coverdir1 --count --file coverdir1/coverage\
_report.dat trace_example/main.py

Skipping counts file 'coverdir1/coverage_report.dat': [Errno 2] No such file or directory: 'coverdir1
This is the main program.
recurse(2)
recurse(1)
recurse(0)

$ python -m trace --coverdir coverdir1 --count --file coverdir1/coverage\
_report.dat trace_example/main.py

This is the main program.
recurse(2)
recurse(1)
recurse(0)

$ python -m trace --coverdir coverdir1 --count --file coverdir1/coverage\
_report.dat trace_example/main.py

This is the main program.
recurse(2)
recurse(1)
recurse(0)
```

Once the coverage information is recorded to the `.cover` files, you can produce reports with the *--report* option.

```
$ python -m trace --coverdir coverdir1 --report --summary --missing --fi\
le coverdir1/coverage_report.dat trace_example/main.py

lines   cov%   module   (path)
  515     0%   trace   (/Library/Frameworks/Python.framework/Versions/2.7/lib/python2.7/trace.py)
    8   100%   trace_example.main   (trace_example/main.py)
    8    87%   trace_example.recurse   (trace_example/recurse.py)
```

Since the program ran three times, the coverage report shows values three times higher than the first report. The *--summary* option adds the percent covered information to the output above. The `recurse` module is only 87% covered. A quick look at the cover file for recurse shows that the body of `not_called()` is indeed never run, indicated by the >>>>>> prefix.

```
    3: def recurse(level):
    9:     print 'recurse(%s)' % level
    9:     if level:
    6:         recurse(level-1)
    9:     return

    3: def not_called():
>>>>>>     print 'This function is never called.'
```

Calling Relationships

In addition to coverage information, `trace` will collect and report on the relationships between functions that call each other.

For a simple list of the functions called, use `--listfuncs`:

```
$ python -m trace --listfuncs trace_example/main.py

This is the main program.
recurse(2)
recurse(1)
recurse(0)

functions called:
filename: /Library/Frameworks/Python.framework/Versions/2.7/lib/python2.7/trace.py, modulename: trace
filename: trace_example/main.py, modulename: main, funcname: <module>
filename: trace_example/main.py, modulename: main, funcname: main
filename: trace_example/recurse.py, modulename: recurse, funcname: <module>
filename: trace_example/recurse.py, modulename: recurse, funcname: recurse
```

For more details about who is doing the calling, use `--trackcalls`.

```
$ python -m trace --listfuncs --trackcalls trace_example/main.py

This is the main program.
recurse(2)
recurse(1)
recurse(0)

calling relationships:

*** /Library/Frameworks/Python.framework/Versions/2.7/lib/python2.7/trace.py ***
    trace.Trace.runctx -> trace._unsettrace
  --> trace_example/main.py
    trace.Trace.runctx -> main.<module>

*** trace_example/main.py ***
    main.<module> -> main.main
  --> trace_example/recurse.py
    main.<module> -> recurse.<module>
    main.main -> recurse.recurse

*** trace_example/recurse.py ***
    recurse.recurse -> recurse.recurse
```

24.3.2 Programming Interface

For a little more control over the trace interface, you can invoke it from within your program using a `Trace` object. `Trace` lets you set up fixtures and other dependencies before running a single function or execing a Python command to be traced.

```
import trace
from trace_example.recurse import recurse

tracer = trace.Trace(count=False, trace=True)
tracer.run('recurse(2)')
```

Since the example only traces into the `recurse()` function, no information from `main.py` is included in the output.

```
$ python trace_run.py

 --- modulename: trace_run, funcname: <module>
<string>(1):   --- modulename: recurse, funcname: recurse
recurse.py(13):     print 'recurse(%s)' % level
recurse(2)
recurse.py(14):     if level:
recurse.py(15):         recurse(level-1)
 --- modulename: recurse, funcname: recurse
recurse.py(13):     print 'recurse(%s)' % level
recurse(1)
recurse.py(14):     if level:
recurse.py(15):         recurse(level-1)
 --- modulename: recurse, funcname: recurse
recurse.py(13):     print 'recurse(%s)' % level
recurse(0)
recurse.py(14):     if level:
recurse.py(16):     return
recurse.py(16):     return
recurse.py(16):     return
```

That same output could have been produced with the `runfunc()` method, too. `runfunc()` accepts arbitrary positional and keyword arguments, which are passed to the function when it is called by the tracer.

```python
import trace
from trace_example.recurse import recurse

tracer = trace.Trace(count=False, trace=True)
tracer.runfunc(recurse, 2)
```

```
$ python trace_runfunc.py

 --- modulename: recurse, funcname: recurse
recurse.py(13):     print 'recurse(%s)' % level
recurse(2)
recurse.py(14):     if level:
recurse.py(15):         recurse(level-1)
 --- modulename: recurse, funcname: recurse
recurse.py(13):     print 'recurse(%s)' % level
recurse(1)
recurse.py(14):     if level:
recurse.py(15):         recurse(level-1)
 --- modulename: recurse, funcname: recurse
recurse.py(13):     print 'recurse(%s)' % level
recurse(0)
recurse.py(14):     if level:
recurse.py(16):     return
recurse.py(16):     return
recurse.py(16):     return
```

Saving Result Data

Counts and coverage information can be recorded as well, just as with the command line interface. The data must be saved explicitly, using the `CoverageResults` instance from the `Trace` object.

```
import trace
from trace_example.recurse import recurse

tracer = trace.Trace(count=True, trace=False)
tracer.runfunc(recurse, 2)

results = tracer.results()
results.write_results(coverdir='coverdir2')
```

```
$ python trace_CoverageResults.py

recurse(2)
recurse(1)
recurse(0)
```

```
$ find coverdir2

coverdir2
coverdir2/trace_example.recurse.cover
```

And the contents of `coverdir2/trace_example.recurse.cover`:

```
       #!/usr/bin/env python
       # encoding: utf-8
       #
       # Copyright (c) 2008 Doug Hellmann All rights reserved.
       #
       """
>>>>>> """

       #__version__ = "$Id$"
       #end_pymotw_header

>>>>>> def recurse(level):
    3:     print 'recurse(%s)' % level
    3:     if level:
    2:         recurse(level-1)
    3:     return

>>>>>> def not_called():
>>>>>>     print 'This function is never called.'
```

To save the counts data for generating reports, use the *infile* and *outfile* argument to `Trace`.

```
import trace
from trace_example.recurse import recurse

tracer = trace.Trace(count=True, trace=False, outfile='trace_report.dat')
tracer.runfunc(recurse, 2)

report_tracer = trace.Trace(count=False, trace=False, infile='trace_report.dat')
results = tracer.results()
results.write_results(summary=True, coverdir='/tmp')
```

Pass a filename to *infile* to read previously stored data, and a filename to *outfile* to write new results after tracing. If *infile* and *outfile* are the same, it has the effect of updating the file with cummulative data.

```
$ python trace_report.py
```

```
recurse(2)
recurse(1)
recurse(0)
lines   cov%   module   (path)
    8    50%   trace_example.recurse   (/Users/dhellmann/Documents/PyMOTW/src/PyMOTW/trace/trace_exa
```

Trace Options

The constructor for `Trace` takes several optional parameters to control runtime behavior.

count Boolean. Turns on line number counting. Defaults to True.

countfuncs Boolean. Turns on list of functions called during the run. Defaults to False.

countcallers Boolean. Turns on tracking for callers and callees. Defaults to False.

ignoremods Sequence. List of modules or packages to ignore when tracking coverage. Defaults to an empty tuple.

ignoredirs Sequence. List of directories containing modules or packages to be ignored. Defaults to an empty tuple.

infile Name of the file containing cached count values. Defaults to None.

outfile Name of the file to use for storing cached count files. Defaults to None, and data is not stored.

See also:

trace (http://docs.python.org/lib/module-trace.html) Standard library documentation for this module.

Tracing a Program As It Runs The `sys` module includes facilities for adding your own tracing function to the interpreter at run-time.

coverage.py (http://nedbatchelder.com/code/modules/coverage.html) Ned Batchelder's coverage module.

figleaf (http://darcs.idyll.org/ t/projects/figleaf/doc/) Titus Brown's coverage app.

CHAPTER

TWENTYFIVE

PYTHON RUNTIME SERVICES

25.1 abc – Abstract Base Classes

Purpose Define and use abstract base classes for API checks in your code.

Available In 2.6

25.1.1 Why use Abstract Base Classes?

Abstract base classes are a form of interface checking more strict than individual `hasattr()` checks for particular methods. By defining an abstract base class, you can define a common API for a set of subclasses. This capability is especially useful in situations where a third-party is going to provide implementations, such as with plugins to an application, but can also aid you when working on a large team or with a large code-base where keeping all classes in your head at the same time is difficult or not possible.

25.1.2 How ABCs Work

`abc` works by marking methods of the base class as abstract, and then registering concrete classes as implementations of the abstract base. If your code requires a particular API, you can use `issubclass()` or `isinstance()` to check an object against the abstract class.

Let's start by defining an abstract base class to represent the API of a set of plugins for saving and loading data.

```
import abc

class PluginBase(object):
    __metaclass__ = abc.ABCMeta

    @abc.abstractmethod
    def load(self, input):
        """Retrieve data from the input source and return an object."""
        return

    @abc.abstractmethod
    def save(self, output, data):
        """Save the data object to the output."""
        return
```

25.1.3 Registering a Concrete Class

There are two ways to indicate that a concrete class implements an abstract: register the class with the abc or subclass directly from the abc.

```
import abc
from abc_base import PluginBase

class RegisteredImplementation(object):

    def load(self, input):
        return input.read()

    def save(self, output, data):
        return output.write(data)

PluginBase.register(RegisteredImplementation)

if __name__ == '__main__':
    print 'Subclass:', issubclass(RegisteredImplementation, PluginBase)
    print 'Instance:', isinstance(RegisteredImplementation(), PluginBase)
```

In this example the `PluginImplementation` is not derived from `PluginBase`, but is registered as implementing the `PluginBase` API.

```
$ python abc_register.py

Subclass: True
Instance: True
```

25.1.4 Implementation Through Subclassing

By subclassing directly from the base, we can avoid the need to register the class explicitly.

```
import abc
from abc_base import PluginBase

class SubclassImplementation(PluginBase):

    def load(self, input):
        return input.read()

    def save(self, output, data):
        return output.write(data)

if __name__ == '__main__':
    print 'Subclass:', issubclass(SubclassImplementation, PluginBase)
    print 'Instance:', isinstance(SubclassImplementation(), PluginBase)
```

In this case the normal Python class management is used to recognize `PluginImplementation` as implementing the abstract `PluginBase`.

```
$ python abc_subclass.py

Subclass: True
Instance: True
```

A side-effect of using direct subclassing is it is possible to find all of the implementations of your plugin by asking the base class for the list of known classes derived from it (this is not an abc feature, all classes can do this).

```
import abc
from abc_base import PluginBase
import abc_subclass
import abc_register

for sc in PluginBase.__subclasses__():
    print sc.__name__
```

Notice that even though `abc_register` is imported, `RegisteredImplementation` is not among the list of subclasses because it is not actually derived from the base.

```
$ python abc_find_subclasses.py

SubclassImplementation
```

Dr. André Roberge has described (http://us.pycon.org/2009/conference/schedule/event/47/) using this capability to discover plugins by importing all of the modules in a directory dynamically and then looking at the subclass list to find the implementation classes.

Incomplete Implementations

Another benefit of subclassing directly from your abstract base class is that the subclass cannot be instantiated unless it fully implements the abstract portion of the API. This can keep half-baked implementations from triggering unexpected errors at runtime.

```
import abc
from abc_base import PluginBase

class IncompleteImplementation(PluginBase):

    def save(self, output, data):
        return output.write(data)

PluginBase.register(IncompleteImplementation)

if __name__ == '__main__':
    print 'Subclass:', issubclass(IncompleteImplementation, PluginBase)
    print 'Instance:', isinstance(IncompleteImplementation(), PluginBase)
```

```
$ python abc_incomplete.py

Subclass: True
Instance:
Traceback (most recent call last):
  File "abc_incomplete.py", line 22, in <module>
    print 'Instance:', isinstance(IncompleteImplementation(), PluginBase)
TypeError: Can't instantiate abstract class IncompleteImplementation with abstract methods load
```

25.1.5 Concrete Methods in ABCs

Although a concrete class must provide an implementation of an abstract methods, the abstract base class can also provide an implementation that can be invoked via `super()`. This lets you re-use common logic by placing it in the base class, but force subclasses to provide an overriding method with (potentially) custom logic.

```
import abc
from cStringIO import StringIO

class ABCWithConcreteImplementation(object):
    __metaclass__ = abc.ABCMeta

    @abc.abstractmethod
    def retrieve_values(self, input):
        print 'base class reading data'
        return input.read()

class ConcreteOverride(ABCWithConcreteImplementation):

    def retrieve_values(self, input):
        base_data = super(ConcreteOverride, self).retrieve_values(input)
        print 'subclass sorting data'
        response = sorted(base_data.splitlines())
        return response

input = StringIO("""line one
line two
line three
""")

reader = ConcreteOverride()
print reader.retrieve_values(input)
print
```

Since `ABCWithConcreteImplementation` is an abstract base class, it isn't possible to instantiate it to use it directly. Subclasses *must* provide an override for `retrieve_values()`, and in this case the concrete class massages the data before returning it at all.

```
$ python abc_concrete_method.py

base class reading data
subclass sorting data
['line one', 'line three', 'line two']
```

25.1.6 Abstract Properties

If your API specification includes attributes in addition to methods, you can require the attributes in concrete classes by defining them with `@abstractproperty`.

```
import abc

class Base(object):
    __metaclass__ = abc.ABCMeta

    @abc.abstractproperty
    def value(self):
        return 'Should never get here'


class Implementation(Base):

    @property
    def value(self):
        return 'concrete property'


try:
    b = Base()
    print 'Base.value:', b.value
except Exception, err:
    print 'ERROR:', str(err)

i = Implementation()
print 'Implementation.value:', i.value
```

The `Base` class in the example cannot be instantiated because it has only an abstract version of the property getter method.

```
$ python abc_abstractproperty.py

ERROR: Can't instantiate abstract class Base with abstract methods value
Implementation.value: concrete property
```

You can also define abstract read/write properties.

```
import abc

class Base(object):
    __metaclass__ = abc.ABCMeta

    def value_getter(self):
        return 'Should never see this'

    def value_setter(self, newvalue):
        return

    value = abc.abstractproperty(value_getter, value_setter)


class PartialImplementation(Base):

    @abc.abstractproperty
    def value(self):
        return 'Read-only'


class Implementation(Base):

    _value = 'Default value'

    def value_getter(self):
        return self._value

    def value_setter(self, newvalue):
        self._value = newvalue

    value = property(value_getter, value_setter)


try:
    b = Base()
    print 'Base.value:', b.value
```

```
except Exception, err:
    print 'ERROR:', str(err)

try:
    p = PartialImplementation()
    print 'PartialImplementation.value:', p.value
except Exception, err:
    print 'ERROR:', str(err)

i = Implementation()
print 'Implementation.value:', i.value

i.value = 'New value'
print 'Changed value:', i.value
```

Notice that the concrete property must be defined the same way as the abstract property. Trying to override a read/write property in `PartialImplementation` with one that is read-only does not work.

```
$ python abc_abstractproperty_rw.py

ERROR: Can't instantiate abstract class Base with abstract methods value
ERROR: Can't instantiate abstract class PartialImplementation with abstract methods value
Implementation.value: Default value
Changed value: New value
```

To use the decorator syntax does with read/write abstract properties, the methods to get and set the value should be named the same.

```
import abc

class Base(object):
    __metaclass__ = abc.ABCMeta

    @abc.abstractproperty
    def value(self):
        return 'Should never see this'

    @value.setter
    def value(self, newvalue):
        return


class Implementation(Base):

    _value = 'Default value'

    @property
    def value(self):
        return self._value

    @value.setter
    def value(self, newvalue):
        self._value = newvalue


i = Implementation()
print 'Implementation.value:', i.value

i.value = 'New value'
```

```
print 'Changed value:', i.value
```

Notice that both methods in the `Base` and `Implementation` classes are named `value()`, although they have different signatures.

```
$ python abc_abstractproperty_rw_deco.py

Implementation.value: Default value
Changed value: New value
```

25.1.7 Collection Types

The `collections` module defines several abstract base classes related to container (and containable) types.

General container classes:

- Container
- Sized

Iterator and Sequence classes:

- Iterable
- Iterator
- Sequence
- MutableSequence

Unique values:

- Hashable
- Set
- MutableSet

Mappings:

- Mapping
- MutableMapping
- MappingView
- KeysView
- ItemsView
- ValuesView

Miscelaneous:

- Callable

In addition to serving as detailed real-world examples of abstract base classes, Python's built-in types are automatically registered to these classes when you import `collections`. This means you can safely use `isinstance()` to check parameters in your code to ensure that they support the API you need. The base classes can also be used to define your own collection types, since many of them provide concrete implementations of the internals and only need a few methods overridden. Refer to the standard library docs for collections for more details.

See also:

abc (http://docs.python.org/library/abc.html) The standard library documentation for this module.

PEP 3119 (http://www.python.org/dev/peps/pep-3119) Introducing Abstract Base Classes

collections The collections module includes abstract base classes for several collection types.

collections (http://docs.python.org/library/collections.html) The standard library documentation for collections.

PEP 3141 (http://www.python.org/dev/peps/pep-3141) A Type Hierarchy for Numbers

Wikipedia: Strategy Pattern (http://en.wikipedia.org/wiki/Strategy_pattern) Description and examples of the strategy pattern.

Plugins and monkeypatching (http://us.pycon.org/2009/conference/schedule/event/47/) PyCon 2009 presentation by Dr. André Roberge

25.2 atexit – Call functions when a program is closing down

Purpose Register function(s) to be called when a program is closing down.

Available In 2.1.3 and later

The atexit module provides a simple interface to register functions to be called when a program closes down normally. The sys module also provides a hook, sys.exitfunc, but only one function can be registered there. The atexit registry can be used by multiple modules and libraries simultaneously.

25.2.1 Examples

A simple example of registering a function via atexit.register() looks like:

```
import atexit

def all_done():
    print 'all_done()'

print 'Registering'
atexit.register(all_done)
print 'Registered'
```

Since the program doesn't do anything else, all_done() is called right away:

```
$ python atexit_simple.py

Registering
Registered
all_done()
```

It is also possible to register more than one function, and to pass arguments. That can be useful to cleanly disconnect from databases, remove temporary files, etc. Since it is possible to pass arguments to the registered functions, we don't even need to keep a separate list of things to clean up – we can just register a clean up function more than once.

```
import atexit

def my_cleanup(name):
    print 'my_cleanup(%s)' % name

atexit.register(my_cleanup, 'first')
atexit.register(my_cleanup, 'second')
atexit.register(my_cleanup, 'third')
```

Notice that order in which the exit functions are called is the reverse of the order they are registered. This allows modules to be cleaned up in the reverse order from which they are imported (and therefore register their atexit functions), which should reduce dependency conflicts.

```
$ python atexit_multiple.py

my_cleanup(third)
my_cleanup(second)
my_cleanup(first)
```

25.2.2 When are atexit functions not called?

The callbacks registered with atexit are not invoked if:

- the program dies because of a signal
- os._exit() is invoked directly
- a Python fatal error is detected (in the interpreter)

To illustrate a program being killed via a signal, we can modify one of the examples from the `subprocess` article. There are 2 files involved, the parent and the child programs. The parent starts the child, pauses, then kills it:

```
import os
import signal
import subprocess
import time

proc = subprocess.Popen('atexit_signal_child.py')
print 'PARENT: Pausing before sending signal...'
time.sleep(1)
print 'PARENT: Signaling child'
os.kill(proc.pid, signal.SIGTERM)
```

The child sets up an atexit callback, to prove that it is not called.

```
import atexit
import time
import sys

def not_called():
    print 'CHILD: atexit handler should not have been called'

print 'CHILD: Registering atexit handler'
sys.stdout.flush()
atexit.register(not_called)

print 'CHILD: Pausing to wait for signal'
sys.stdout.flush()
time.sleep(5)
```

When run, the output should look something like this:

```
$ python atexit_signal_parent.py

CHILD: Registering atexit handler
CHILD: Pausing to wait for signal
PARENT: Pausing before sending signal...
PARENT: Signaling child
```

Note that the child does not print the message embedded in not_called().

Similarly, if a program bypasses the normal exit path it can avoid having the atexit callbacks invoked.

```
import atexit
import os

def not_called():
    print 'This should not be called'

print 'Registering'
atexit.register(not_called)
print 'Registered'

print 'Exiting...'
os._exit(0)
```

Since we call os._exit() instead of exiting normally, the callback is not invoked.

```
$ python atexit_os_exit.py
```

If we had instead used sys.exit(), the callbacks would still have been called.

```
import atexit
import sys

def all_done():
    print 'all_done()'

print 'Registering'
atexit.register(all_done)
print 'Registered'

print 'Exiting...'
sys.exit()
```

```
$ python atexit_sys_exit.py

Registering
Registered
Exiting...
all_done()
```

Simulating a fatal error in the Python interpreter is left as an exercise to the reader.

25.2.3 Exceptions in atexit Callbacks

Tracebacks for exceptions raised in atexit callbacks are printed to the console and the last exception raised is re-raised to be the final error message of the program.

```
import atexit

def exit_with_exception(message):
    raise RuntimeError(message)

atexit.register(exit_with_exception, 'Registered first')
atexit.register(exit_with_exception, 'Registered second')
```

Notice again that the registration order controls the execution order. If an error in one callback introduces an error in another (registered earlier, but called later), the final error message might not be the most useful error message to show the user.

```
$ python atexit_exception.py

Error in atexit._run_exitfuncs:
Traceback (most recent call last):
  File "/Library/Frameworks/Python.framework/Versions/2.7/lib/python2.7/atexit.py", line 24, in _run_
    func(*targs, **kargs)
  File "atexit_exception.py", line 37, in exit_with_exception
    raise RuntimeError(message)
RuntimeError: Registered second
Error in atexit._run_exitfuncs:
Traceback (most recent call last):
  File "/Library/Frameworks/Python.framework/Versions/2.7/lib/python2.7/atexit.py", line 24, in _run_
    func(*targs, **kargs)
  File "atexit_exception.py", line 37, in exit_with_exception
    raise RuntimeError(message)
RuntimeError: Registered first
Error in sys.exitfunc:
Traceback (most recent call last):
  File "/Library/Frameworks/Python.framework/Versions/2.7/lib/python2.7/atexit.py", line 24, in _run_
    func(*targs, **kargs)
  File "atexit_exception.py", line 37, in exit_with_exception
    raise RuntimeError(message)
RuntimeError: Registered first
```

In general you will probably want to handle and quietly log all exceptions in your cleanup functions, since it is messy to have a program dump errors on exit.

See also:

atexit (http://docs.python.org/library/atexit.html) The standard library documentation for this module.

25.3 contextlib – Context manager utilities

Purpose Utilities for creating and working with context managers.

Available In 2.5 and later

The `contextlib` module contains utilities for working with context managers and the **with** statement.

Note: Context managers are tied to the **with** statement. Since **with** is officially part of Python 2.6, you have to import it from `__future__` before using contextlib in Python 2.5.

25.3.1 Context Manager API

A *context manager* is responsible for a resource within a code block, possibly creating it when the block is entered and then cleaning it up after the block is exited. For example, files support the context manager API to make it easy to ensure they are closed after all reading or writing is done.

```
with open('/tmp/pymotw.txt', 'wt') as f:
    f.write('contents go here')
# file is automatically closed
```

A context manager is enabled by the **with** statement, and the API involves two methods. The `__enter__()` method is run when execution flow enters the code block inside the **with**. It returns an object to be used within the context. When execution flow leaves the **with** block, the `__exit__()` method of the context manager is called to clean up any resources being used.

```
class Context(object):

    def __init__(self):
        print '__init__()'

    def __enter__(self):
        print '__enter__()'
        return self

    def __exit__(self, exc_type, exc_val, exc_tb):
        print '__exit__()'

with Context():
    print 'Doing work in the context'
```

Combining a context manager and the **with** statement is a more compact way of writing a `try:finally` block, since the context manager's `__exit__()` method is always called, even if an exception is raised.

```
$ python contextlib_api.py

__init__()
__enter__()
Doing work in the context
__exit__()
```

`__enter__()` can return any object to be associated with a name specified in the **as** clause of the **with** statement. In this example, the `Context` returns an object that uses the open context.

```
class WithinContext(object):

    def __init__(self, context):
        print 'WithinContext.__init__(%s)' % context

    def do_something(self):
        print 'WithinContext.do_something()'

    def __del__(self):
        print 'WithinContext.__del__'


class Context(object):

    def __init__(self):
        print 'Context.__init__()'

    def __enter__(self):
        print 'Context.__enter__()'
        return WithinContext(self)

    def __exit__(self, exc_type, exc_val, exc_tb):
        print 'Context.__exit__()'

with Context() as c:
    c.do_something()
```

It can be a little confusing, but the value associated with the variable `c` is the object returned by `__enter__()` and *not* the `Context` instance created in the **with** statement.

```
$ python contextlib_api_other_object.py

Context.__init__()
Context.__enter__()
WithinContext.__init__(<__main__.Context object at 0x10045f6d0>)
WithinContext.do_something()
Context.__exit__()
WithinContext.__del__
```

The `__exit__()` method receives arguments containing details of any exception raised in the **with** block.

```
class Context(object):

    def __init__(self, handle_error):
        print '__init__(%s)' % handle_error
        self.handle_error = handle_error

    def __enter__(self):
        print '__enter__()'
        return self

    def __exit__(self, exc_type, exc_val, exc_tb):
        print '__exit__(%s, %s, %s)' % (exc_type, exc_val, exc_tb)
        return self.handle_error

with Context(True):
    raise RuntimeError('error message handled')

print

with Context(False):
    raise RuntimeError('error message propagated')
```

If the context manager can handle the exception, `__exit__()` should return a true value to indicate that the exception does not need to be propagated. Returning false causes the exception to be re-raised after `__exit__()` returns.

```
$ python contextlib_api_error.py

__init__(True)
__enter__()
__exit__(<type 'exceptions.RuntimeError'>, error message handled, <traceback object at 0x10046a5f0>)

__init__(False)
__enter__()
__exit__(<type 'exceptions.RuntimeError'>, error message propagated, <traceback object at 0x10046a68
Traceback (most recent call last):
  File "contextlib_api_error.py", line 30, in <module>
    raise RuntimeError('error message propagated')
RuntimeError: error message propagated
```

25.3.2 From Generator to Context Manager

Creating context managers the traditional way, by writing a class with `__enter__()` and `__exit__()` methods, is not difficult. But sometimes it is more overhead than you need just to manage a trivial bit of context. In those sorts of situations, you can use the `contextmanager()` decorator to convert a generator function into a context manager.

```
import contextlib

@contextlib.contextmanager
def make_context():
    print '  entering'
    try:
        yield {}
    except RuntimeError, err:
        print '  ERROR:', err
    finally:
        print '  exiting'

print 'Normal:'
with make_context() as value:
    print '  inside with statement:', value

print
print 'Handled error:'
with make_context() as value:
    raise RuntimeError('showing example of handling an error')

print
print 'Unhandled error:'
with make_context() as value:
    raise ValueError('this exception is not handled')
```

The generator should initialize the context, yield exactly one time, then clean up the context. The value yielded, if any, is bound to the variable in the **as** clause of the **with** statement. Exceptions from within the **with** block are re-raised inside the generator, so they can be handled there.

```
$ python contextlib_contextmanager.py

Normal:
  entering
  inside with statement: {}
  exiting

Handled error:
  entering
  ERROR: showing example of handling an error
  exiting

Unhandled error:
  entering
  exiting
Traceback (most recent call last):
  File "contextlib_contextmanager.py", line 34, in <module>
    raise ValueError('this exception is not handled')
ValueError: this exception is not handled
```

25.3.3 Nesting Contexts

At times it is necessary to manage multiple contexts simultaneously (such as when copying data between input and output file handles, for example). It is possible to nest **with** statements one inside another. If the outer contexts do not need their own separate block, though, this adds to the indention level without giving any real benefit. Using `nested()` nests the contexts using a single **with** statement.

```
import contextlib

@contextlib.contextmanager
def make_context(name):
    print 'entering:', name
    yield name
    print 'exiting :', name

with contextlib.nested(make_context('A'), make_context('B'), make_context('C')) as (A, B, C):
    print 'inside with statement:', A, B, C
```

Notice that the contexts are exited in the reverse order in which they are entered.

```
$ python contextlib_nested.py

entering: A
entering: B
entering: C
inside with statement: A B C
exiting : C
exiting : B
exiting : A
```

In Python 2.7 and later, `nested()` is deprecated because the **with** statement supports nesting directly.

```
import contextlib

@contextlib.contextmanager
def make_context(name):
    print 'entering:', name
    yield name
    print 'exiting :', name

with make_context('A') as A, make_context('B') as B, make_context('C') as C:
    print 'inside with statement:', A, B, C
```

Each context manager and optional **as** clause are separated by a comma (`,`). The effect is similar to using `nested()`, but avoids some of the edge-cases around error handling that `nested()` could not implement correctly.

```
$ python contextlib_nested_with.py

entering: A
entering: B
entering: C
inside with statement: A B C
exiting : C
exiting : B
exiting : A
```

25.3.4 Closing Open Handles

The `file` class supports the context manager API directly, but some other objects that represent open handles do not. The example given in the standard library documentation for `contextlib` is the object returned from `urllib.urlopen()`. There are other legacy classes that use a `close()` method but do not support the context manager API. To ensure that a handle is closed, use `closing()` to create a context manager for it.

```
import contextlib

class Door(object):
    def __init__(self):
        print '  __init__()'
    def close(self):
        print '  close()'

print 'Normal Example:'
with contextlib.closing(Door()) as door:
    print '  inside with statement'

print
print 'Error handling example:'
try:
    with contextlib.closing(Door()) as door:
        print '  raising from inside with statement'
        raise RuntimeError('error message')
except Exception, err:
    print '  Had an error:', err
```

The handle is closed whether there is an error in the **with** block or not.

```
$ python contextlib_closing.py

Normal Example:
  __init__()
  inside with statement
  close()

Error handling example:
  __init__()
  raising from inside with statement
  close()
  Had an error: error message
```

See also:

contextlib **(http://docs.python.org/library/contextlib.html)** The standard library documentation for this module.

PEP 343 **(http://www.python.org/dev/peps/pep-0343)** The **with** statement.

Context Manager Types **(http://docs.python.org/library/stdtypes.html#typecontextmanager)** Description of the context manager API from the standard library documentation.

With Statement Context Managers **(http://docs.python.org/reference/datamodel.html#context-managers)** Description of the context manager API from the Python Reference Guide.

25.4 gc – Garbage Collector

Purpose Manages memory used by Python objects

Available In 2.1+

`gc` exposes the underlying memory management mechanism of Python, the automatic garbage collector. The module includes functions for controlling how the collector operates and to examine the objects known to the system, either pending collection or stuck in reference cycles and unable to be freed.

25.4.1 Tracing References

With gc you can use the incoming and outgoing references between objects to find cycles in complex data structures. If you know the data structure with the cycle, you can construct custom code to examine its properties. If not, you can the `get_referents()` and `get_referrers()` functions to build generic debugging tools.

For example, `get_referents()` shows the objects *referred to* by the input arguments.

```
import gc
import pprint

class Graph(object):
    def __init__(self, name):
        self.name = name
        self.next = None
    def set_next(self, next):
        print 'Linking nodes %s.next = %s' % (self, next)
        self.next = next
    def __repr__(self):
        return '%s(%s)' % (self.__class__.__name__, self.name)

# Construct a graph cycle
one = Graph('one')
two = Graph('two')
three = Graph('three')
one.set_next(two)
two.set_next(three)
three.set_next(one)

print
print 'three refers to:'
for r in gc.get_referents(three):
    pprint.pprint(r)
```

In this case, the `Graph` instance `three` holds references to its instance dictionary (in the `__dict__` attribute) and its class.

```
$ python gc_get_referents.py

Linking nodes Graph(one).next = Graph(two)
Linking nodes Graph(two).next = Graph(three)
Linking nodes Graph(three).next = Graph(one)

three refers to:
{'name': 'three', 'next': Graph(one)}
<class '__main__.Graph'>
```

This example uses a Queue to perform a breadth-first traversal of all of the object references looking for cycles. The items inserted into the queue are tuples containing the reference chain so far and the next object to examine. It starts with `three`, and look at everything it refers to. Skipping classes lets us avoid looking at methods, modules, etc.

```
import gc
import pprint
import Queue

class Graph(object):
    def __init__(self, name):
        self.name = name
        self.next = None
    def set_next(self, next):
        print 'Linking nodes %s.next = %s' % (self, next)
        self.next = next
    def __repr__(self):
        return '%s(%s)' % (self.__class__.__name__, self.name)

# Construct a graph cycle
one = Graph('one')
two = Graph('two')
three = Graph('three')
one.set_next(two)
two.set_next(three)
three.set_next(one)

print

seen = set()
to_process = Queue.Queue()

# Start with an empty object chain and Graph three.
to_process.put( ([], three) )

# Look for cycles, building the object chain for each object we find
# in the queue so we can print the full cycle when we're done.
while not to_process.empty():
    chain, next = to_process.get()
    chain = chain[:]
    chain.append(next)
    print 'Examining:', repr(next)
    seen.add(id(next))
    for r in gc.get_referents(next):
        if isinstance(r, basestring) or isinstance(r, type):
            # Ignore strings and classes
            pass
        elif id(r) in seen:
            print
            print 'Found a cycle to %s:' % r
            for i, link in enumerate(chain):
                print '  %d: ' % i,
                pprint.pprint(link)
        else:
            to_process.put( (chain, r) )
```

The cycle in the nodes is easily found by watching for objects that have already been processed. To avoid holding references to those objects, their `id()` values are cached in a set. The dictionary objects found in the cycle are the `__dict__` values for the `Graph` instances, and hold their instance attributes.

```
$ python gc_get_referents_cycles.py

Linking nodes Graph(one).next = Graph(two)
Linking nodes Graph(two).next = Graph(three)
Linking nodes Graph(three).next = Graph(one)

Examining: Graph(three)
Examining: {'name': 'three', 'next': Graph(one)}
Examining: Graph(one)
Examining: {'name': 'one', 'next': Graph(two)}
Examining: Graph(two)
```

```
Examining: {'name': 'two', 'next': Graph(three)}

Found a cycle to Graph(three):
  0: Graph(three)
  1: {'name': 'three', 'next': Graph(one)}
  2: Graph(one)
  3: {'name': 'one', 'next': Graph(two)}
  4: Graph(two)
  5: {'name': 'two', 'next': Graph(three)}
```

25.4.2 Forcing Garbage Collection

Although the garbage collector runs automatically as the interpreter executes your program, you may want to trigger collection to run at a specific time when you know there are a lot of objects to free or there is not much work happening in your application. Trigger collection using `collect()`.

```python
import gc
import pprint

class Graph(object):
    def __init__(self, name):
        self.name = name
        self.next = None
    def set_next(self, next):
        print 'Linking nodes %s.next = %s' % (self, next)
        self.next = next
    def __repr__(self):
        return '%s(%s)' % (self.__class__.__name__, self.name)

# Construct a graph cycle
one = Graph('one')
two = Graph('two')
three = Graph('three')
one.set_next(two)
two.set_next(three)
three.set_next(one)

print

# Remove references to the graph nodes in this module's namespace
one = two = three = None

# Show the effect of garbage collection
for i in range(2):
    print 'Collecting %d ...' % i
    n = gc.collect()
    print 'Unreachable objects:', n
    print 'Remaining Garbage:',
    pprint.pprint(gc.garbage)
    print
```

In this example, the cycle is cleared as soon as collection runs the first time, since nothing refers to the `Graph` nodes except themselves. `collect()` returns the number of "unreachable" objects it found. In this case, the value is `6` because there are 3 objects with their instance attribute dictionaries.

```
$ python gc_collect.py
```

```
Linking nodes Graph(one).next = Graph(two)
Linking nodes Graph(two).next = Graph(three)
Linking nodes Graph(three).next = Graph(one)

Collecting 0 ...
Unreachable objects: 6
Remaining Garbage:[]

Collecting 1 ...
Unreachable objects: 0
Remaining Garbage:[]
```

If `Graph` has a `__del__()` method, however, the garbage collector cannot break the cycle.

```
import gc
import pprint

class Graph(object):
    def __init__(self, name):
        self.name = name
        self.next = None
    def set_next(self, next):
        print '%s.next = %s' % (self, next)
        self.next = next
    def __repr__(self):
        return '%s(%s)' % (self.__class__.__name__, self.name)
    def __del__(self):
        print '%s.__del__()' % self

# Construct a graph cycle
one = Graph('one')
two = Graph('two')
three = Graph('three')
one.set_next(two)
two.set_next(three)
three.set_next(one)

# Remove references to the graph nodes in this module's namespace
one = two = three = None

# Show the effect of garbage collection
print 'Collecting...'
n = gc.collect()
print 'Unreachable objects:', n
print 'Remaining Garbage:',
pprint.pprint(gc.garbage)
```

Because more than one object in the cycle has a finalizer method, the order in which the objects need to be finalized and then garbage collected cannot be determined, so the garbage collector plays it safe and keeps the objects.

```
$ python gc_collect_with_del.py

Graph(one).next = Graph(two)
Graph(two).next = Graph(three)
Graph(three).next = Graph(one)
Collecting...
Unreachable objects: 6
Remaining Garbage:[Graph(one), Graph(two), Graph(three)]
```

When the cycle is broken, the `Graph` instances can be collected.

```
import gc
import pprint

class Graph(object):
    def __init__(self, name):
        self.name = name
        self.next = None
    def set_next(self, next):
        print 'Linking nodes %s.next = %s' % (self, next)
        self.next = next
    def __repr__(self):
        return '%s(%s)' % (self.__class__.__name__, self.name)
    def __del__(self):
        print '%s.__del__()' % self

# Construct a graph cycle
one = Graph('one')
two = Graph('two')
three = Graph('three')
one.set_next(two)
two.set_next(three)
three.set_next(one)

# Remove references to the graph nodes in this module's namespace
one = two = three = None

# Collecting now keeps the objects as uncollectable
print
print 'Collecting...'
n = gc.collect()
print 'Unreachable objects:', n
print 'Remaining Garbage:',
pprint.pprint(gc.garbage)

# Break the cycle
print
print 'Breaking the cycle'
gc.garbage[0].set_next(None)
print 'Removing references in gc.garbage'
del gc.garbage[:]

# Now the objects are removed
print
print 'Collecting...'
n = gc.collect()
print 'Unreachable objects:', n
print 'Remaining Garbage:',
pprint.pprint(gc.garbage)
```

Because `gc.garbage` holds a reference to the objects from the previous garbage collection run, it needs to be cleared out after the cycle is broken to reduce the reference counts so they can be finalized and freed.

```
$ python gc_collect_break_cycle.py

Linking nodes Graph(one).next = Graph(two)
Linking nodes Graph(two).next = Graph(three)
Linking nodes Graph(three).next = Graph(one)
```

```
Collecting...
Unreachable objects: 6
Remaining Garbage:[Graph(one), Graph(two), Graph(three)]

Breaking the cycle
Linking nodes Graph(one).next = None
Removing references in gc.garbage
Graph(two).__del__()
Graph(three).__del__()
Graph(one).__del__()

Collecting...
Unreachable objects: 0
Remaining Garbage:[]
```

25.4.3 Finding References to Objects that Can't be Collected

Looking for the object holding a reference to something in the garbage is a little trickier than seeing what an object references. Because the code asking about the reference needs to hold a reference itself, some of the referrers need to be ignored. This example creates a graph cycle, then works through the `Graph` instances in the garbage and removes the reference in the "parent" node.

```
import gc
import pprint
import Queue

class Graph(object):
    def __init__(self, name):
        self.name = name
        self.next = None
    def set_next(self, next):
        print 'Linking nodes %s.next = %s' % (self, next)
        self.next = next
    def __repr__(self):
        return '%s(%s)' % (self.__class__.__name__, self.name)
    def __del__(self):
        print '%s.__del__()' % self

# Construct two graph cycles
one = Graph('one')
two = Graph('two')
three = Graph('three')
one.set_next(two)
two.set_next(three)
three.set_next(one)

# Remove references to the graph nodes in this module's namespace
one = two = three = None

# Collecting now keeps the objects as uncollectable
print
print 'Collecting...'
n = gc.collect()
print 'Unreachable objects:', n
print 'Remaining Garbage:',
pprint.pprint(gc.garbage)
```

```
REFERRERS_TO_IGNORE = [ locals(), globals(), gc.garbage ]

def find_referring_graphs(obj):
    print 'Looking for references to %s' % repr(obj)
    referrers = (r for r in gc.get_referrers(obj)
                 if r not in REFERRERS_TO_IGNORE)
    for ref in referrers:
        if isinstance(ref, Graph):
            # A graph node
            yield ref
        elif isinstance(ref, dict):
            # An instance or other namespace dictionary
            for parent in find_referring_graphs(ref):
                yield parent

# Look for objects that refer to the objects that remain in
# gc.garbage.
print
print 'Clearing referrers:'
for obj in gc.garbage:
    for ref in find_referring_graphs(obj):
        ref.set_next(None)
        del ref # remove local reference so the node can be deleted
    del obj # remove local reference so the node can be deleted

# Clear references held by gc.garbage
print
print 'Clearing gc.garbage:'
del gc.garbage[:]

# Everything should have been freed this time
print
print 'Collecting...'
n = gc.collect()
print 'Unreachable objects:', n
print 'Remaining Garbage:',
pprint.pprint(gc.garbage)
```

This sort of logic is overkill if you understand why the cycles are being created in the first place, but if you have an unexplained cycle in your data using `get_referrers()` can expose the unexpected relationship.

```
$ python gc_get_referrers.py

Linking nodes Graph(one).next = Graph(two)
Linking nodes Graph(two).next = Graph(three)
Linking nodes Graph(three).next = Graph(one)

Collecting...
Unreachable objects: 6
Remaining Garbage:[Graph(one), Graph(two), Graph(three)]

Clearing referrers:
Looking for references to Graph(one)
Looking for references to {'name': 'three', 'next': Graph(one)}
Linking nodes Graph(three).next = None
Looking for references to Graph(two)
Looking for references to {'name': 'one', 'next': Graph(two)}
Linking nodes Graph(one).next = None
```

```
Looking for references to Graph(three)
Looking for references to {'name': 'two', 'next': Graph(three)}
Linking nodes Graph(two).next = None

Clearing gc.garbage:
Graph(three).__del__()
Graph(two).__del__()
Graph(one).__del__()

Collecting...
Unreachable objects: 0
Remaining Garbage:[]
```

25.4.4 Collection Thresholds and Generations

The garbage collector maintains three lists of objects it sees as it runs, one for each “generation” tracked by the collector. As objects are examined in each generation, they are either collected or they age into subsequent generations until they finally reach the stage where they are kept permanently.

The collector routines can be tuned to occur at different frequencies based on the difference between the number of object allocations and deallocations between runs. When the number of allocations minus the number of deallocations is greater than the threshold for the generation, the garbage collector is run. The current thresholds can be examined with `get_threshold()`.

```python
import gc

print gc.get_threshold()
```

The return value is a tuple with the threshold for each generation.

```
$ python gc_get_threshold.py

(700, 10, 10)
```

The thresholds can be changed with `set_threshold()`. This example program reads the threshold for generation `0` from the command line, adjusts the `gc` settings, then allocates a series of objects.

```python
import gc
import pprint
import sys

try:
    threshold = int(sys.argv[1])
except (IndexError, ValueError, TypeError):
    print 'Missing or invalid threshold, using default'
    threshold = 5

class MyObj(object):
    def __init__(self, name):
        self.name = name
        print 'Created', self.name

gc.set_debug(gc.DEBUG_STATS)

gc.set_threshold(threshold, 1, 1)
print 'Thresholds:', gc.get_threshold()
print 'Clear the collector by forcing a run'
gc.collect()
print

print 'Creating objects'
objs = []
for i in range(10):
    objs.append(MyObj(i))
```

Different threshold values introduce the garbage collection sweeps at different times, shown here because debugging is enabled.

```
$ python -u gc_threshold.py 5

Thresholds: (5, 1, 1)
Clear the collector by forcing a run
gc: collecting generation 2...
gc: objects in each generation: 144 3163 0
gc: done, 0.0004s elapsed.

Creating objects
gc: collecting generation 0...
gc: objects in each generation: 7 0 3234
gc: done, 0.0000s elapsed.
Created 0
Created 1
Created 2
Created 3
Created 4
gc: collecting generation 0...
gc: objects in each generation: 6 4 3234
gc: done, 0.0000s elapsed.
Created 5
Created 6
Created 7
Created 8
Created 9
gc: collecting generation 2...
gc: objects in each generation: 5 6 3232
gc: done, 0.0004s elapsed.
```

A smaller threshold causes the sweeps to run more frequently.

```
$ python -u gc_threshold.py 2

Thresholds: (2, 1, 1)
Clear the collector by forcing a run
gc: collecting generation 2...
gc: objects in each generation: 144 3163 0
gc: done, 0.0004s elapsed.

Creating objects
gc: collecting generation 0...
gc: objects in each generation: 3 0 3234
gc: done, 0.0000s elapsed.
gc: collecting generation 0...
gc: objects in each generation: 4 3 3234
gc: done, 0.0000s elapsed.
Created 0
Created 1
gc: collecting generation 1...
gc: objects in each generation: 3 4 3234
gc: done, 0.0000s elapsed.
Created 2
Created 3
Created 4
gc: collecting generation 0...
gc: objects in each generation: 5 0 3239
gc: done, 0.0000s elapsed.
Created 5
Created 6
Created 7
gc: collecting generation 0...
gc: objects in each generation: 5 3 3239
gc: done, 0.0000s elapsed.
Created 8
Created 9
gc: collecting generation 2...
gc: objects in each generation: 2 6 3235
gc: done, 0.0004s elapsed.
```

25.4.5 Debugging

Debugging memory leaks can be challenging. `gc` includes several options to expose the inner workings to make the job easier. The options are bit-flags meant to be combined and passed to `set_debug()` to configure the garbage collector while your program is running. Debugging information is printed to *stderr*.

The `DEBUG_STATS` flag turns on statistics reporting, causing the garbage collector to report when it is running, the number of objects tracked for each generation, and the amount of time it took to perform the sweep.

```
import gc

gc.set_debug(gc.DEBUG_STATS)

gc.collect()
```

This example output shows two separate runs of the collector because it runs once when it is invoked explicitly, and a second time when the interpreter exits.

```
$ python gc_debug_stats.py

gc: collecting generation 2...
gc: objects in each generation: 667 2808 0
gc: done, 0.0011s elapsed.
gc: collecting generation 2...
gc: objects in each generation: 0 0 3164
gc: done, 0.0009s elapsed.
```

Enabling `DEBUG_COLLECTABLE` and `DEBUG_UNCOLLECTABLE` causes the collector to report on whether each object it examines can or cannot be collected. You need to combine these flags need with `DEBUG_OBJECTS` so `gc` will print information about the objects being held.

```
import gc

flags = (gc.DEBUG_COLLECTABLE |
         gc.DEBUG_UNCOLLECTABLE |
         gc.DEBUG_OBJECTS
         )
gc.set_debug(flags)

class Graph(object):
    def __init__(self, name):
        self.name = name
        self.next = None
        print 'Creating %s 0x%x (%s)' % (self.__class__.__name__, id(self), name)
    def set_next(self, next):
        print 'Linking nodes %s.next = %s' % (self, next)
        self.next = next
    def __repr__(self):
        return '%s(%s)' % (self.__class__.__name__, self.name)

class CleanupGraph(Graph):
    def __del__(self):
        print '%s.__del__()' % self

# Construct a graph cycle
one = Graph('one')
two = Graph('two')
one.set_next(two)
two.set_next(one)

# Construct another node that stands on its own
three = CleanupGraph('three')

# Construct a graph cycle with a finalizer
four = CleanupGraph('four')
five = CleanupGraph('five')
four.set_next(five)
five.set_next(four)

# Remove references to the graph nodes in this module's namespace
one = two = three = four = five = None

print

# Force a sweep
print 'Collecting'
gc.collect()
print 'Done'
```

The two classes `Graph` and `CleanupGraph` are constructed so it is possible to create structures that are automatically collectable and structures where cycles need to be explicitly broken by the user.

The output shows that the `Graph` instances `one` and `two` create a cycle, but are still collectable because they do not have a finalizer and their only incoming references are from other objects that can be collected. Although `CleanupGraph` has a finalizer, `three` is reclaimed as soon as its reference count goes to zero. In contrast, `four` and `five` create a cycle and cannot be freed.

```
$ python -u gc_debug_collectable_objects.py

Creating Graph 0x10045f750 (one)
Creating Graph 0x10045f790 (two)
Linking nodes Graph(one).next = Graph(two)
Linking nodes Graph(two).next = Graph(one)
```

```
Creating CleanupGraph 0x10045f7d0 (three)
Creating CleanupGraph 0x10045f810 (four)
Creating CleanupGraph 0x10045f850 (five)
Linking nodes CleanupGraph(four).next = CleanupGraph(five)
Linking nodes CleanupGraph(five).next = CleanupGraph(four)
CleanupGraph(three).__del__()

Collecting
gc: collectable <Graph 0x10045f750>
gc: collectable <Graph 0x10045f790>
gc: collectable <dict 0x100360a30>
gc: collectable <dict 0x100361cc0>
gc: uncollectable <CleanupGraph 0x10045f810>
gc: uncollectable <CleanupGraph 0x10045f850>
gc: uncollectable <dict 0x100361de0>
gc: uncollectable <dict 0x100362140>
Done
```

The flag `DEBUG_INSTANCES` works much the same way for instances of old-style classes (not derived from `object`.

```
import gc

flags = (gc.DEBUG_COLLECTABLE |
         gc.DEBUG_UNCOLLECTABLE |
         gc.DEBUG_INSTANCES
         )
gc.set_debug(flags)

class Graph:
    def __init__(self, name):
        self.name = name
        self.next = None
        print 'Creating %s 0x%x (%s)' % (self.__class__.__name__, id(self), name)
    def set_next(self, next):
        print 'Linking nodes %s.next = %s' % (self, next)
        self.next = next
    def __repr__(self):
        return '%s(%s)' % (self.__class__.__name__, self.name)

class CleanupGraph(Graph):
    def __del__(self):
        print '%s.__del__()' % self

# Construct a graph cycle
one = Graph('one')
two = Graph('two')
one.set_next(two)
two.set_next(one)

# Construct another node that stands on its own
three = CleanupGraph('three')

# Construct a graph cycle with a finalizer
four = CleanupGraph('four')
five = CleanupGraph('five')
four.set_next(five)
five.set_next(four)
```

```
# Remove references to the graph nodes in this module's namespace
one = two = three = four = five = None

print

# Force a sweep
print 'Collecting'
gc.collect()
print 'Done'
```

In this case, however, the `dict` objects holding the instance attributes are not included in the output.

```
$ python -u gc_debug_collectable_instances.py

Creating Graph 0x1004687a0 (one)
Creating Graph 0x1004687e8 (two)
Linking nodes Graph(one).next = Graph(two)
Linking nodes Graph(two).next = Graph(one)
Creating CleanupGraph 0x100468878 (three)
Creating CleanupGraph 0x1004688c0 (four)
Creating CleanupGraph 0x100468908 (five)
Linking nodes CleanupGraph(four).next = CleanupGraph(five)
Linking nodes CleanupGraph(five).next = CleanupGraph(four)
CleanupGraph(three).__del__()

Collecting
gc: collectable <Graph instance at 0x1004687a0>
gc: collectable <Graph instance at 0x1004687e8>
gc: uncollectable <CleanupGraph instance at 0x1004688c0>
gc: uncollectable <CleanupGraph instance at 0x100468908>
Done
```

If seeing the uncollectable objects is not enough information to understand where data is being retained, you can enable `DEBUG_SAVEALL` to cause `gc` to preserve all objects it finds without any references in the `garbage` list, so you can examine them. This is helpful if, for example, you don't have access to the constructor to print the object id when each object is created.

```
import gc

flags = (gc.DEBUG_COLLECTABLE |
         gc.DEBUG_UNCOLLECTABLE |
         gc.DEBUG_OBJECTS |
         gc.DEBUG_SAVEALL
         )

gc.set_debug(flags)

class Graph(object):
    def __init__(self, name):
        self.name = name
        self.next = None
    def set_next(self, next):
        self.next = next
    def __repr__(self):
        return '%s(%s)' % (self.__class__.__name__, self.name)

class CleanupGraph(Graph):
    def __del__(self):
        print '%s.__del__()' % self

# Construct a graph cycle
one = Graph('one')
two = Graph('two')
one.set_next(two)
two.set_next(one)

# Construct another node that stands on its own
three = CleanupGraph('three')

# Construct a graph cycle with a finalizer
four = CleanupGraph('four')
five = CleanupGraph('five')
four.set_next(five)
five.set_next(four)

# Remove references to the graph nodes in this module's namespace
one = two = three = four = five = None

# Force a sweep
print 'Collecting'
gc.collect()
print 'Done'

# Report on what was left
for o in gc.garbage:
    if isinstance(o, Graph):
        print 'Retained: %s 0x%x' % (o, id(o))
```

```
$ python -u gc_debug_saveall.py

CleanupGraph(three).__del__()
Collecting
gc: collectable <Graph 0x10045f790>
gc: collectable <Graph 0x10045f7d0>
gc: collectable <dict 0x100361890>
gc: collectable <dict 0x100361cb0>
gc: uncollectable <CleanupGraph 0x10045f850>
gc: uncollectable <CleanupGraph 0x10045f890>
gc: uncollectable <dict 0x100361dd0>
gc: uncollectable <dict 0x100362130>
Done
Retained: Graph(one) 0x10045f790
Retained: Graph(two) 0x10045f7d0
Retained: CleanupGraph(four) 0x10045f850
Retained: CleanupGraph(five) 0x10045f890
```

For simplicity, DEBUG_LEAK is defined as a combination of all of the other options.

```
import gc

flags = gc.DEBUG_LEAK

gc.set_debug(flags)

class Graph(object):
    def __init__(self, name):
        self.name = name
        self.next = None
    def set_next(self, next):
        self.next = next
    def __repr__(self):
        return '%s(%s)' % (self.__class__.__name__, self.name)

class CleanupGraph(Graph):
    def __del__(self):
        print '%s.__del__()' % self

# Construct a graph cycle
one = Graph('one')
two = Graph('two')
one.set_next(two)
two.set_next(one)

# Construct another node that stands on its own
three = CleanupGraph('three')

# Construct a graph cycle with a finalizer
four = CleanupGraph('four')
five = CleanupGraph('five')
four.set_next(five)
five.set_next(four)

# Remove references to the graph nodes in this module's namespace
one = two = three = four = five = None

# Force a sweep
print 'Collecting'
gc.collect()
print 'Done'

# Report on what was left
for o in gc.garbage:
    if isinstance(o, Graph):
        print 'Retained: %s 0x%x' % (o, id(o))
```

Keep in mind that because `DEBUG_SAVEALL` is enabled by `DEBUG_LEAK`, even the unreferenced objects that would normally have been collected and deleted are retained.

```
$ python -u gc_debug_leak.py

CleanupGraph(three).__del__()
Collecting
gc: collectable <Graph 0x10045f790>
gc: collectable <Graph 0x10045f7d0>
gc: collectable <dict 0x100360a20>
gc: collectable <dict 0x100361c20>
gc: uncollectable <CleanupGraph 0x10045f850>
gc: uncollectable <CleanupGraph 0x10045f890>
gc: uncollectable <dict 0x100361d40>
gc: uncollectable <dict 0x1003620a0>
Done
Retained: Graph(one) 0x10045f790
Retained: Graph(two) 0x10045f7d0
Retained: CleanupGraph(four) 0x10045f850
```

```
Retained: CleanupGraph(five) 0x10045f890
```

See also:

gc **(http://docs.python.org/library/gc.html)** The standard library documentation for this module.

weakref The weakref module gives you references to objects without increasing their reference count, so they can still be garbage collected.

Supporting Cyclic Garbage Collection **(http://docs.python.org/c-api/gcsupport.html)** Background material from Python's C API documentation.

How does Python manage memory? **(http://effbot.org/pyfaq/how-does-python-manage-memory.htm)** An article on Python memory management by Fredrik Lundh.

25.5 inspect – Inspect live objects

Purpose The inspect module provides functions for introspecting on live objects and their source code.

Available In added in 2.1, with updates in 2.3 and 2.5

The inspect module provides functions for learning about live objects, including modules, classes, instances, functions, and methods. You can use functions in this module to retrieve the original source code for a function, look at the arguments to a method on the stack, and extract the sort of information useful for producing library documentation for your source code. My own CommandLineApp (http://www.doughellmann.com/projects/CommandLineApp/) module uses inspect to determine the valid options to a command line program, as well as any arguments and their names so command line programs are self-documenting and the help text is generated automatically.

25.5.1 Module Information

The first kind of introspection supported lets you probe live objects to learn about them. For example, it is possible to discover the classes and functions in a module, the methods of a class, etc. Let's start with the module-level details and work our way down to the function level.

To determine how the interpreter will treat and load a file as a module, use `getmoduleinfo()`. Pass a filename as the only argument, and the return value is a tuple including the module base name, the suffix of the file, the mode that will be used for reading the file, and the module type as defined in the imp module. It is important to note that the function looks only at the file's name, and does not actually check if the file exists or try to read the file.

```python
import imp
import inspect
import sys

if len(sys.argv) >= 2:
    filename = sys.argv[1]
else:
    filename = 'example.py'

try:
    (name, suffix, mode, mtype)  = inspect.getmoduleinfo(filename)
except TypeError:
    print 'Could not determine module type of %s' % filename
else:
    mtype_name = { imp.PY_SOURCE:'source',
                   imp.PY_COMPILED:'compiled',
                   }.get(mtype, mtype)
    mode_description = { 'rb':'(read-binary)',
                         'U':'(universal newline)',
                         }.get(mode, '')

    print 'NAME   :', name
    print 'SUFFIX :', suffix
    print 'MODE   :', mode, mode_description
    print 'MTYPE  :', mtype_name
```

Here are a few sample runs:

```
$ python inspect_getmoduleinfo.py example.py

NAME   : example
SUFFIX : .py
MODE   : U (universal newline)
MTYPE  : source

$ python inspect_getmoduleinfo.py readme.txt

Could not determine module type of readme.txt

$ python inspect_getmoduleinfo.py notthere.pyc

NAME   : notthere
SUFFIX : .pyc
MODE   : rb (read-binary)
MTYPE  : compiled
```

25.5.2 Example Module

The rest of the examples for this tutorial use a single example file source file, found in `PyMOTW/inspect/example.py` and which is included below. The file is also available as part of the source distribution associated with this series of articles.

```
"""Sample file to serve as the basis for inspect examples.
"""

def module_level_function(arg1, arg2='default', *args, **kwargs):
    """This function is declared in the module."""
    local_variable = arg1
    return

class A(object):
    """The A class."""
    def __init__(self, name):
        self.name = name

    def get_name(self):
        "Returns the name of the instance."
        return self.name

instance_of_a = A('sample_instance')

class B(A):
    """This is the B class.
    It is derived from A.
    """

    # This method is not part of A.
    def do_something(self):
        """Does some work"""
        pass

    def get_name(self):
        "Overrides version from A"
        return 'B(' + self.name + ')'
```

25.5.3 Modules

It is possible to probe live objects to determine their components using `getmembers()`. The arguments to `getmembers()` are an object to scan (a module, class, or instance) and an optional predicate function that is used to filter the objects returned. The return value is a list of tuples with 2 values: the name of the member, and the type of the member. The inspect module includes several such predicate functions with names like `ismodule()`, `isclass()`, etc. You can provide your own predicate function as well.

The types of members that might be returned depend on the type of object scanned. Modules can contain classes and functions; classes can contain methods and attributes; and so on.

```
import inspect

import example

for name, data in inspect.getmembers(example):
    if name == '__builtins__':
        continue
    print '%s :' % name, repr(data)
```

This sample prints the members of the example module. Modules have a set of `__builtins__`, which are ignored in the output for this example because they are not actually part of the module and the list is long.

```
$ python inspect_getmembers_module.py
A : <class 'example.A'>
B : <class 'example.B'>
__doc__ : 'Sample file to serve as the basis for inspect examples.\n'
__file__ : '/Users/dhellmann/Documents/PyMOTW/branches/inspect/example.pyc'
__name__ : 'example'
instance_of_a : <example.A object at 0xbb810>
module_level_function : <function module_level_function at 0xc8230>
```

The predicate argument can be used to filter the types of objects returned.

```
import inspect

import example

for name, data in inspect.getmembers(example, inspect.isclass):
    print '%s :' % name, repr(data)
```

Notice that only classes are included in the output, now:

```
$ python inspect_getmembers_module_class.py
```

```
A : <class 'example.A'>
B : <class 'example.B'>
```

25.5.4 Classes

Classes are scanned using `getmembers()` in the same way as modules, though the types of members are different.

```
import inspect
from pprint import pprint

import example

pprint(inspect.getmembers(example.A))
```

Since no filtering is applied, the output shows the attributes, methods, slots, and other members of the class:

```
$ python inspect_getmembers_class.py
[('__class__', <type 'type'>),
 ('__delattr__', <slot wrapper '__delattr__' of 'object' objects>),
 ('__dict__', <dictproxy object at 0xca090>),
 ('__doc__', 'The A class.'),
 ('__getattribute__', <slot wrapper '__getattribute__' of 'object' objects>),
 ('__hash__', <slot wrapper '__hash__' of 'object' objects>),
 ('__init__', <unbound method A.__init__>),
 ('__module__', 'example'),
 ('__new__', <built-in method __new__ of type object at 0x32ff38>),
 ('__reduce__', <method '__reduce__' of 'object' objects>),
 ('__reduce_ex__', <method '__reduce_ex__' of 'object' objects>),
 ('__repr__', <slot wrapper '__repr__' of 'object' objects>),
 ('__setattr__', <slot wrapper '__setattr__' of 'object' objects>),
 ('__str__', <slot wrapper '__str__' of 'object' objects>),
 ('__weakref__', <attribute '__weakref__' of 'A' objects>),
 ('get_name', <unbound method A.get_name>)]
```

To find the methods of a class, use the `ismethod()` predicate:

```
import inspect
from pprint import pprint

import example

pprint(inspect.getmembers(example.A, inspect.ismethod))
```

```
$ python inspect_getmembers_class_methods.py

[('__init__', <unbound method A.__init__>),
 ('get_name', <unbound method A.get_name>)]
```

If we look at class B, we see the over-ride for `get_name()` as well as the new method, and the inherited `__init__()` method implented in A.

```
import inspect
from pprint import pprint

import example

pprint(inspect.getmembers(example.B, inspect.ismethod))
```

Notice that even though `__init__()` is inherited from `A`, it is identified as a method of `B`.

```
$ python inspect_getmembers_class_methods_b.py

[('__init__', <unbound method B.__init__>),
 ('do_something', <unbound method B.do_something>),
 ('get_name', <unbound method B.get_name>)]
```

25.5.5 Documentation Strings

The docstring for an object can be retrieved with `getdoc()`. The return value is the `__doc__` attribute with tabs expanded to spaces and with indentation made uniform.

```
import inspect
import example

print 'B.__doc__:'
print example.B.__doc__
print
print 'getdoc(B):'
print inspect.getdoc(example.B)
```

Notice the difference in indentation on the second line of the doctring:

```
$ python inspect_getdoc.py

B.__doc__:
This is the B class.
    It is derived from A.


getdoc(B):
This is the B class.
It is derived from A.
```

In addition to the actual docstring, it is possible to retrieve the comments from the source file where an object is implemented, if the source is available. The `getcomments()` function looks at the source of the object and finds comments on lines preceding the implementation.

```
import inspect
import example

print inspect.getcomments(example.B.do_something)
```

The lines returned include the comment prefix, but any whitespace prefix is stripped off.

```
$ python inspect_getcomments_method.py

# This method is not part of A.
```

When a module is passed to `getcomments()`, the return value is always the first comment in the module.

```
import inspect
import example

print inspect.getcomments(example)
```

Notice that contiguous lines from the example file are included as a single comment, but as soon as a blank line appears the comment is stopped.

```
$ python inspect_getcomments_module.py

# This comment appears first
# and spans 2 lines.
```

25.5.6 Retrieving Source

If the `.py` file is available for a module, the original source code for the class or method can be retrieved using `getsource()` and `getsourcelines()`.

```
import inspect
import example

print inspect.getsource(example.A.get_name)
```

The original indent level is retained in this case.

```
$ python inspect_getsource_method.py

    def get_name(self):
        "Returns the name of the instance."
        return self.name
```

When a class is passed in, all of the methods for the class are included in the output.

```
import inspect
import example

print inspect.getsource(example.A)
```

```
$ python inspect_getsource_class.py

class A(object):
    """The A class."""
    def __init__(self, name):
        self.name = name

    def get_name(self):
        "Returns the name of the instance."
        return self.name
```

If you need the lines of source split up, it can be easier to use `getsourcelines()` instead of `getsource()`. The return value from `getsourcelines()` is a tuple containing a list of strings (the lines from the source file), and a starting line number in the file where the source appears.

```
import inspect
import pprint
import example

pprint.pprint(inspect.getsourcelines(example.A.get_name))
```

```
$ python inspect_getsourcelines_method.py

(['    def get_name(self):\n',
  '        "Returns the name of the instance."\n',
  '        return self.name\n'],
 48)
```

If the source file is not available, `getsource()` and `getsourcelines()` raise an *IOError*.

25.5.7 Method and Function Arguments

In addition to the documentation for a function or method, it is possible to ask for a complete specification of the arguments the callable takes, including default values. The `getargspec()` function returns a tuple containing the list of positional argument names, the name of any variable positional arguments (e.g., `*args`), the names of any variable named arguments (e.g., `**kwds`), and default values for the arguments. If there are default values, they match up with the end of the positional argument list.

```
import inspect
import example

arg_spec = inspect.getargspec(example.module_level_function)
print 'NAMES   :', arg_spec[0]
print '*       :', arg_spec[1]
print '**      :', arg_spec[2]
print 'defaults:', arg_spec[3]

args_with_defaults = arg_spec[0][-len(arg_spec[3]):]
print 'args & defaults:', zip(args_with_defaults, arg_spec[3])
```

Note that the first argument, *arg1*, does not have a default value. The single default therefore is matched up with *arg2*.

```
$ python inspect_getargspec_function.py

NAMES   : ['arg1', 'arg2']
*       : args
**      : kwargs
defaults: ('default',)
args & defaults: [('arg2', 'default')]
```

25.5.8 Class Hierarchies

`inspect` includes two methods for working directly with class hierarchies. The first, `getclasstree()`, creates a tree-like data structure using nested lists and tuples based on the classes it is given and their base classes. Each element in the list returned is either a tuple with a class and its base classes, or another list containing tuples for subclasses.

```
import inspect
import example

class C(example.B):
    pass

class D(C, example.A):
    pass

def print_class_tree(tree, indent=-1):
    if isinstance(tree, list):
        for node in tree:
            print_class_tree(node, indent+1)
    else:
        print '  ' * indent, tree[0].__name__
    return

if __name__ == '__main__':
    print 'A, B, C, D:'
    print_class_tree(inspect.getclasstree([example.A, example.B, C, D]))
```

The output from this example is the "tree" of inheritance for the A, B, C, and D classes. Note that D appears twice, since it inherits from both C and A.

```
$ python inspect_getclasstree.py

A, B, C, D:
 object
   A
     D
     B
       C
         D
```

If we call `getclasstree()` with `unique=True`, the output is different.

```
import inspect
import example
from inspect_getclasstree import *

print_class_tree(inspect.getclasstree([example.A, example.B, C, D],
                                      unique=True,
                                      ))
```

This time, D only appears in the output once:

```
$ python inspect_getclasstree_unique.py

 object
   A
     B
       C
         D
```

25.5.9 Method Resolution Order

The other function for working with class hierarchies is `getmro()`, which returns a tuple of classes in the order they should be scanned when resolving an attribute that might be inherited from a base class. Each class in the sequence appears only once.

```
import inspect
import example

class C(object):
    pass

class C_First(C, example.B):
    pass

class B_First(example.B, C):
    pass

print 'B_First:'
for c in inspect.getmro(B_First):
    print '\t', c.__name__
print
```

```
print 'C_First:'
for c in inspect.getmro(C_First):
    print '\t', c.__name__
```

This output demonstrates the "depth-first" nature of the MRO (http://www.python.org/download/releases/2.3/mro/) search. For B_First, A also comes before C in the search order, because B is derived from A.

```
$ python inspect_getmro.py

B_First:
        B_First
        B
        A
        C
        object

C_First:
        C_First
        C
        B
        A
        object
```

25.5.10 The Stack and Frames

In addition to introspection of code objects, inspect includes functions for inspecting the runtime environment while a program is running. Most of these functions work with the call stack, and operate on "call frames". Each frame record in the stack is a 6 element tuple containing the frame object, the filename where the code exists, the line number in that file for the current line being run, the function name being called, a list of lines of context from the source file, and the index into that list of the current line. Typically such information is used to build tracebacks when exceptions are raised. It can also be useful when debugging programs, since the stack frames can be interrogated to discover the argument values passed into the functions.

`currentframe()` returns the frame at the top of the stack (for the current function). `getargvalues()` returns a tuple with argument names, the names of the variable arguments, and a dictionary with local values from the frame. By combining them, we can see the arguments to functions and local variables at different points in the call stack.

```
import inspect

def recurse(limit):
    local_variable = '.' * limit
    print limit, inspect.getargvalues(inspect.currentframe())
    if limit <= 0:
        return
    recurse(limit - 1)
    return

if __name__ == '__main__':
    recurse(3)
```

The value for `local_variable` is included in the frame's local variables even though it is not an argument to the function.

```
$ python inspect_getargvalues.py

3 ArgInfo(args=['limit'], varargs=None, keywords=None, locals={'local_variable': '...', 'limit': 3})
2 ArgInfo(args=['limit'], varargs=None, keywords=None, locals={'local_variable': '..', 'limit': 2})
```

```
1 ArgInfo(args=['limit'], varargs=None, keywords=None, locals={'local_variable': '.', 'limit': 1})
0 ArgInfo(args=['limit'], varargs=None, keywords=None, locals={'local_variable': '', 'limit': 0})
```

Using `stack()`, it is also possible to access all of the stack frames from the current frame to the first caller. This example is similar to the one above, except it waits until reaching the end of the recursion to print the stack information.

```python
import inspect

def recurse(limit):
    local_variable = '.' * limit
    if limit <= 0:
        for frame, filename, line_num, func, source_code, source_index in inspect.stack():
            print '%s[%d]\n  -> %s' % (filename, line_num, source_code[source_index].strip())
            print inspect.getargvalues(frame)
            print
        return
    recurse(limit - 1)
    return

if __name__ == '__main__':
    recurse(3)
```

The last part of the output represents the main program, outside of the recurse function.

```
$ python inspect_stack.py
inspect_stack.py[37]
  -> for frame, filename, line_num, func, source_code, source_index in inspect.stack():
(['limit'], None, None, {'local_variable': '', 'line_num': 37, 'frame': <frame object at 0x61ba30>,
'filename': 'inspect_stack.py', 'limit': 0, 'func': 'recurse', 'source_index': 0,
'source_code': ['        for frame, filename, line_num, func, source_code, source_index in inspect.st

inspect_stack.py[42]
  -> recurse(limit - 1)
(['limit'], None, None, {'local_variable': '.', 'limit': 1})

inspect_stack.py[42]
  -> recurse(limit - 1)
(['limit'], None, None, {'local_variable': '..', 'limit': 2})

inspect_stack.py[42]
  -> recurse(limit - 1)
(['limit'], None, None, {'local_variable': '...', 'limit': 3})

inspect_stack.py[46]
  -> recurse(3)
([], None, None, {'__builtins__': <module '__builtin__' (built-in)>,
'__file__': 'inspect_stack.py',
'inspect': <module 'inspect' from '/Library/Frameworks/Python.framework/Versions/2.5/lib/python2.5/in
'recurse': <function recurse at 0xc81b0>, '__name__': '__main__',
'__doc__': 'Inspecting the call stack.\n\n'})
```

There are other functions for building lists of frames in different contexts, such as when an exception is being processed. See the documentation for `trace()`, `getouterframes()`, and `getinnerframes()` for more details.

See also:

inspect **(http://docs.python.org/library/inspect.html)** The standard library documentation for this module.

CommandLineApp **(http://www.doughellmann.com/projects/CommandLineApp/)** Base class for object-oriented command line applications

Python 2.3 Method Resolution Order (http://www.python.org/download/releases/2.3/mro/) Documentation for the C3 Method Resolution order used by Python 2.3 and later.

25.6 site – Site-wide configuration

The `site` module handles site-specific configuration, especially the *import path*.

25.6.1 Import Path

`site` is automatically imported each time the interpreter starts up. On import, it extends *sys.path* with site-specific names constructed by combining the prefix values *sys.prefix* and *sys.exec_prefix* with several suffixes. The prefix values used are saved in the module-level variable `PREFIXES` for reference later. Under Windows, the suffixes are an empty string and `lib/site-packages`. For Unix-like platforms, the values are `lib/python$version/site-packages` and `lib/site-python`.

```
import sys
import os
import platform
import site

if 'Windows' in platform.platform():
    SUFFIXES = [
        '',
        'lib/site-packages',
        ]
else:
    SUFFIXES = [
        'lib/python%s/site-packages' % sys.version[:3],
        'lib/site-python',
        ]

print 'Path prefixes:'
for p in site.PREFIXES:
    print '   ', p

for prefix in sorted(set(site.PREFIXES)):
    print
    for suffix in SUFFIXES:
        path = os.path.join(prefix, suffix).rstrip(os.sep)
        print path
        print '   exists:', os.path.exists(path)
        print '  in path:', path in sys.path
```

Each of the paths resulting from the combinations is tested, and those that exist are added to *sys.path*.

```
$ python site_import_path.py
Path prefixes:
   /Library/Frameworks/Python.framework/Versions/2.7
   /Library/Frameworks/Python.framework/Versions/2.7

/Library/Frameworks/Python.framework/Versions/2.7/lib/python2.7/site-packages
   exists: True
  in path: True
/Library/Frameworks/Python.framework/Versions/2.7/lib/site-python
```

```
   exists: False
  in path: False
```

25.6.2 User Directories

In addition to the global site-packages paths, `site` is responsible for adding the user-specific locations to the import path. The user-specific paths are all based on the `USER_BASE` directory, which usually located in a part of the filesystem owned (and writable) by the current user. Inside the `USER_BASE` is a site-packages directory, with the path accessible as `USER_SITE`.

```
import site

print 'Base:', site.USER_BASE
print 'Site:', site.USER_SITE
```

The `USER_SITE` path name is created using the same platform-specific values described above.

```
$ python site_user_base.py

Base: /Users/dhellmann/.local
Site: /Users/dhellmann/.local/lib/python2.7/site-packages
```

The user base directory can be set through the `PYTHONUSERBASE` environment variable, and has platform-specific defaults (`~/Python$version/site-packages` for Windows and `~/.local` for non-Windows).

You can check the `USER_BASE` value from outside of your Python program by running `site` from the command line. `site` will give you the name of the directory whether or not it exists, but it is only added to the import path when it does.

```
$ python -m site --user-base


$ python -m site --user-site


$ PYTHONUSERBASE=/tmp/$USER python -m site --user-base


$ PYTHONUSERBASE=/tmp/$USER python -m site --user-site
```

The user directory is disabled under some circumstances that would pose security issues. For example, if the process is running with a different effective user or group id than the actual user that started it. Your application can check the setting by examining `ENABLE_USER_SITE`.

```
import site

status = {
    None:'Disabled for security',
    True:'Enabled',
    False:'Disabled by command-line option',
    }

print 'Flag   :', site.ENABLE_USER_SITE
print 'Meaning:', status[site.ENABLE_USER_SITE]
```

The user directory can also be explicitly disabled on the command line with `-s`.

```
$ python site_enable_user_site.py

Flag   : True
Meaning: Enabled

$ python -s site_enable_user_site.py

Flag   : False
Meaning: Disabled by command-line option
```

25.6.3 Path Configuration Files

As paths are added to the import path, they are also scanned for *path configuration files*. A path configuration file is a plain text file with the extension `.pth`. Each line in the file can take one of four forms:

1. A full or relative path to another location that should be added to the import path.
2. A Python statement to be executed. All such lines must begin with an `import` statement.
3. Blank lines are ignored.
4. A line starting with # is treated as a comment and ignored.

Path configuration files can be used to extend the import path to look in locations that would not have been added automatically. For example, Distribute (http://packages.python.org/distribute) adds a path to `easy-install.pth` when it installs a package in "develop" mode using `python setup.py develop`.

The function for extending `sys.path` is public, so we can use it in example programs to show how the path configuration files work. Given a directory `with_modules` containing the file `mymodule.py` with this `print` statement showing how the module was imported:

```
import os
print 'Loaded', __name__, 'from', __file__[len(os.getcwd())+1:]
```

This script shows how `addsitedir()` extends the import path so the interpreter can find the desired module.

```
import site
import os
import sys

script_directory = os.path.dirname(__file__)
module_directory = os.path.join(script_directory, sys.argv[1])

try:
    import mymodule
except ImportError, err:
    print 'Could not import mymodule:', err

print
before_len = len(sys.path)
site.addsitedir(module_directory)
print 'New paths:'
for p in sys.path[before_len:]:
    print '   ', p

print
import mymodule
```

After the directory containing the module is added to `sys.path`, the script can import `mymodule` without issue.

```
$ python site_addsitedir.py with_modules

Could not import mymodule: No module named mymodule

New paths:
   /Users/dhellmann/Documents/PyMOTW/src/PyMOTW/site/with_modules

Loaded mymodule from with_modules/mymodule.py
```

If the directory given to `addsitedir()` includes any files matching the pattern `*.pth`, they are loaded as path configuration files. For example, if we create `with_pth/pymotw.pth` containing:

```
# Add a single subdirectory to the path.
./subdir
```

and copy `mymodule.py` to `with_pth/subdir/mymodule.py`, then we can import it by adding `with_pth` as a site directory, even though the module is not in that directory.

```
$ python site_addsitedir.py with_pth

Could not import mymodule: No module named mymodule

New paths:
   /Users/dhellmann/Documents/PyMOTW/src/PyMOTW/site/with_pth
   /Users/dhellmann/Documents/PyMOTW/src/PyMOTW/site/with_pth/subdir

Loaded mymodule from with_pth/subdir/mymodule.py
```

If a site directory contains multiple `.pth` files, they are processed in alphabetical order.

```
$ ls -F with_multiple_pth

a.pth
b.pth
from_a/
from_b/

$ cat with_multiple_pth/a.pth

./from_a

$ cat with_multiple_pth/b.pth

./from_b
```

In this case, the module is found in `with_multiple_pth/from_a` because `a.pth` is read before `b.pth`.

```
$ python site_addsitedir.py with_multiple_pth

Could not import mymodule: No module named mymodule

New paths:
   /Users/dhellmann/Documents/PyMOTW/src/PyMOTW/site/with_multiple_pth
   /Users/dhellmann/Documents/PyMOTW/src/PyMOTW/site/with_multiple_pth/from_a
   /Users/dhellmann/Documents/PyMOTW/src/PyMOTW/site/with_multiple_pth/from_b

Loaded mymodule from with_multiple_pth/from_a/mymodule.py
```

25.6.4 sitecustomize

The site module is also responsible for loading site-wide customization defined by the local site owner in a sitecustomize module. Uses for sitecustomize include extending the import path and enabling coverage (http://nedbatchelder.com/blog/201001/running_code_at_python_startup.html), profiling, or other development tools.

For example, this `sitecustomize.py` script extends the import path with a directory based on the current platform. The platform-specific path in `/opt/python` is added to the import path, so any packages installed there can be imported. A system like this is useful for sharing packages containing compiled extension modules between hosts on a network via a shared filesystem. Only the `sitecustomize.py` script needs to be installed on each host, and the other packages can be accessed from the file server.

```
print 'Loading sitecustomize.py'

import site
import platform
import os
import sys

path = os.path.join('/opt', 'python', sys.version[:3], platform.platform())
print 'Adding new path', path

site.addsitedir(path)
```

A simple script can be used to show that `sitecustomize.py` is imported before Python starts running your own code.

```
import sys

print 'Running main program'

print 'End of path:', sys.path[-1]
```

Since sitecustomize is meant for system-wide configuration, it should be installed somewere in the default path (usally in the `site-packages` directory). This example sets `PYTHONPATH` explicitly to ensure the module is picked up.

```
$ PYTHONPATH=with_sitecustomize python with_sitecustomize/site_sitecusto\
mize.py

Loading sitecustomize.py
Adding new path /opt/python/2.7/Darwin-11.4.2-x86_64-i386-64bit
Running main program
End of path: /opt/python/2.7/Darwin-11.4.2-x86_64-i386-64bit
```

25.6.5 usercustomize

Similar to sitecustomize, the usercustomize module can be used to set up user-specific settings each time the interpreter starts up. usercustomize is loaded after sitecustomize, so site-wide customizations can be overridden.

In environments where a user's home directory is shared on several servers running different operating systems or versions, the standard user directory mechanism may not work for user-specific installations of packages. In these cases, platform-specific directory tree can be used instead.

```
print 'Loading usercustomize.py'
```

```
import site
import platform
import os
import sys

path = os.path.expanduser(os.path.join('~', 'python', sys.version[:3], platform.platform()))
print 'Adding new path', path

site.addsitedir(path)
```

Another simple script, similar to the one used for `sitecustomize`, can be used to show that `usercustomize.py` is imported before Python starts running your own code.

```
import sys

print 'Running main program'

print 'End of path:', sys.path[-1]
```

Since `usercustomize` is meant for user-specific configuration for a user, it should be installed somewhere in the user's default path, but not on the site-wide path. The default `USER_BASE` directory is a good location. This example sets `PYTHONPATH` explicitly to ensure the module is picked up.

```
$ PYTHONPATH=with_usercustomize python with_usercustomize/site_usercusto\
mize.py

Loading usercustomize.py
Adding new path /Users/dhellmann/python/2.7/Darwin-11.4.2-x86_64-i386-64bit
Running main program
End of path: /Users/dhellmann/python/2.7/Darwin-11.4.2-x86_64-i386-64bit
```

When the user site directory feature is disabled, `usercustomize` is not imported, whether it is located in the user site directory or elsewhere.

```
$ PYTHONPATH=with_usercustomize python -s with_usercustomize/site_usercu\
stomize.py

Running main program
End of path: /Library/Frameworks/Python.framework/Versions/2.7/lib/python2.7/site-packages
```

25.6.6 Disabling site

To maintain backwards-compatibility with versions of Python from before the automatic import was added, the interpreter accepts an *-S* option.

```
$ python -S site_import_path.py
Path prefixes:
   sys.prefix     : /Library/Frameworks/Python.framework/Versions/2.7
   sys.exec_prefix: /Library/Frameworks/Python.framework/Versions/2.7

/Library/Frameworks/Python.framework/Versions/2.7/lib/python2.7/site-packages
   exists: True
  in path: False
/Library/Frameworks/Python.framework/Versions/2.7/lib/site-python
   exists: False
  in path: False
```

See also:

site (http://docs.python.org/library/site.html) The standard library documentation for this module.

Modules and Imports Description of how the import path defined in `sys` works.

Running code at Python startup (http://nedbatchelder.com/blog/201001/running_code_at_python_startup.html)
Post from Ned Batchelder discussing ways to cause the Python interpreter to run your custom initialization code before starting the main program execution.

25.7 sys – System-specific Configuration

Purpose Provides system-specific configuration and operations.

Available In 1.4 and later

The `sys` module includes a collection of services for probing or changing the configuration of the interpreter at runtime and resources for interacting with the operating environment outside of the current program.

25.7.1 Interpreter Settings

`sys` contains attributes and functions for accessing compile-time or runtime configuration settings for the interpreter.

Build-time Version Information

The version used to build the C interpreter is available in a few forms. `sys.version` is a human-readable string that usually includes the full version number as well as information about the build date, compiler, and platform. `sys.hexversion` is easier to use for checking the interpreter version since it is a simple integer. When formatted using `hex()`, it is clear that parts of `sys.hexversion` come from the version information also visible in the more readable `sys.version_info` (a 5-part tuple representing just the version number).

More specific information about the source that went into the build can be found in the `sys.subversion` tuple, which includes the actual branch and subversion revision that was checked out and built. The separate C API version used by the current interpreter is saved in `sys.api_version`.

```
import sys

print 'Version info:'
print
print 'sys.version      =', repr(sys.version)
print 'sys.version_info =', sys.version_info
print 'sys.hexversion   =', hex(sys.hexversion)
print 'sys.subversion   =', sys.subversion
print 'sys.api_version  =', sys.api_version
```

All of the values depend on the actual interpreter used to run the sample program, of course.

```
$ python2.6 sys_version_values.py

Version info:

sys.version      = '2.6.8 (unknown, Aug 31 2012, 07:19:38) \n[GCC 4.2.
1 (Based on Apple Inc. build 5658) (LLVM build 2336.1.00)]'
sys.version_info = (2, 6, 8, 'final', 0)
sys.hexversion   = 0x20608f0
sys.subversion   = ('CPython', '', '')
sys.api_version  = 1013
```

```
$ python2.7 sys_version_values.py

Version info:

sys.version      = '2.7.2 (v2.7.2:8527427914a2, Jun 11 2011, 15:22:34)
 \n[GCC 4.2.1 (Apple Inc. build 5666) (dot 3)]'
sys.version_info = sys.version_info(major=2, minor=7, micro=2, release
level='final', serial=0)
sys.hexversion   = 0x20702f0
sys.subversion   = ('CPython', '', '')
sys.api_version  = 1013
```

The operating system platform used to build the interpreter is saved as `sys.platform`.

```
import sys

print 'This interpreter was built for:', sys.platform
```

For most Unix systems, the value comes from combining the output of `uname -s` with the first part of the version in `uname -r`. For other operating systems there is a hard-coded table of values (http://docs.python.org/library/sys.html#sys.platform).

```
$ python sys_platform.py

This interpreter was built for: darwin
```

Install Location

The path to the actual interpreter program is available in `sys.executable` on all systems for which having a path to the interpreter makes sense. This can be useful for ensuring that the *correct* interpreter is being used, and also gives clues about paths that might be set based on the interpreter location.

`sys.prefix` refers to the parent directory of the interpreter installation. It usually includes `bin` and `lib` directories for executables and installed modules, respectively.

```
import sys

print 'Interpreter executable:', sys.executable
print 'Installation prefix   :', sys.prefix
```

Note: This example output was produced on a Mac running a framework build installed from python.org. Other versions may produce different path information, even on a Mac.

```
$ python sys_locations.py

Interpreter executable: /Users/dhellmann/Envs/pymotw/bin/python
Installation prefix   : /Users/dhellmann/Envs/pymotw/bin/..
```

Command Line Options

The CPython interpreter accepts several command line options to control its behavior.

```
$ python -h

usage: python [option] ... [-c cmd | -m mod | file | -] [arg] ...
```

```
Options and arguments (and corresponding environment variables):
-B     : don't write .py[co] files on import; also PYTHONDONTWRITEBYTECODE=x
-c cmd : program passed in as string (terminates option list)
-d     : debug output from parser; also PYTHONDEBUG=x
-E     : ignore PYTHON* environment variables (such as PYTHONPATH)
-h     : print this help message and exit (also --help)
-i     : inspect interactively after running script; forces a prompt even
         if stdin does not appear to be a terminal; also PYTHONINSPECT=x
-m mod : run library module as a script (terminates option list)
-O     : optimize generated bytecode slightly; also PYTHONOPTIMIZE=x
-OO    : remove doc-strings in addition to the -O optimizations
-Q arg : division options: -Qold (default), -Qwarn, -Qwarnall, -Qnew
-s     : don't add user site directory to sys.path; also PYTHONNOUSERSITE
-S     : don't imply 'import site' on initialization
-t     : issue warnings about inconsistent tab usage (-tt: issue errors)
-u     : unbuffered binary stdout and stderr; also PYTHONUNBUFFERED=x
         see man page for details on internal buffering relating to '-u'
-v     : verbose (trace import statements); also PYTHONVERBOSE=x
         can be supplied multiple times to increase verbosity
-V     : print the Python version number and exit (also --version)
-W arg : warning control; arg is action:message:category:module:lineno
         also PYTHONWARNINGS=arg
-x     : skip first line of source, allowing use of non-Unix forms of #!cmd
-3     : warn about Python 3.x incompatibilities that 2to3 cannot trivially fix
file   : program read from script file
-      : program read from stdin (default; interactive mode if a tty)
arg ...: arguments passed to program in sys.argv[1:]

Other environment variables:
PYTHONSTARTUP: file executed on interactive startup (no default)
PYTHONPATH   : ':'-separated list of directories prefixed to the
               default module search path.  The result is sys.path.
PYTHONHOME   : alternate <prefix> directory (or <prefix>:<exec_prefix>).
               The default module search path uses <prefix>/pythonX.X.
PYTHONCASEOK : ignore case in 'import' statements (Windows).
PYTHONIOENCODING: Encoding[:errors] used for stdin/stdout/stderr.
```

Some of these are available for programs to check through `sys.flags`.

```python
import sys

if sys.flags.debug:
    print 'Debuging'
if sys.flags.py3k_warning:
    print 'Warning about Python 3.x incompatibilities'
if sys.flags.division_warning:
    print 'Warning about division change'
if sys.flags.division_new:
    print 'New division behavior enabled'
if sys.flags.inspect:
    print 'Will enter interactive mode after running'
if sys.flags.optimize:
    print 'Optimizing byte-code'
if sys.flags.dont_write_bytecode:
    print 'Not writing byte-code files'
if sys.flags.no_site:
    print 'Not importing "site"'
if sys.flags.ignore_environment:
    print 'Ignoring environment'
if sys.flags.tabcheck:
    print 'Checking for mixed tabs and spaces'
if sys.flags.verbose:
    print 'Verbose mode'
if sys.flags.unicode:
    print 'Unicode'
```

Experiment with `sys_flags.py` to learn how the command line options map to the flags settings.

```
$ python -3 -S -E sys_flags.py

Warning about Python 3.x incompatibilities
Warning about division change
Not importing "site"
Ignoring environment
Checking for mixed tabs and spaces
```

Unicode Defaults

To get the name of the default Unicode encoding being used by the interpreter, use `getdefaultencoding()`. The value is set during startup by `site`, which calls `sys.setdefaultencoding()` and then removes it from the namespace in `sys` to avoid having it called again.

The internal encoding default and the filesystem encoding may be different for some operating systems, so there is a separate way to retrieve the filesystem setting. `getfilesystemencoding()` returns an OS-specific (*not* filesystem-specific) value.

```
import sys

print 'Default encoding    :', sys.getdefaultencoding()
print 'Filesystem encoding :', sys.getfilesystemencoding()
```

Rather than changing the global default encoding, most Unicode experts recommend making an application explicitly Unicode-aware. This provides two benefits: Different Unicode encodings for different data sources can be handled more cleanly, and the number of assumptions about encodings in the application code is reduced.

```
$ python sys_unicode.py

Default encoding    : ascii
Filesystem encoding : utf-8
```

Interactive Prompts

The interactive interpreter uses two separate prompts for indicating the default input level (`ps1`) and the "continuation" of a multi-line statement (`ps2`). The values are only used by the interactive interpreter.

```
>>> import sys
>>> sys.ps1
'>>> '
>>> sys.ps2
'... '
>>>
```

Either or both prompt can be changed to a different string

```
>>> sys.ps1 = '::: '
::: sys.ps2 = '~~~ '
::: for i in range(3):
~~~   print i
~~~
0
1
2
:::
```

Alternately, any object that can be converted to a string (via `__str__`) can be used for the prompt.

```
import sys

class LineCounter(object):
    def __init__(self):
        self.count = 0
    def __str__(self):
        self.count += 1
        return '(%3d)> ' % self.count
```

The `LineCounter` keeps track of how many times it has been used, so the number in the prompt increases each time.

```
$ python
Python 2.6.2 (r262:71600, Apr 16 2009, 09:17:39)
[GCC 4.0.1 (Apple Computer, Inc. build 5250)] on darwin
Type "help", "copyright", "credits" or "license" for more information.
>>> from PyMOTW.sys.sys_ps1 import LineCounter
>>> import sys
>>> sys.ps1 = LineCounter()
(  1)>
(  2)>
(  3)>
```

Display Hook

`sys.displayhook` is invoked by the interactive interpreter each time the user enters an expression. The *result* of the expression is passed as the only argument to the function.

```
import sys

class ExpressionCounter(object):

    def __init__(self):
        self.count = 0
        self.previous_value = self

    def __call__(self, value):
        print
        print '  Previous:', self.previous_value
        print '  New     :', value
        print
        if value != self.previous_value:
            self.count += 1
            sys.ps1 = '(%3d)> ' % self.count
        self.previous_value = value
        sys.__displayhook__(value)
```

```
print 'installing'
sys.displayhook = ExpressionCounter()
```

The default value (saved in `sys.__displayhook__`) prints the result to stdout and saves it in `__builtin__._` for easy reference later.

```
$ python
Python 2.6.2 (r262:71600, Apr 16 2009, 09:17:39)
[GCC 4.0.1 (Apple Computer, Inc. build 5250)] on darwin
Type "help", "copyright", "credits" or "license" for more information.
>>> import PyMOTW.sys.sys_displayhook
installing
>>> 1+2

  Previous: <PyMOTW.sys.sys_displayhook.ExpressionCounter object at 0x9c5f90>
  New     : 3

3
(  1)> 'abc'

  Previous: 3
  New     : abc

'abc'
(  2)> 'abc'

  Previous: abc
  New     : abc

'abc'
(  2)> 'abc' * 3

  Previous: abc
  New     : abcabcabc

'abcabcabc'
(  3)>
```

25.7.2 Runtime Environment

`sys` provides low-level APIs for interacting with the system outside of an application, by accepting command line arguments, accessing user input, and passing messages and status values to the user.

Command Line Arguments

The arguments captured by the interpreter are processed there and not passed along to the program directly. Any remaining options and arguments, including the name of the script itself, are saved to `sys.argv` in case the program does need to use them.

```
import sys

print 'Arguments:', sys.argv
```

In the third example below, the `-u` option is understood by the interpreter, and is not passed directly to the program being run.

```
$ python sys_argv.py

Arguments: ['sys_argv.py']

$ python sys_argv.py -v foo blah

Arguments: ['sys_argv.py', '-v', 'foo', 'blah']

$ python -u sys_argv.py

Arguments: ['sys_argv.py']
```

See also:

getopt, **optparse**, **argparse** Modules for parsing command line arguments.

Input and Output Steams

Following the Unix paradigm, Python programs can access three file descriptors by default.

```
import sys

print >>sys.stderr, 'STATUS: Reading from stdin'

data = sys.stdin.read()

print >>sys.stderr, 'STATUS: Writing data to stdout'

sys.stdout.write(data)
sys.stdout.flush()

print >>sys.stderr, 'STATUS: Done'
```

`stdin` is the standard way to read input, usually from a console but also from other programs via a pipeline. `stdout` is the standard way to write output for a user (to the console) or to be sent to the next program in a pipeline. `stderr` is intended for use with warning or error messages.

```
$ cat sys_stdio.py | python sys_stdio.py

STATUS: Reading from stdin
STATUS: Writing data to stdout
#!/usr/bin/env python
# encoding: utf-8
#
# Copyright (c) 2009 Doug Hellmann All rights reserved.
#
"""
"""
#end_pymotw_header

import sys

print >>sys.stderr, 'STATUS: Reading from stdin'

data = sys.stdin.read()

print >>sys.stderr, 'STATUS: Writing data to stdout'
```

```
sys.stdout.write(data)
sys.stdout.flush()

print >>sys.stderr, 'STATUS: Done'
STATUS: Done
```

See also:

subprocess, pipes Both subprocess and pipes have features for pipelining programs together.

Returning Status

To return an exit code from your program, pass an integer value to `sys.exit()`.

```
import sys

exit_code = int(sys.argv[1])
sys.exit(exit_code)
```

A non-zero value means the program exited with an error.

```
$ python sys_exit.py 0 ; echo "Exited $?"

Exited 0

$ python sys_exit.py 1 ; echo "Exited $?"

Exited 1
```

25.7.3 Memory Management and Limits

`sys` includes several functions for understanding and controlling memory usage.

Reference Counts

Python uses *reference counting* and *garbage collection* for automatic memory management. An object is automatically marked to be collected when its reference count drops to zero. To examine the reference count of an existing object, use `getrefcount()`.

```
import sys

one = []
print 'At start         :', sys.getrefcount(one)

two = one

print 'Second reference :', sys.getrefcount(one)

del two

print 'After del        :', sys.getrefcount(one)
```

The count is actually one higher than expected because there is a temporary reference to the object held by `getrefcount()` itself.

```
$ python sys_getrefcount.py

At start          : 2
Second reference : 3
After del         : 2
```

See also:

`gc` Control the garbage collector via the functions exposed in `gc`.

Object Size

Knowing how many references an object has may help find cycles or a memory leak, but it isn't enough to determine what objects are consuming the *most* memory. That requires knowledge about how big objects are.

```
import sys

class OldStyle:
    pass

class NewStyle(object):
    pass

for obj in [ [], (), {}, 'c', 'string', 1, 2.3,
             OldStyle, OldStyle(), NewStyle, NewStyle(),
             ]:
    print '%10s : %s' % (type(obj).__name__, sys.getsizeof(obj))
```

`getsizeof()` reports the size in bytes.

```
$ python sys_getsizeof.py

      list : 72
     tuple : 56
      dict : 280
       str : 38
       str : 43
       int : 24
     float : 24
  classobj : 104
  instance : 72
      type : 904
  NewStyle : 64
```

The reported size for a custom class does not include the size of the attribute values.

```
import sys

class WithoutAttributes(object):
    pass

class WithAttributes(object):
    def __init__(self):
        self.a = 'a'
        self.b = 'b'
        return

without_attrs = WithoutAttributes()
```

```
print 'WithoutAttributes:', sys.getsizeof(without_attrs)

with_attrs = WithAttributes()
print 'WithAttributes:', sys.getsizeof(with_attrs)
```

This can give a false impression of the amount of memory being consumed.

```
$ python sys_getsizeof_object.py

WithoutAttributes: 64
WithAttributes: 64
```

For a more complete estimate of the space used by a class, provide a `__sizeof__()` method to compute the value by aggregating the sizes of attributes of an object.

```
import sys

class WithAttributes(object):
    def __init__(self):
        self.a = 'a'
        self.b = 'b'
        return
    def __sizeof__(self):
        return object.__sizeof__(self) + \
            sum(sys.getsizeof(v) for v in self.__dict__.values())

my_inst = WithAttributes()
print sys.getsizeof(my_inst)
```

This version adds the base size of the object to the sizes of all of the attributes stored in the internal `__dict__`.

```
$ python sys_getsizeof_custom.py

140
```

Recursion

Allowing infinite recursion in a Python application may introduce a stack overflow in the interpreter itself, leading to a crash. To eliminate this situation, the interpreter provides a way to control the maximum recursion depth using `setrecursionlimit()` and `getrecursionlimit()`.

```
import sys

print 'Initial limit:', sys.getrecursionlimit()

sys.setrecursionlimit(10)

print 'Modified limit:', sys.getrecursionlimit()

def generate_recursion_error(i):
    print 'generate_recursion_error(%s)' % i
    generate_recursion_error(i+1)

try:
    generate_recursion_error(1)
except RuntimeError, err:
    print 'Caught exception:', err
```

Once the recursion limit is reached, the interpreter raises a *RuntimeError* exception so the program has an opportunity to handle the situation.

```
$ python sys_recursionlimit.py

Initial limit: 1000
Modified limit: 10
generate_recursion_error(1)
generate_recursion_error(2)
generate_recursion_error(3)
generate_recursion_error(4)
generate_recursion_error(5)
generate_recursion_error(6)
generate_recursion_error(7)
generate_recursion_error(8)
Caught exception: maximum recursion depth exceeded while getting the str of an object
```

Maximum Values

Along with the runtime configurable values, `sys` includes variables defining the maximum values for types that vary from system to system.

```
import sys

print 'maxint    :', sys.maxint
print 'maxsize   :', sys.maxsize
print 'maxunicode:', sys.maxunicode
```

`maxint` is the largest representable regular integer. `maxsize` is the maximum size of a list, dictionary, string, or other data structure dictated by the C interpreter's size type. `maxunicode` is the largest integer Unicode point supported by the interpreter as currently configured.

```
$ python sys_maximums.py

maxint    : 9223372036854775807
maxsize   : 9223372036854775807
maxunicode: 65535
```

Floating Point Values

The structure `float_info` contains information about the floating point type representation used by the interpreter, based on the underlying system's float implementation.

```
import sys

print 'Smallest difference (epsilon):', sys.float_info.epsilon
print
print 'Digits (dig)              :', sys.float_info.dig
print 'Mantissa digits (mant_dig):', sys.float_info.mant_dig
print
print 'Maximum (max):', sys.float_info.max
print 'Minimum (min):', sys.float_info.min
print
print 'Radix of exponents (radix):', sys.float_info.radix
print
print 'Maximum exponent for radix (max_exp):', sys.float_info.max_exp
print 'Minimum exponent for radix (min_exp):', sys.float_info.min_exp
print
print 'Maximum exponent for power of 10 (max_10_exp):', sys.float_info.max_10_exp
print 'Minimum exponent for power of 10 (min_10_exp):', sys.float_info.min_10_exp
print
print 'Rounding for addition (rounds):', sys.float_info.rounds
```

Note: These values depend on the compiler and underlying system. These examples were produced on OS X 10.6.4.

```
$ python sys_float_info.py

Smallest difference (epsilon): 2.22044604925e-16

Digits (dig)              : 15
Mantissa digits (mant_dig): 53

Maximum (max): 1.79769313486e+308
Minimum (min): 2.22507385851e-308

Radix of exponents (radix): 2

Maximum exponent for radix (max_exp): 1024
Minimum exponent for radix (min_exp): -1021

Maximum exponent for power of 10 (max_10_exp): 308
Minimum exponent for power of 10 (min_10_exp): -307

Rounding for addition (rounds): 1
```

See also:

The `float.h` C header file for the local compiler contains more details about these settings.

Byte Ordering

`byteorder` is set to the native byte order.

```
import sys

print sys.byteorder
```

The value is either `big` for big-endian or `little` for little-endian.

```
$ python sys_byteorder.py

little
```

See also:

Wikipedia: Endianness **(http://en.wikipedia.org/wiki/Byte_order)** Description of big and little endian memory systems.

array, **struct** Other modules that depend on the byte order.

25.7.4 Exception Handling

`sys` includes features for trapping and working with exceptions.

Unhandled Exceptions

Many applications are structured with a main loop that wraps execution in a global exception handler to trap errors not handled at a lower level. Another way to achieve the same thing is by setting the `sys.excepthook` to a function that takes three arguments (error type, error value, and traceback) and let it deal with unhandled errors.

```
import sys

def my_excepthook(type, value, traceback):
    print 'Unhandled error:', type, value

sys.excepthook = my_excepthook

print 'Before exception'

raise RuntimeError('This is the error message')

print 'After exception'
```

Since there is no **try:except** block around the line where the exception is raised the following **print** statement is not run, even though the except hook is set.

```
$ python sys_excepthook.py

Before exception
Unhandled error: <type 'exceptions.RuntimeError'> This is the error message
```

Current Exception

There are times when an explicit exception handler is preferred, either for code clarity or to avoid conflicts with libraries that try to install their own excepthook. In these cases you may want to write a common handler function, but avoid passing the exception object to it explicitly. You can get the current exception for a thread by calling `exc_info()`.

The return value of `exc_info()` is a three member tuple containing the exception class, an exception instance, and a traceback. Using `exc_info()` is preferred over the old form (with `exc_type`, `exc_value`, and `exc_traceback`) because it is thread-safe.

```
import sys
import threading
import time

def do_something_with_exception():
    exc_type, exc_value = sys.exc_info()[:2]
    print 'Handling %s exception with message "%s" in %s' % \
        (exc_type.__name__, exc_value, threading.current_thread().name)

def cause_exception(delay):
    time.sleep(delay)
    raise RuntimeError('This is the error message')

def thread_target(delay):
    try:
        cause_exception(delay)
    except:
        do_something_with_exception()
```

```
threads = [ threading.Thread(target=thread_target, args=(0.3,)),
            threading.Thread(target=thread_target, args=(0.1,)),
            ]
for t in threads:
    t.start()
for t in threads:
    t.join()
```

This example avoids introducing a circular reference between the traceback object and a local variable in the current frame by ignoring that part of the return value from `exc_info()`. If the traceback is needed (e.g., so it can be logged), explicitly delete the local variable (using **del**) to avoid cycles.

```
$ python sys_exc_info.py

Handling RuntimeError exception with message "This is the error message" in Thread-2
Handling RuntimeError exception with message "This is the error message" in Thread-1
```

Previous Interactive Exception

In the interactive interpreter, there is only one thread of interaction. Unhandled exceptions in that thread are saved to three variables in `sys` (`last_type`, `last_value`, and `last_traceback`) to make it easy to retrieve them for debugging. Using the post-mortem debugger in `pdb` avoids any need to use the values directly.

```
$ python
Python 2.6.2 (r262:71600, Apr 16 2009, 09:17:39)
[GCC 4.0.1 (Apple Computer, Inc. build 5250)] on darwin
Type "help", "copyright", "credits" or "license" for more information.
>>> def cause_exception():
...   raise RuntimeError('This is the error message')
...
>>> cause_exception()
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
  File "<stdin>", line 2, in cause_exception
RuntimeError: This is the error message
>>> import pdb
>>> pdb.pm()
> <stdin>(2)cause_exception()
(Pdb) where
  <stdin>(1)<module>()
> <stdin>(2)cause_exception()
(Pdb)
```

See also:

`exceptions` Built-in errors

`pdb` Python debugger

`traceback` Module for working with tracebacks.

25.7.5 Tracing a Program As It Runs

There are two ways to inject code to watch a program run: *tracing* and *profiling*. They are similar, but intended for different purposes and so have different constraints. The easiest, but least efficient, way to monitor a program is through a *trace hook*, which can be used for writing a debugger, code coverage monitoring, or many other purposes.

The trace hook is modified by passing a callback function to `sys.settrace()`. The callback will receive three arguments, frame (the stack frame from the code being run), event (a string naming the type of notification), and arg (an event-specific value). There are 7 event types for different levels of information that occur as a program is being executed.

Event	When	arg value
`'call'`	Before a function is executed.	`None`
`'line'`	Before a line is executed.	`None`
`'return'`	Before a function returns.	The value being returned.
`'exception'`	After an exception occurs.	The (exception, value, traceback) tuple.
`'c_call'`	Before a C function is called.	The C function object.
`'c_return'`	After a C function returns.	`None`
`'c_exception'`	After a C function throws an error.	`None`

Tracing Function Calls

A `call` event is generated before every function call. The frame passed to the callback can be used to find out which function is being called and from where.

```
#!/usr/bin/env python
# encoding: utf-8

import sys

def trace_calls(frame, event, arg):
    if event != 'call':
        return
    co = frame.f_code
    func_name = co.co_name
    if func_name == 'write':
        # Ignore write() calls from print statements
        return
    func_line_no = frame.f_lineno
    func_filename = co.co_filename
    caller = frame.f_back
    caller_line_no = caller.f_lineno
    caller_filename = caller.f_code.co_filename
    print 'Call to %s on line %s of %s from line %s of %s' % \
        (func_name, func_line_no, func_filename,
         caller_line_no, caller_filename)
    return

def b():
    print 'in b()'

def a():
    print 'in a()'
    b()

sys.settrace(trace_calls)
a()
```

This example ignores calls to `write()`, as used by **print** to write to `sys.stdout`.

```
$ python sys_settrace_call.py

Exception AttributeError: "'NoneType' object has no attribute 'f_lineno'" in <function _remove at 0x
```

```
Call to a on line 27 of sys_settrace_call.py from line 32 of sys_settrace_call.py
in a()
Call to b on line 24 of sys_settrace_call.py from line 29 of sys_settrace_call.py
in b()
```

Tracing Inside Functions

The trace hook can return a new hook to be used inside the new scope (the *local* trace function). It is possible, for instance, to control tracing to only run line-by-line within certain modules or functions.

```
#!/usr/bin/env python
# encoding: utf-8

import sys

def trace_lines(frame, event, arg):
    if event != 'line':
        return
    co = frame.f_code
    func_name = co.co_name
    line_no = frame.f_lineno
    filename = co.co_filename
    print '  %s line %s' % (func_name, line_no)

def trace_calls(frame, event, arg):
    if event != 'call':
        return
    co = frame.f_code
    func_name = co.co_name
    if func_name == 'write':
        # Ignore write() calls from print statements
        return
    line_no = frame.f_lineno
    filename = co.co_filename
    print 'Call to %s on line %s of %s' % (func_name, line_no, filename)
    if func_name in TRACE_INTO:
        # Trace into this function
        return trace_lines
    return

def c(input):
    print 'input =', input
    print 'Leaving c()'

def b(arg):
    val = arg * 5
    c(val)
    print 'Leaving b()'

def a():
    b(2)
    print 'Leaving a()'

TRACE_INTO = ['b']

sys.settrace(trace_calls)
a()
```

Here the global list of functions is kept in the variable `TRACE_INTO`, so when `trace_calls()` runs it can return `trace_lines()` to enable tracing inside of `b()`.

```
$ python sys_settrace_line.py

Exception TypeError: "argument of type 'NoneType' is not iterable" in <function _remove at 0x1004479b
Call to a on line 40 of sys_settrace_line.py
Call to b on line 35 of sys_settrace_line.py
  b line 36
  b line 37
Call to c on line 31 of sys_settrace_line.py
input = 10
Leaving c()
  b line 38
Leaving b()
Leaving a()
Call to _remove on line 38 of /Users/dhellmann/Envs/pymotw/bin/../lib/python2.7/_weakrefset.py
```

Watching the Stack

Another useful way to use the hooks is to keep up with which functions are being called, and what their return values are. To monitor return values, watch for the `return` event.

```python
#!/usr/bin/env python
# encoding: utf-8

import sys

def trace_calls_and_returns(frame, event, arg):
    co = frame.f_code
    func_name = co.co_name
    if func_name == 'write':
        # Ignore write() calls from print statements
        return
    line_no = frame.f_lineno
    filename = co.co_filename
    if event == 'call':
        print 'Call to %s on line %s of %s' % (func_name, line_no, filename)
        return trace_calls_and_returns
    elif event == 'return':
        print '%s => %s' % (func_name, arg)
    return

def b():
    print 'in b()'
    return 'response_from_b '

def a():
    print 'in a()'
    val = b()
    return val * 2

sys.settrace(trace_calls_and_returns)
a()
```

The local trace function is used for watching returns, so `trace_calls_and_returns()` needs to return a reference to itself when a function is called, so the return value can be monitored.

```
$ python sys_settrace_return.py

Call to a on line 25 of sys_settrace_return.py
in a()
Call to b on line 21 of sys_settrace_return.py
in b()
b => response_from_b
a => response_from_b response_from_b
Call to _remove on line 38 of /Users/dhellmann/Envs/pymotw/bin/../lib/python2.7/_weakrefset.py
Call to _remove on line 38 of /Users/dhellmann/Envs/pymotw/bin/../lib/python2.7/_weakrefset.py
```

Exception Propagation

Exceptions can be monitored by looking for the `exception` event in a local trace function. When an exception occurs, the trace hook is called with a tuple containing the type of exception, the exception object, and a traceback object.

```python
#!/usr/bin/env python
# encoding: utf-8

import sys

def trace_exceptions(frame, event, arg):
    if event != 'exception':
        return
    co = frame.f_code
    func_name = co.co_name
    line_no = frame.f_lineno
    filename = co.co_filename
    exc_type, exc_value, exc_traceback = arg
    print 'Tracing exception: %s "%s" on line %s of %s' % \
        (exc_type.__name__, exc_value, line_no, func_name)

def trace_calls(frame, event, arg):
    if event != 'call':
        return
    co = frame.f_code
    func_name = co.co_name
    if func_name in TRACE_INTO:
        return trace_exceptions

def c():
    raise RuntimeError('generating exception in c()')

def b():
    c()
    print 'Leaving b()'

def a():
    b()
    print 'Leaving a()'

TRACE_INTO = ['a', 'b', 'c']

sys.settrace(trace_calls)
try:
    a()
```

```
except Exception, e:
    print 'Exception handler:', e
```

Take care to limit where the local function is applied because some of the internals of formatting error messages generate, and ignore, their own exceptions. **Every** exception is seen by the trace hook, whether the caller catches and ignores it or not.

```
$ python sys_settrace_exception.py

Exception TypeError: "argument of type 'NoneType' is not iterable" in <function _remove at 0x1004479b
Tracing exception: RuntimeError "generating exception in c()" on line 26 of c
Tracing exception: RuntimeError "generating exception in c()" on line 29 of b
Tracing exception: RuntimeError "generating exception in c()" on line 33 of a
Exception handler: generating exception in c()
```

See also:

`profile` The profile module documentation shows how to use a ready-made profiler.

`trace` The trace module implements several code analysis features.

Types and Members **(http://docs.python.org/library/inspect.html#types-and-members)** The descriptions of frame and code objects and their attributes.

Tracing python code **(http://www.dalkescientific.com/writings/diary/archive/2005/04/20/tracing_python_code.html)** Another `settrace()` tutorial.

Wicked hack: Python bytecode tracing **(http://nedbatchelder.com/blog/200804/wicked_hack_python_bytecode_tracing.html)** Ned Batchelder's experiments with tracing with more granularity than source line level.

25.7.6 Low-level Thread Support

`sys` includes low-level functions for controlling and debugging thread behavior.

Check Interval

Python 2 uses a form of cooperative multitasking in its thread implementation. At a fixed interval, bytecode execution is paused and the interpreter checks if any signal handlers need to be executed. During the same interval check, the global interpreter lock is also released by the current thread and then reacquired, giving other threads an opportunity to take over execution by grabbing the lock first.

The default check interval is 100 bytecodes and the current value can always be retrieved with `sys.getcheckinterval()`. Changing the interval with `sys.setcheckinterval()` may have an impact on the performance of an application, depending on the nature of the operations being performed.

```
import sys
import threading
from Queue import Queue
import time

def show_thread(q, extraByteCodes):
    for i in range(5):
        for j in range(extraByteCodes):
            pass
        q.put(threading.current_thread().name)
    return

def run_threads(prefix, interval, extraByteCodes):
    print '%(prefix)s interval = %(interval)s with %(extraByteCodes)s extra operations' % locals()
    sys.setcheckinterval(interval)
    q = Queue()
    threads = [ threading.Thread(target=show_thread, name='%s T%s' % (prefix, i),
                                 args=(q, extraByteCodes)
                                 )
                for i in range(3)
              ]
    for t in threads:
        t.start()
    for t in threads:
        t.join()
    while not q.empty():
        print q.get()
    print
    return

run_threads('Default', interval=10, extraByteCodes=1000)
run_threads('Custom', interval=10, extraByteCodes=0)
```

When the check interval is smaller than the number of bytecodes in a thread, the interpreter may give another thread control so that it runs for a while. This is illustrated in the first set of output where the check interval is set to 100 (the default) and 1000 extra loop iterations are performed for each step through the `i` loop.

On the other hand, when the check interval is *greater* than the number of bytecodes being executed by a thread that doesn't release control for another reason, the thread will finish its work before the interval comes up. This is illustrated by the order of the name values in the queue in the second example.

```
$ python sys_checkinterval.py
Default interval = 10 with 1000 extra operations
Default T0
Default T0
Default T0
Default T1
Default T2
Default T2
Default T0
Default T1
Default T2
Default T0
Default T1
Default T2
Default T1
Default T2
Default T1

Custom interval = 10 with 0 extra operations
Custom T0
Custom T0
Custom T0
Custom T0
Custom T0
Custom T1
Custom T1
Custom T1
Custom T1
Custom T1
Custom T2
Custom T2
Custom T2
Custom T2
Custom T2
```

Modifying the check interval is not as clearly useful as it might seem. Many other factors may control the context switching behavior of Python's threads. For example, if a thread performs I/O, it releases the GIL and may therefore allow another thread to take over execution.

```
import sys
import threading
from Queue import Queue
import time

def show_thread(q, extraByteCodes):
    for i in range(5):
        for j in range(extraByteCodes):
            pass
        #q.put(threading.current_thread().name)
        print threading.current_thread().name
    return

def run_threads(prefix, interval, extraByteCodes):
    print '%(prefix)s interval = %(interval)s with %(extraByteCodes)s extra operations' % locals()
    sys.setcheckinterval(interval)
    q = Queue()
    threads = [ threading.Thread(target=show_thread, name='%s T%s' % (prefix, i),
                                 args=(q, extraByteCodes)
                                 )
                for i in range(3)
              ]
    for t in threads:
        t.start()
    for t in threads:
        t.join()
    while not q.empty():
        print q.get()
    print
    return

run_threads('Default', interval=100, extraByteCodes=1000)
run_threads('Custom', interval=10, extraByteCodes=0)
```

This example is modified from the first so that the thread prints directly to `sys.stdout` instead of appending to a queue. The output is much less predictable.

```
$ python sys_checkinterval_io.py
Default interval = 100 with 1000 extra operations
Default T0
Default T1
Default T1Default T2

Default T0Default T2

Default T2
Default T2
Default T1
Default T2
Default T1
Default T1
Default T0
Default T0
Default T0

Custom interval = 10 with 0 extra operations
Custom T0
Custom T0
Custom T0
Custom T0
Custom T0
Custom T1
Custom T1
Custom T1
Custom T1
Custom T2
Custom T2
Custom T2
Custom T1Custom T2

Custom T2
```

See also:

dis Disassembling your Python code with the dis module is one way to count bytecodes.

Debugging

Identifying deadlocks can be on of the most difficult aspects of working with threads. `sys._current_frames()` can help by showing exactly where a thread is stopped.

```python
#!/usr/bin/env python
# encoding: utf-8

import sys
import threading
import time

io_lock = threading.Lock()
blocker = threading.Lock()

def block(i):
    t = threading.current_thread()
    with io_lock:
        print '%s with ident %s going to sleep' % (t.name, t.ident)
    if i:
        blocker.acquire() # acquired but never released
        time.sleep(0.2)
    with io_lock:
        print t.name, 'finishing'
    return

# Create and start several threads that "block"
threads = [ threading.Thread(target=block, args=(i,)) for i in range(3) ]
for t in threads:
    t.setDaemon(True)
    t.start()

```

```
# Map the threads from their identifier to the thread object
threads_by_ident = dict((t.ident, t) for t in threads)

# Show where each thread is "blocked"
time.sleep(0.01)
with io_lock:
    for ident, frame in sys._current_frames().items():
        t = threads_by_ident.get(ident)
        if not t:
            # Main thread
            continue
        print t.name, 'stopped in', frame.f_code.co_name,
        print 'at line', frame.f_lineno, 'of', frame.f_code.co_filename

# Let the threads finish
# for t in threads:
#     t.join()
```

The dictionary returned by `sys._current_frames()` is keyed on the thread identifier, rather than its name. A little work is needed to map those identifiers back to the thread object.

Since **Thread-1** does not sleep, it finishes before its status is checked. Since it is no longer active, it does not appear in the output. **Thread-2** acquires the lock *blocker*, then sleeps for a short period. Meanwhile **Thread-3** tries to acquire *blocker* but cannot because **Thread-2** already has it.

```
$ python sys_current_frames.py

Thread-1 with ident 4315942912 going to sleep
Thread-1 finishing
Thread-3 with ident 4336926720 going to sleep
Thread-2 with ident 4332720128 going to sleep
Thread-3 stopped in block at line 17 of sys_current_frames.py
Thread-2 stopped in block at line 16 of sys_current_frames.py
```

See also:

`threading` The threading module includes classes for creating Python threads.

`Queue` The Queue module provides a thread-safe implementation of a FIFO data structure.

Python Threads and the Global Interpreter Lock (http://jessenoller.com/2009/02/01/python-threads-and-the-global-interpreter-l
Jesse Noller's article from the December 2007 issue of Python Magazine.

Inside the Python GIL (http://www.dabeaz.com/python/GIL.pdf) Presentation by David Beazley describing thread implementation and performance issues, including how the check interval and GIL are related.

25.7.7 Modules and Imports

Most Python programs end up as a combination of several modules with a main application importing them. Whether using the features of the standard library, or organizing custom code in separate files to make it easier to maintain, understanding and managing the dependencies for a program is an important aspect of development. `sys` includes information about the modules available to an application, either as built-ins or after being imported. It also defines hooks for overriding the standard import behavior for special cases.

Imported Modules

`sys.modules` is a dictionary mapping the names of imported modules to the module object holding the code.

```
import sys
import textwrap

names = sorted(sys.modules.keys())
name_text = ', '.join(names)

print textwrap.fill(name_text)
```

The contents of `sys.modules` change as new modules are imported.

```
$ python sys_modules.py

UserDict, __builtin__, __main__, _abcoll, _codecs, _sre, _warnings,
_weakref, _weakrefset, abc, codecs, copy_reg, encodings,
encodings.__builtin__, encodings.aliases, encodings.codecs,
encodings.encodings, encodings.utf_8, errno, exceptions, genericpath,
linecache, os, os.path, posix, posixpath, re, signal, site,
sphinxcontrib, sre_compile, sre_constants, sre_parse, stat, string,
strop, sys, textwrap, types, warnings, zipimport
```

Built-in Modules

The Python interpreter can be compiled with some C modules built right in, so they do not need to be distributed as separate shared libraries. These modules don't appear in the list of imported modules managed in `sys.modules` because they were not technically imported. The only way to find the available built-in modules is through `sys.builtin_module_names`.

```
import sys

for name in sys.builtin_module_names:
    print name
```

The output of this script will vary, especially if run with a custom-built version of the interpreter. This output was created using a copy of the interpreter installed from the standard python.org installer for OS X.

```
$ python sys_builtins.py

__builtin__
__main__
_ast
_codecs
_sre
_symtable
_warnings
_weakref
errno
exceptions
gc
imp
marshal
posix
pwd
signal
sys
thread
xxsubtype
zipimport
```

See also:

Build instructions (http://svn.python.org/view/python/trunk/README?view=markup) Instructions for building Python, from the README distributed with the source.

Import Path

The search path for modules is managed as a Python list saved in `sys.path`. The default contents of the path include the directory of the script used to start the application and the current working directory.

```
import sys

for d in sys.path:
    print d
```

The first directory in the search path is the home for the sample script itself. That is followed by a series of platform-specific paths where compiled extension modules (written in C) might be installed, and then the global `site-packages` directory is listed last.

```
$ python sys_path_show.py
/Users/dhellmann/Documents/PyMOTW/src/PyMOTW/sys
/Library/Frameworks/Python.framework/Versions/2.6/lib/python2.6
/Library/Frameworks/Python.framework/Versions/2.6/lib/python2.6/plat-darwin
/Library/Frameworks/Python.framework/Versions/2.6/lib/python2.6/lib-tk
/Library/Frameworks/Python.framework/Versions/2.6/lib/python2.6/plat-mac
/Library/Frameworks/Python.framework/Versions/2.6/lib/python2.6/plat-mac/lib-scriptpackages
/Library/Frameworks/Python.framework/Versions/2.6/lib/python2.6/site-packages
```

The import search path list can be modified before starting the interpreter by setting the shell variable `PYTHONPATH` to a colon-separated list of directories.

```
$ PYTHONPATH=/my/private/site-packages:/my/shared/site-packages python sys_path_show.py
/Users/dhellmann/Documents/PyMOTW/src/PyMOTW/sys
/my/private/site-packages
/my/shared/site-packages
/Library/Frameworks/Python.framework/Versions/2.6/lib/python2.6
/Library/Frameworks/Python.framework/Versions/2.6/lib/python2.6/plat-darwin
/Library/Frameworks/Python.framework/Versions/2.6/lib/python2.6/lib-tk
/Library/Frameworks/Python.framework/Versions/2.6/lib/python2.6/plat-mac
/Library/Frameworks/Python.framework/Versions/2.6/lib/python2.6/plat-mac/lib-scriptpackages
/Library/Frameworks/Python.framework/Versions/2.6/lib/python2.6/site-packages
```

A program can also modify its path by adding elements to `sys.path` directly.

```
import sys
import os

base_dir = os.path.dirname(__file__) or '.'
print 'Base directory:', base_dir

# Insert the package_dir_a directory at the front of the path.
package_dir_a = os.path.join(base_dir, 'package_dir_a')
sys.path.insert(0, package_dir_a)

# Import the example module
import example
print 'Imported example from:', example.__file__
print '\t', example.DATA
```

```
# Make package_dir_b the first directory in the search path
package_dir_b = os.path.join(base_dir, 'package_dir_b')
sys.path.insert(0, package_dir_b)

# Reload the module to get the other version
reload(example)
print 'Reloaded example from:', example.__file__
print '\t', example.DATA
```

Reloading an imported module re-imports the file, and uses the same `module` object to hold the results. Changing the path between the initial import and the call to `reload()` means a different module may be loaded the second time.

```
$ python sys_path_modify.py

Base directory: .
Imported example from: ./package_dir_a/example.pyc
        This is example A
Reloaded example from: ./package_dir_b/example.pyc
        This is example B
```

Custom Importers

Modifying the search path lets a programmer control how standard Python modules are found, but what if a program needs to import code from somewhere other than the usual `.py` or `.pyc` files on the filesystem? **PEP 302** (http://www.python.org/dev/peps/pep-0302) solves this problem by introducing the idea of *import hooks* that can trap an attempt to find a module on the search path and take alternative measures to load the code from somewhere else or apply pre-processing to it.

Finders

Custom importers are implemented in two separate phases. The *finder* is responsible for locating a module and providing a *loader* to manage the actual import. Adding a custom module finder is as simple as appending a factory to the `sys.path_hooks` list. On import, each part of the path is given to a finder until one claims support (by not raising *ImportError*). That finder is then responsible for searching data storage represented by its path entry for named modules.

```
import sys

class NoisyImportFinder(object):

    PATH_TRIGGER = 'NoisyImportFinder_PATH_TRIGGER'

    def __init__(self, path_entry):
        print 'Checking NoisyImportFinder support for %s' % path_entry
        if path_entry != self.PATH_TRIGGER:
            print 'NoisyImportFinder does not work for %s' % path_entry
            raise ImportError()
        return

    def find_module(self, fullname, path=None):
        print 'NoisyImportFinder looking for "%s"' % fullname
        return None

sys.path_hooks.append(NoisyImportFinder)
sys.path.insert(0, NoisyImportFinder.PATH_TRIGGER)

try:
    import target_module
except Exception, e:
    print 'Import failed:', e
```

This example illustrates how the finders are instantiated and queried. The `NoisyImportFinder` raises *ImportError* when instantiated with a path entry that does not match its special trigger value, which is obviously not a real path on the filesystem. This test prevents the `NoisyImportFinder` from breaking imports of real modules.

```
$ python sys_path_hooks_noisy.py

Checking NoisyImportFinder support for NoisyImportFinder_PATH_TRIGGER
NoisyImportFinder looking for "target_module"
Checking NoisyImportFinder support for /Users/dhellmann/Documents/PyMOTW/src/PyMOTW/sys
NoisyImportFinder does not work for /Users/dhellmann/Documents/PyMOTW/src/PyMOTW/sys
Import failed: No module named target_module
```

Importing from a Shelve

When the finder locates a module, it is responsible for returning a *loader* capable of importing that module. This example illustrates a custom importer that saves its module contents in a database created by `shelve`.

The first step is to create a script to populate the shelf with a package containing a sub-module and sub-package.

```
import sys
import shelve
import os

filename = '/tmp/pymotw_import_example.shelve'
if os.path.exists(filename):
    os.unlink(filename)
db = shelve.open(filename)
try:
    db['data:README'] = """
==============
package README
==============

This is the README for ``package``.
"""
    db['package.__init__'] = """
print 'package imported'
message = 'This message is in package.__init__'
"""
    db['package.module1'] = """
print 'package.module1 imported'
message = 'This message is in package.module1'
"""
    db['package.subpackage.__init__'] = """
print 'package.subpackage imported'
message = 'This message is in package.subpackage.__init__'
"""
    db['package.subpackage.module2'] = """
print 'package.subpackage.module2 imported'
message = 'This message is in package.subpackage.module2'
```

```
"""
    db['package.with_error'] = """
print 'package.with_error being imported'
raise ValueError('raising exception to break import')
"""
    print 'Created %s with:' % filename
    for key in sorted(db.keys()):
        print '\t', key
finally:
    db.close()
```

A real packaging script would read the contents from the filesystem, but using hard-coded values is sufficient for a simple example like this.

```
$ python sys_shelve_importer_create.py

Created /tmp/pymotw_import_example.shelve with:
        data:README
        package.__init__
        package.module1
        package.subpackage.__init__
        package.subpackage.module2
        package.with_error
```

Next, it needs to provide finder and loader classes that know how to look in a shelf for the source of a module or package.

```
import contextlib
import imp
import os
import shelve
import sys


@contextlib.contextmanager
def shelve_context(filename, flag='r'):
    """Context manager to make shelves work with 'with' statement."""
    db = shelve.open(filename, flag)
    try:
        yield db
    finally:
        db.close()


def _mk_init_name(fullname):
    """Return the name of the __init__ module for a given package name."""
    if fullname.endswith('.__init__'):
        return fullname
    return fullname + '.__init__'


def _get_key_name(fullname, db):
    """Look in an open shelf for fullname or fullname.__init__, return the name found."""
    if fullname in db:
        return fullname
    init_name = _mk_init_name(fullname)
    if init_name in db:
        return init_name
    return None
```

```
class ShelveFinder(object):
    """Find modules collected in a shelve archive."""

    def __init__(self, path_entry):
        if not os.path.isfile(path_entry):
            raise ImportError
        try:
            # Test the path_entry to see if it is a valid shelf
            with shelve_context(path_entry):
                pass
        except Exception, e:
            raise ImportError(str(e))
        else:
            print 'new shelf added to import path:', path_entry
            self.path_entry = path_entry
        return

    def __str__(self):
        return '<%s for "%s">' % (self.__class__.__name__, self.path_entry)

    def find_module(self, fullname, path=None):
        path = path or self.path_entry
        print 'looking for "%s" in %s ...' % (fullname, path),
        with shelve_context(path) as db:
            key_name = _get_key_name(fullname, db)
            if key_name:
                print 'found it as %s' % key_name
                return ShelveLoader(path)
        print 'not found'
        return None


class ShelveLoader(object):
    """Load source for modules from shelve databases."""

    def __init__(self, path_entry):
        self.path_entry = path_entry
        return

    def _get_filename(self, fullname):
        # Make up a fake filename that starts with the path entry
        # so pkgutil.get_data() works correctly.
        return os.path.join(self.path_entry, fullname)

    def get_source(self, fullname):
        print 'loading source for "%s" from shelf' % fullname
        try:
            with shelve_context(self.path_entry) as db:
                key_name = _get_key_name(fullname, db)
                if key_name:
                    return db[key_name]
                raise ImportError('could not find source for %s' % fullname)
        except Exception, e:
            print 'could not load source:', e
            raise ImportError(str(e))

    def get_code(self, fullname):
        source = self.get_source(fullname)
        print 'compiling code for "%s"' % fullname
        return compile(source, self._get_filename(fullname), 'exec', dont_inherit=True)

    def get_data(self, path):
        print 'looking for data in %s for "%s"' % (self.path_entry, path)
        if not path.startswith(self.path_entry):
            raise IOError
        path = path[len(self.path_entry)+1:]
        key_name = 'data:' + path
        try:
            with shelve_context(self.path_entry) as db:
                return db[key_name]
        except Exception, e:
            # Convert all errors to IOError
            raise IOError

    def is_package(self, fullname):
        init_name = _mk_init_name(fullname)
        with shelve_context(self.path_entry) as db:
            return init_name in db

    def load_module(self, fullname):
        source = self.get_source(fullname)

        if fullname in sys.modules:
            print 'reusing existing module from previous import of "%s"' % fullname
            mod = sys.modules[fullname]
        else:
            print 'creating a new module object for "%s"' % fullname
            mod = sys.modules.setdefault(fullname, imp.new_module(fullname))

        # Set a few properties required by PEP 302
        mod.__file__ = self._get_filename(fullname)
        mod.__name__ = fullname
        mod.__path__ = self.path_entry
        mod.__loader__ = self
        mod.__package__ = '.'.join(fullname.split('.')[:-1])

        if self.is_package(fullname):
            print 'adding path for package'
            # Set __path__ for packages
            # so we can find the sub-modules.
            mod.__path__ = [ self.path_entry ]
        else:
            print 'imported as regular module'

        print 'execing source...'
        exec source in mod.__dict__
        print 'done'
        return mod
```

Now `ShelveFinder` and `ShelveLoader` can be used to import code from a shelf. For example, importing the `package` created above:

```
import sys
import sys_shelve_importer
```

```
def show_module_details(module):
    print '  message    :', module.message
    print '  __name__   :', module.__name__
    print '  __package__:', module.__package__
    print '  __file__   :', module.__file__
    print '  __path__   :', module.__path__
    print '  __loader__ :', module.__loader__

filename = '/tmp/pymotw_import_example.shelve'
sys.path_hooks.append(sys_shelve_importer.ShelveFinder)
sys.path.insert(0, filename)

print 'Import of "package":'
import package

print
print 'Examine package details:'
show_module_details(package)

print
print 'Global settings:'
print 'sys.modules entry:', sys.modules['package']
```

The shelf is added to the import path the first time an import occurs after the path is modified. The finder recognizes the shelf and returns a loader, which is used for all imports from that shelf. The initial package-level import creates a new module object and then execs the source loaded from the shelf, using the new module as the namespace so that names defined in the source are preserved as module-level attributes.

```
$ python sys_shelve_importer_package.py

Import of "package":
new shelf added to import path: /tmp/pymotw_import_example.shelve
looking for "package" in /tmp/pymotw_import_example.shelve ... found i
t as package.__init__
loading source for "package" from shelf
creating a new module object for "package"
adding path for package
execing source...
package imported
done

Examine package details:
  message    : This message is in package.__init__
  __name__   : package
  __package__:
  __file__   : /tmp/pymotw_import_example.shelve/package
  __path__   : ['/tmp/pymotw_import_example.shelve']
  __loader__ : <sys_shelve_importer.ShelveLoader object at 0x100473950
>

Global settings:
sys.modules entry: <module 'package' from '/tmp/pymotw_import_example.
shelve/package'>
```

Packages

The loading of other modules and sub-packages proceeds in the same way.

```
import sys
import sys_shelve_importer

def show_module_details(module):
    print '  message    :', module.message
    print '  __name__   :', module.__name__
    print '  __package__:', module.__package__
    print '  __file__   :', module.__file__
    print '  __path__   :', module.__path__
    print '  __loader__ :', module.__loader__

filename = '/tmp/pymotw_import_example.shelve'
sys.path_hooks.append(sys_shelve_importer.ShelveFinder)
sys.path.insert(0, filename)

print
print 'Import of "package.module1":'
import package.module1

print
print 'Examine package.module1 details:'
show_module_details(package.module1)

print
print 'Import of "package.subpackage.module2":'
import package.subpackage.module2

print
print 'Examine package.subpackage.module2 details:'
show_module_details(package.subpackage.module2)
```

```
$ python sys_shelve_importer_module.py


Import of "package.module1":
new shelf added to import path: /tmp/pymotw_import_example.shelve
looking for "package" in /tmp/pymotw_import_example.shelve ... found i
t as package.__init__
loading source for "package" from shelf
creating a new module object for "package"
adding path for package
execing source...
package imported
done
looking for "package.module1" in /tmp/pymotw_import_example.shelve ...
 found it as package.module1
loading source for "package.module1" from shelf
creating a new module object for "package.module1"
imported as regular module
execing source...
package.module1 imported
done

Examine package.module1 details:
  message    : This message is in package.module1
  __name__   : package.module1
  __package__: package
  __file__   : /tmp/pymotw_import_example.shelve/package.module1
  __path__    : /tmp/pymotw_import_example.shelve
  __loader__ : <sys_shelve_importer.ShelveLoader object at 0x100473a90
>

Import of "package.subpackage.module2":
looking for "package.subpackage" in /tmp/pymotw_import_example.shelve
... found it as package.subpackage.__init__
loading source for "package.subpackage" from shelf
creating a new module object for "package.subpackage"
adding path for package
execing source...
package.subpackage imported
done
looking for "package.subpackage.module2" in /tmp/pymotw_import_example
.shelve ... found it as package.subpackage.module2
loading source for "package.subpackage.module2" from shelf
creating a new module object for "package.subpackage.module2"
imported as regular module
execing source...
package.subpackage.module2 imported
done

Examine package.subpackage.module2 details:
  message    : This message is in package.subpackage.module2
  __name__    : package.subpackage.module2
  __package__: package.subpackage
  __file__    : /tmp/pymotw_import_example.shelve/package.subpackage.mo
dule2
  __path__    : /tmp/pymotw_import_example.shelve
  __loader__ : <sys_shelve_importer.ShelveLoader object at 0x1006db990
>
```

Reloading

Reloading a module is handled slightly differently. Instead of creating a new module object, the existing module is re-used.

```python
import sys
import sys_shelve_importer

filename = '/tmp/pymotw_import_example.shelve'
sys.path_hooks.append(sys_shelve_importer.ShelveFinder)
sys.path.insert(0, filename)

print 'First import of "package":'
import package

print
print 'Reloading "package":'
reload(package)
```

By re-using the same object, existing references to the module are preserved even if class or function definitions are modified by the reload.

```
$ python sys_shelve_importer_reload.py

First import of "package":
```

```
new shelf added to import path: /tmp/pymotw_import_example.shelve
looking for "package" in /tmp/pymotw_import_example.shelve ... found i
t as package.__init__
loading source for "package" from shelf
creating a new module object for "package"
adding path for package
execing source...
package imported
done

Reloading "package":
looking for "package" in /tmp/pymotw_import_example.shelve ... found i
t as package.__init__
loading source for "package" from shelf
reusing existing module from previous import of "package"
adding path for package
execing source...
package imported
done
```

Import Errors

When a module cannot be located by any finder, *ImportError* is raised by the main import code.

```
import sys
import sys_shelve_importer

filename = '/tmp/pymotw_import_example.shelve'
sys.path_hooks.append(sys_shelve_importer.ShelveFinder)
sys.path.insert(0, filename)

try:
    import package.module3
except ImportError, e:
    print 'Failed to import:', e
```

Other errors during the import are propagated.

```
$ python sys_shelve_importer_missing.py

new shelf added to import path: /tmp/pymotw_import_example.shelve
looking for "package" in /tmp/pymotw_import_example.shelve ... found i
t as package.__init__
loading source for "package" from shelf
creating a new module object for "package"
adding path for package
execing source...
package imported
done
looking for "package.module3" in /tmp/pymotw_import_example.shelve ...
 not found
Failed to import: No module named module3
```

Package Data

In addition to defining the API loading executable Python code, **PEP 302** (http://www.python.org/dev/peps/pep-0302) defines an optional API for retrieving package data intended for distributing data files, documentation, and other non-code resources used by a package. By implementing `get_data()`, a loader can allow calling applications to support retrieval of data associated with the package without considering how the package is actually installed (especially without assuming that the package is stored as files on a filesystem).

```
import sys
import sys_shelve_importer
import os
import pkgutil

filename = '/tmp/pymotw_import_example.shelve'
sys.path_hooks.append(sys_shelve_importer.ShelveFinder)
sys.path.insert(0, filename)

import package

readme_path = os.path.join(package.__path__[0], 'README')

#readme = package.__loader__.get_data(readme_path)
readme = pkgutil.get_data('package', 'README')
print readme

foo_path = os.path.join(package.__path__[0], 'foo')
#foo = package.__loader__.get_data(foo_path)
foo = pkgutil.get_data('package', 'foo')
print foo
```

`get_data()` takes a path based on the module or package that owns the data, and returns the contents of the resource "file" as a string, or raises *IOError* if the resource does not exist.

```
$ python sys_shelve_importer_get_data.py

new shelf added to import path: /tmp/pymotw_import_example.shelve
looking for "package" in /tmp/pymotw_import_example.shelve ... found i
t as package.__init__
loading source for "package" from shelf
creating a new module object for "package"
adding path for package
execing source...
package imported
done
looking for data in /tmp/pymotw_import_example.shelve for "/tmp/pymotw
_import_example.shelve/README"

==============
package README
==============

This is the README for ``package``.

looking for data in /tmp/pymotw_import_example.shelve for "/tmp/pymotw
_import_example.shelve/foo"
Traceback (most recent call last):
  File "sys_shelve_importer_get_data.py", line 29, in <module>
    foo = pkgutil.get_data('package', 'foo')
  File "/Library/Frameworks/Python.framework/Versions/2.7/lib/python2.
7/pkgutil.py", line 583, in get_data
    return loader.get_data(resource_name)
  File "/Users/dhellmann/Documents/PyMOTW/src/PyMOTW/sys/sys_shelve_im
porter.py", line 116, in get_data
    raise IOError
IOError
```

See also:

pkgutil Includes `get_data()` for retrieving data from a package.

Importer Cache

Searching through all of the hooks each time a module is imported can become expensive. To save time, `sys.path_importer_cache` is maintained as a mapping between a path entry and the loader that can use the value to find modules.

```
import sys
import pprint

print 'PATH:',
pprint.pprint(sys.path)
print
print 'IMPORTERS:'
for name, cache_value in sys.path_importer_cache.items():
    name = name.replace(sys.prefix, '...')
    print '%s: %r' % (name, cache_value)
```

A cache value of `None` means to use the default filesystem loader. Each missing directory is associated with an `imp.NullImporter` instance, since modules cannot be imported from directories that do not exist. In the example output below, several `zipimport.zipimporter` instances are used to manage EGG files found on the path.

```
$ python sys_path_importer_cache.py

PATH:['/Users/dhellmann/Documents/PyMOTW/src/PyMOTW/sys',
 '/Users/dhellmann/Documents/PyMOTW/sphinx-graphviz-paragraphs',
 '/Users/dhellmann/Envs/pymotw/lib/python2.7/site-packages/distribute-
0.6.14-py2.7.egg',
 '/Users/dhellmann/Envs/pymotw/lib/python2.7/site-packages/pip-0.8.1-p
y2.7.egg',
 '/Users/dhellmann/Envs/pymotw/lib/python27.zip',
 '/Library/Frameworks/Python.framework/Versions/2.7/lib/python2.7/site
-packages/distribute-0.6.10-py2.7.egg',
 '/Users/dhellmann/Devel/virtualenvwrapper/virtualenvwrapper',
 '/Users/dhellmann/Devel/virtualenvwrapper/bitbucket',
 '/Users/dhellmann/Devel/virtualenvwrapper/emacs-desktop',
 '/Users/dhellmann/Envs/pymotw/lib/python2.7',
 '/Users/dhellmann/Envs/pymotw/lib/python2.7/plat-darwin',
 '/Users/dhellmann/Envs/pymotw/lib/python2.7/plat-mac',
 '/Users/dhellmann/Envs/pymotw/lib/python2.7/plat-mac/lib-scriptpackag
es',
 '/Users/dhellmann/Envs/pymotw/lib/python2.7/lib-tk',
 '/Users/dhellmann/Envs/pymotw/lib/python2.7/lib-old',
 '/Users/dhellmann/Envs/pymotw/lib/python2.7/lib-dynload',
 '/Library/Frameworks/Python.framework/Versions/2.7/lib/python2.7',
 '/Library/Frameworks/Python.framework/Versions/2.7/lib/python2.7/plat
-darwin',
 '/Library/Frameworks/Python.framework/Versions/2.7/lib/python2.7/lib-
tk',
 '/Library/Frameworks/Python.framework/Versions/2.7/lib/python2.7/plat
-mac',
 '/Library/Frameworks/Python.framework/Versions/2.7/lib/python2.7/plat
-mac/lib-scriptpackages',
 '/Users/dhellmann/Envs/pymotw/lib/python2.7/site-packages',
 '/Library/Frameworks/Python.framework/Versions/2.7/lib/python2.7/site
-packages']

IMPORTERS:
/Users/dhellmann/Documents/PyMOTW/src/PyMOTW/sys: None
/Users/dhellmann/Envs/pymotw/lib/python2.7/lib-old: <imp.NullImporter
object at 0x1002ae0d0>
/Users/dhellmann/Devel/virtualenvwrapper/virtualenvwrapper: None
sys_path_importer_cache.py: <imp.NullImporter object at 0x1002ae0e0>
/Users/dhellmann/Devel/virtualenvwrapper/bitbucket: None
/Users/dhellmann/Envs/pymotw/lib/python2.7/site-packages: None
/Users/dhellmann/Envs/pymotw/lib/python2.7/site-packages/distribute-0.
6.14-py2.7.egg: None
/Users/dhellmann/Envs/pymotw/lib/python2.7/encodings: None
/Users/dhellmann/Envs/pymotw/lib/python2.7: None
/Users/dhellmann/Envs/pymotw/lib/python27.zip: <imp.NullImporter objec
t at 0x1002ae080>
/Library/Frameworks/Python.framework/Versions/2.7/lib/python2.7/lib-tk
: None
/Users/dhellmann/Envs/pymotw/lib/python2.7/plat-darwin: <imp.NullImpor
ter object at 0x1002ae090>
/Library/Frameworks/Python.framework/Versions/2.7/lib/python2.7: None
/Users/dhellmann/Envs/pymotw/lib/python2.7/site-packages/pip-0.8.1-py2
.7.egg: None
/Library/Frameworks/Python.framework/Versions/2.7/lib/python2.7/site-p
ackages: None
/Users/dhellmann/Envs/pymotw/lib/python2.7/lib-dynload: None
/Library/Frameworks/Python.framework/Versions/2.7/lib/python2.7/plat-d
arwin: None
/Library/Frameworks/Python.framework/Versions/2.7/lib/python2.7/plat-m
ac/lib-scriptpackages: None
/Users/dhellmann/Envs/pymotw/lib/python2.7/plat-mac: <imp.NullImporter
 object at 0x1002ae0a0>
/Users/dhellmann/Devel/virtualenvwrapper/emacs-desktop: None
/Users/dhellmann/Documents/PyMOTW/sphinx-graphviz-paragraphs: None
.../lib/python2.7/: None
/Users/dhellmann/Envs/pymotw/lib/python2.7/plat-mac/lib-scriptpackages
: <imp.NullImporter object at 0x1002ae0b0>
.../lib/python27.zip: <imp.NullImporter object at 0x1002ae030>
/Users/dhellmann/Envs/pymotw/lib/python2.7/lib-tk: <imp.NullImporter o
bject at 0x1002ae0c0>
/Library/Frameworks/Python.framework/Versions/2.7/lib/python2.7/site-p
ackages/distribute-0.6.10-py2.7.egg: None
/Library/Frameworks/Python.framework/Versions/2.7/lib/python2.7/plat-m
ac: None
```

Meta Path

The `sys.meta_path` further extends the sources of potential imports by allowing a finder to be searched *before* the regular `sys.path` is scanned. The API for a finder on the meta-path is the same as for a regular path. The difference is that the meta-finder is not limited to a single entry in `sys.path`, it can search anywhere at all.

```
import sys
import sys_shelve_importer
import imp


class NoisyMetaImportFinder(object):

    def __init__(self, prefix):
        print 'Creating NoisyMetaImportFinder for %s' % prefix
        self.prefix = prefix
        return

    def find_module(self, fullname, path=None):
        print 'NoisyMetaImportFinder looking for "%s" with path "%s"' % (fullname, path)
        name_parts = fullname.split('.')
        if name_parts and name_parts[0] == self.prefix:
            print ' ... found prefix, returning loader'
            return NoisyMetaImportLoader(path)
        else:
            print ' ... not the right prefix, cannot load'
        return None


class NoisyMetaImportLoader(object):

    def __init__(self, path_entry):
        self.path_entry = path_entry
        return

    def load_module(self, fullname):
        print 'loading %s' % fullname
        if fullname in sys.modules:
            mod = sys.modules[fullname]
        else:
            mod = sys.modules.setdefault(fullname, imp.new_module(fullname))

        # Set a few properties required by PEP 302
        mod.__file__ = fullname
        mod.__name__ = fullname
        # always looks like a package
        mod.__path__ = [ 'path-entry-goes-here' ]
        mod.__loader__ = self
        mod.__package__ = '.'.join(fullname.split('.')[:-1])

        return mod


# Install the meta-path finder
sys.meta_path.append(NoisyMetaImportFinder('foo'))

# Import some modules that are "found" by the meta-path finder
print
import foo

print
import foo.bar
```

```
# Import a module that is not found
print
try:
    import bar
except ImportError, e:
    pass
```

Each finder on the meta-path is interrogated before `sys.path` is searched, so there is always an opportunity to have a central importer load modules without explicitly modifying `sys.path`. Once the module is "found", the loader API works in the same way as for regular loaders (although this example is truncated for simplicity).

```
$ python sys_meta_path.py

Creating NoisyMetaImportFinder for foo

NoisyMetaImportFinder looking for "foo" with path "None"
 ... found prefix, returning loader
loading foo

NoisyMetaImportFinder looking for "foo.bar" with path "['path-entry-goes-here']"
 ... found prefix, returning loader
loading foo.bar

NoisyMetaImportFinder looking for "bar" with path "None"
 ... not the right prefix, cannot load
```

See also:

PEP 302 (http://www.python.org/dev/peps/pep-0302) Import Hooks

`imp` The imp module provides tools used by importers.

`zipimport` Implements importing Python modules from inside ZIP archives.

`importlib` Base classes and other tools for creating custom importers.

The Quick Guide to Python Eggs (http://peak.telecommunity.com/DevCenter/PythonEggs) PEAK documentation for working with EGGs.

Import this, that, and the other thing: custom importers (http://us.pycon.org/2010/conference/talks/?filter=core) Brett Cannon's PyCon 2010 presentation.

Python 3 stdlib module "importlib" (http://docs.python.org/py3k/library/importlib.html) Python 3.x includes abstract base classes that makes it easier to create custom importers.

See also:

sys (http://docs.python.org/library/sys.html) The standard library documentation for this module.

25.8 sysconfig – Interpreter Compile-time Configuration

Purpose Access the configuration settings used to build Python.

Available In 2.7 and later

In Python 2.7 `sysconfig` has been extracted from `distutils` to become a stand-alone module. It includes functions for determining the settings used to compile and install the current interpreter.

25.8.1 Configuration Variables

You can access the build-time configuration settings through two functions. `get_config_vars()` returns a dictionary mapping the configuration variable names to values.

```
import sysconfig

config_values = sysconfig.get_config_vars()
print 'Found %d configuration settings' % len(config_values.keys())
print

print 'Some highlights:'

print
print '  Installation prefixes:'
print '    prefix={prefix}'.format(**config_values)
print '    exec_prefix={exec_prefix}'.format(**config_values)

print
print '  Version info:'
print '    py_version={py_version}'.format(**config_values)
print '    py_version_short={py_version_short}'.format(**config_values)
print '    py_version_nodot={py_version_nodot}'.format(**config_values)

print
print '  Base directories:'
print '    base={base}'.format(**config_values)
print '    platbase={platbase}'.format(**config_values)
print '    userbase={userbase}'.format(**config_values)
print '    srcdir={srcdir}'.format(**config_values)

print
print '  Compiler and linker flags:'
print '    LDFLAGS={LDFLAGS}'.format(**config_values)
print '    BASECFLAGS={BASECFLAGS}'.format(**config_values)
print '    Py_ENABLE_SHARED={Py_ENABLE_SHARED}'.format(**config_values)
```

The level of detail available through the `sysconfig` API depends on the platform where your program is running. On POSIX systems such as Linux and OS X, the `Makefile` used to build the interpreter and `config.h` header file generated for the build are parsed and all of the variables found within are available. On non-POSIX-compliant systems such as Windows, the settings are limited to a few paths, filename extensions, and version details.

```
$ python sysconfig_get_config_vars.py

Found 517 configuration settings

Some highlights:

  Installation prefixes:
    prefix=/Library/Frameworks/Python.framework/Versions/2.7
    exec_prefix=/Library/Frameworks/Python.framework/Versions/2.7

  Version info:
    py_version=2.7.2
    py_version_short=2.7
    py_version_nodot=27

  Base directories:
    base=/Users/dhellmann/Envs/pymotw
    platbase=/Users/dhellmann/Envs/pymotw
    userbase=/Users/dhellmann/Library/Python/2.7
    srcdir=/Users/sysadmin/build/v2.7.2

  Compiler and linker flags:
    LDFLAGS=-arch i386 -arch x86_64 -isysroot /Developer/SDKs/MacOSX10.6.sdk -isysroot /Developer/SDK
    BASECFLAGS=-fno-strict-aliasing -fno-common -dynamic
    Py_ENABLE_SHARED=0
```

If you pass variable names to `get_config_vars()`, the return value is a `list` created by appending all of the values for those variables together.

```
import sysconfig

bases = sysconfig.get_config_vars('base', 'platbase', 'userbase')
print 'Base directories:'
for b in bases:
    print '   ', b
```

This example builds a list of all of the installation base directories where modules can be found on the current system.

```
$ python sysconfig_get_config_vars_by_name.py

Base directories:
   /Users/dhellmann/Envs/pymotw
   /Users/dhellmann/Envs/pymotw
   /Users/dhellmann/Library/Python/2.7
```

When you only need a single configuration value, use `get_config_var()` to retrieve it.

```
import sysconfig

print 'User base directory:', sysconfig.get_config_var('userbase')
print 'Unknown variable   :', sysconfig.get_config_var('NoSuchVariable')
```

If the variable is not found, `get_config_var()` returns `None` instead of raising an exception.

```
$ python sysconfig_get_config_var.py

User base directory: /Users/dhellmann/Library/Python/2.7
Unknown variable   : None
```

25.8.2 Installation Paths

`sysconfig` is primarily meant to be used by installation and packaging tools. As a result, while it provides access to general configuration settings such as the interpreter version, it is primarily focused on the information needed to locate parts of the Python distribution currently installed on a system. The locations used by for installing a package depend on the *scheme* used.

A scheme is a set of platform-specific default directories organized based on the platform's packaging standards and guidelines. There are different schemes for installing into a site-wide location or a private directory owned by the user. The full set of schemes can be accessed with `get_scheme_names()`.

```
import sysconfig

for name in sysconfig.get_scheme_names():
    print name
```

There is no concept of a “current scheme” per se. The default scheme depends on the platform, and the actual scheme used depends on options given to the installation program. If the current system is running a POSIX-compliant operating system, the default is `posix_prefix`. Otherwise the default is `os.name`.

```
$ python sysconfig_get_scheme_names.py

nt
nt_user
os2
os2_home
osx_framework_user
posix_home
posix_prefix
posix_user
```

Each scheme defines a set of paths used for installing packages. For a list of the path names, use `get_path_names()`.

```
import sysconfig

for name in sysconfig.get_path_names():
    print name
```

Some of the paths may be the same for a given scheme, but installers should not make any assumptions about what the actual paths are. Each name has a particular semantic meaning, so the correct name should be used to find the path for a given file during installation.

Name	Description
stdlib	Standard Python library files, not platform-specific
platstdlib	Standard Python library files, platform-specific
platlib	Site-specific, platform-specific files
purelib	Site-specific, non-platform-specific files
include	Header files, not platform-specific
platinclude	Header files, platform-specific
scripts	Executable script files
data	Data files

```
$ python sysconfig_get_path_names.py

stdlib
platstdlib
purelib
platlib
include
scripts
data
```

Use `get_paths()` to retrieve the actual directories associated with a scheme.

```
import sysconfig
import pprint

for scheme in ['posix_prefix', 'posix_user']:
    print scheme
    print '=' * len(scheme)
    pprint.pprint(sysconfig.get_paths(scheme=scheme))
    print
```

This example shows the difference between the system-wide paths uses for `posix_prefix` and the user-specific values for posix_user.

```
$ python sysconfig_get_paths.py

posix_prefix
============
{'data': '/Users/dhellmann/Envs/pymotw',
 'include': '/Users/dhellmann/Envs/pymotw/include/python2.7',
 'platinclude': '/Users/dhellmann/Envs/pymotw/include/python2.7',
 'platlib': '/Users/dhellmann/Envs/pymotw/lib/python2.7/site-packages',
 'platstdlib': '/Users/dhellmann/Envs/pymotw/lib/python2.7',
 'purelib': '/Users/dhellmann/Envs/pymotw/lib/python2.7/site-packages',
 'scripts': '/Users/dhellmann/Envs/pymotw/bin',
 'stdlib': '/Users/dhellmann/Envs/pymotw/lib/python2.7'}

posix_user
==========
{'data': '/Users/dhellmann/Library/Python/2.7',
 'include': '/Users/dhellmann/Library/Python/2.7/include/python2.7',
 'platlib': '/Users/dhellmann/Library/Python/2.7/lib/python2.7/site-packages',
 'platstdlib': '/Users/dhellmann/Library/Python/2.7/lib/python2.7',
 'purelib': '/Users/dhellmann/Library/Python/2.7/lib/python2.7/site-packages',
 'scripts': '/Users/dhellmann/Library/Python/2.7/bin',
 'stdlib': '/Users/dhellmann/Library/Python/2.7/lib/python2.7'}
```

For an individual path, call get_path().

```python
import sysconfig
import pprint

for scheme in ['posix_prefix', 'posix_user']:
    print scheme
    print '=' * len(scheme)
    print 'purelib =', sysconfig.get_path(name='purelib', scheme=scheme)
    print
```

Using get_path() is equivalent to saving the value of get_paths() and looking up the individual key in the dictionary. If you need several paths, get_paths() is more efficient because it does not recompute all of the paths each time.

```
$ python sysconfig_get_path.py

posix_prefix
============
purelib = /Users/dhellmann/Envs/pymotw/lib/python2.7/site-packages

posix_user
==========
purelib = /Users/dhellmann/Library/Python/2.7/lib/python2.7/site-packages
```

25.8.3 Python Version and Platform

While sys includes some basic platform identification (see *Build-time Version Information*), it is not specific enough to be used for installing binary packages because sys.platform does not always include information about hardware architecture, bit-ness, or other values that effect the compatibility of binary libraries. For a more precise platform specifier, use get_platform().

```
import sysconfig

print sysconfig.get_platform()
```

Although this sample output was prepared on an OS X 10.6 system, the interpreter is compiled for 10.5 compatibility, so that is the version number included in the platform string.

```
$ python sysconfig_get_platform.py

macosx-10.6-intel
```

As a convenience, the interpreter version from `sys.version_info` is also available through `get_python_version()` in `sysconfig`.

```
import sysconfig
import sys

print 'sysconfig.get_python_version() =>', sysconfig.get_python_version()
print 'sys.version_info =>', sys.version_info
```

`get_python_version()` returns a string suitable for use when building a version-specific path.

```
$ python sysconfig_get_python_version.py

sysconfig.get_python_version() => 2.7
sys.version_info => sys.version_info(major=2, minor=7, micro=2, releaselevel='final', serial=0)
```

See also:

sysconfig (http://docs.python.org/library/sysconfig.html) The standard library documentation for this module.

`distutils` `sysconfig` used to be part of the `distutils` package.

distutils2 (http://hg.python.org/distutils2/) Updates to `distutils`, managed by Tarek Ziadé.

`site` The `site` module describes the paths searched when importing in more detail.

`os` Includes `os.name`, the name of the current operating system.

`sys` Includes other build-time information such as the platform.

25.9 traceback – Extract, format, and print exceptions and stack traces.

Purpose Extract, format, and print exceptions and stack traces.

Available In 1.4 and later, with modifications over time

The `traceback` module works with the call stack to produce error messages. A traceback is a stack trace from the point of an exception handler down the call chain to the point where the exception was raised. You can also work with the current call stack up from the point of a call (and without the context of an error), which is useful for finding out the paths being followed into a function.

The functions in `traceback` fall into several common categories. There are functions for extracting raw tracebacks from the current runtime environment (either an exception handler for a traceback, or the regular stack). The extracted stack trace is a sequence of tuples containing the filename, line number, function name, and text of the source line.

Once extracted, the stack trace can be formatted using functions like `format_exception()`, `format_stack()`, etc. The format functions return a list of strings with messages formatted to be printed. There are shorthand functions for printing the formatted values, as well.

Although the functions in traceback mimic the behavior of the interactive interpreter by default, they also are useful for handling exceptions in situations where dumping the full stack trace to stderr is not desirable. For example, a web application may need to format the traceback so it looks good in HTML. An IDE may convert the elements of the stack trace into a clickable list that lets the user browse the source.

25.9.1 Supporting Functions

The examples below use the module traceback_example.py (provided in the source package for PyMOTW). The contents are:

```
import traceback
import sys

def produce_exception(recursion_level=2):
    sys.stdout.flush()
    if recursion_level:
        produce_exception(recursion_level-1)
    else:
        raise RuntimeError()

def call_function(f, recursion_level=2):
    if recursion_level:
        return call_function(f, recursion_level-1)
    else:
        return f()
```

25.9.2 Working With Exceptions

The simplest way to handle exception reporting is with `print_exc()`. It uses `sys.exc_info()` to obtain the exception information for the current thread, formats the results, and prints the text to a file handle (`sys.stderr`, by default).

```
import traceback
import sys

from traceback_example import produce_exception

print 'print_exc() with no exception:'
traceback.print_exc(file=sys.stdout)
print

try:
    produce_exception()
except Exception, err:
    print 'print_exc():'
    traceback.print_exc(file=sys.stdout)
    print
    print 'print_exc(1):'
    traceback.print_exc(limit=1, file=sys.stdout)
```

In this example, the file handle for `sys.stdout` is substituted so the informational and traceback messages are mingled correctly:

```
$ python traceback_print_exc.py

print_exc() with no exception:
```

```
None

print_exc():
Traceback (most recent call last):
  File "traceback_print_exc.py", line 20, in <module>
    produce_exception()
  File "/Users/dhellmann/Documents/PyMOTW/src/PyMOTW/traceback/traceback_example.py", line 16, in pro
    produce_exception(recursion_level-1)
  File "/Users/dhellmann/Documents/PyMOTW/src/PyMOTW/traceback/traceback_example.py", line 16, in pro
    produce_exception(recursion_level-1)
  File "/Users/dhellmann/Documents/PyMOTW/src/PyMOTW/traceback/traceback_example.py", line 18, in pro
    raise RuntimeError()
RuntimeError

print_exc(1):
Traceback (most recent call last):
  File "traceback_print_exc.py", line 20, in <module>
    produce_exception()
RuntimeError
```

`print_exc()` is just a shortcut for `print_exception()`, which requires explicit arguments:

```
import traceback
import sys

from traceback_example import produce_exception

try:
    produce_exception()
except Exception, err:
    print 'print_exception():'
    exc_type, exc_value, exc_tb = sys.exc_info()
    traceback.print_exception(exc_type, exc_value, exc_tb)
```

```
$ python traceback_print_exception.py

Traceback (most recent call last):
  File "traceback_print_exception.py", line 16, in <module>
    produce_exception()
  File "/Users/dhellmann/Documents/PyMOTW/src/PyMOTW/traceback/traceback_example.py", line 16, in pro
    produce_exception(recursion_level-1)
  File "/Users/dhellmann/Documents/PyMOTW/src/PyMOTW/traceback/traceback_example.py", line 16, in pro
    produce_exception(recursion_level-1)
  File "/Users/dhellmann/Documents/PyMOTW/src/PyMOTW/traceback/traceback_example.py", line 18, in pro
    raise RuntimeError()
RuntimeError
print_exception():
```

And `print_exception()` uses `format_exception()`:

```
import traceback
import sys
from pprint import pprint

from traceback_example import produce_exception

try:
    produce_exception()
except Exception, err:
    print 'format_exception():'
    exc_type, exc_value, exc_tb = sys.exc_info()
    pprint(traceback.format_exception(exc_type, exc_value, exc_tb))
```

```
$ python traceback_format_exception.py

format_exception():
['Traceback (most recent call last):\n',
 '  File "traceback_format_exception.py", line 17, in <module>\n    produce_exception()\n',
 '  File "/Users/dhellmann/Documents/PyMOTW/src/PyMOTW/traceback/traceback_example.py", line 16, in p
 '  File "/Users/dhellmann/Documents/PyMOTW/src/PyMOTW/traceback/traceback_example.py", line 16, in p
 '  File "/Users/dhellmann/Documents/PyMOTW/src/PyMOTW/traceback/traceback_example.py", line 18, in p
 'RuntimeError\n']
```

25.9.3 Working With the Stack

There are a similar set of functions for performing the same operations with the current call stack instead of a traceback.

print_stack()

```
import traceback
import sys

from traceback_example import call_function

def f():
    traceback.print_stack(file=sys.stdout)

print 'Calling f() directly:'
f()

print
print 'Calling f() from 3 levels deep:'
call_function(f)
```

```
$ python traceback_print_stack.py

Calling f() directly:
  File "traceback_print_stack.py", line 19, in <module>
    f()
  File "traceback_print_stack.py", line 16, in f
    traceback.print_stack(file=sys.stdout)

Calling f() from 3 levels deep:
  File "traceback_print_stack.py", line 23, in <module>
    call_function(f)
  File "/Users/dhellmann/Documents/PyMOTW/src/PyMOTW/traceback/traceback_example.py", line 22, in ca
    return call_function(f, recursion_level-1)
  File "/Users/dhellmann/Documents/PyMOTW/src/PyMOTW/traceback/traceback_example.py", line 22, in ca
    return call_function(f, recursion_level-1)
  File "/Users/dhellmann/Documents/PyMOTW/src/PyMOTW/traceback/traceback_example.py", line 24, in ca
    return f()
  File "traceback_print_stack.py", line 16, in f
    traceback.print_stack(file=sys.stdout)
```

format_stack()

```
import traceback
import sys
from pprint import pprint

from traceback_example import call_function

def f():
    return traceback.format_stack()

formatted_stack = call_function(f)
pprint(formatted_stack)
```

```
$ python traceback_format_stack.py

['  File "traceback_format_stack.py", line 19, in <module>\n    formatted_stack = call_function(f)\n'
 '  File "/Users/dhellmann/Documents/PyMOTW/src/PyMOTW/traceback/traceback_example.py", line 22, in c
 '  File "/Users/dhellmann/Documents/PyMOTW/src/PyMOTW/traceback/traceback_example.py", line 22, in c
 '  File "/Users/dhellmann/Documents/PyMOTW/src/PyMOTW/traceback/traceback_example.py", line 24, in c
 '  File "traceback_format_stack.py", line 17, in f\n    return traceback.format_stack()\n']
```

extract_stack()

```
import traceback
import sys
from pprint import pprint

from traceback_example import call_function

def f():
    return traceback.extract_stack()

stack = call_function(f)
pprint(stack)
```

```
$ python traceback_extract_stack.py

[('traceback_extract_stack.py', 19, '<module>', 'stack = call_function(f)'),
 ('/Users/dhellmann/Documents/PyMOTW/src/PyMOTW/traceback/traceback_example.py',
  22,
  'call_function',
  'return call_function(f, recursion_level-1)'),
 ('/Users/dhellmann/Documents/PyMOTW/src/PyMOTW/traceback/traceback_example.py',
  22,
  'call_function',
  'return call_function(f, recursion_level-1)'),
 ('/Users/dhellmann/Documents/PyMOTW/src/PyMOTW/traceback/traceback_example.py',
  24,
  'call_function',
  'return f()'),
 ('traceback_extract_stack.py', 17, 'f', 'return traceback.extract_stack()')]
```

See also:

traceback **(http://docs.python.org/lib/module-traceback.html)** Standard library documentation for this module.

`sys` The sys module includes singletons that hold the current exception.

inspect The inspect module includes other functions for probing the frames on the stack.

cgitb Another module for formatting tracebacks nicely.

25.10 warnings – Non-fatal alerts

Purpose Deliver non-fatal alerts to the user about issues encountered when running a program.

Available In 2.1 and later

The `warnings` module was introduced in **PEP 230** (http://www.python.org/dev/peps/pep-0230) as a way to warn programmers about changes in language or library features in anticipation of backwards incompatible changes coming with Python 3.0. Since warnings are not fatal, a program may encounter the same warn-able situation many times in the course of running. The `warnings` module suppresses repeated warnings from the same source to cut down on the annoyance of seeing the same message over and over. You can control the messages printed on a case-by-case basis using the `-W` option to the interpreter or by calling functions found in `warnings` from your code.

25.10.1 Categories and Filtering

Warnings are categorized using subclasses of the built-in exception class `Warning`. Several standard values are *described in the documentation*, and you can add your own by subclassing from `Warning` to create a new class.

Messages are filtered using settings controlled through the `-W` option to the interpreter. A filter consists of 5 parts, the *action*, *message*, *category*, *module*, and *line number*. When a warning is generated, it is compared against all of the registered filters. The first filter that matches controls the action taken for the warning. If no filter matches, the default action is taken.

The actions understood by the filtering mechanism are:

- error: Turn the warning into an exception.
- ignore: Discard the warning.
- always: Always emit a warning.
- default: Print the warning the first time it is generated from each location.
- module: Print the warning the first time it is generated from each module.
- once: Print the warning the first time it is generated.

The *message* portion of the filter is a regular expression that is used to match the warning text.

The *category* is a name of an exception class, as described above.

The *module* contains a regular expression to be matched against the module name generating the warning.

And the *line number* can be used to change the handling on specific occurrences of a warning. Use `0` to have the filter apply to all occurrences.

25.10.2 Generating Warnings

The simplest way to emit a warning from your own code is to just call `warn()` with the message as an argument:

```
import warnings

print 'Before the warning'
warnings.warn('This is a warning message')
print 'After the warning'
```

Then when your program runs, the message is printed:

```
$ python warnings_warn.py

warnings_warn.py:13: UserWarning: This is a warning message
  warnings.warn('This is a warning message')
Before the warning
After the warning
```

Even though the warning is printed, the default behavior is to continue past the warning and run the rest of the program. We can change that behavior with a filter:

```
import warnings

warnings.simplefilter('error', UserWarning)

print 'Before the warning'
warnings.warn('This is a warning message')
print 'After the warning'
```

This filter tells the warnings module to raise an exception when the warning is issued.

```
$ python warnings_warn_raise.py

Before the warning
Traceback (most recent call last):
  File "warnings_warn_raise.py", line 15, in <module>
    warnings.warn('This is a warning message')
UserWarning: This is a warning message
```

We can also control the filter behavior from the command line. For example, if we go back to `warnings_warn.py` and set the filter to raise an error on `UserWarning`, we see the exception:

```
$ python -W "error::UserWarning::0" warnings_warn.py

Before the warning
Traceback (most recent call last):
  File "warnings_warn.py", line 13, in <module>
    warnings.warn('This is a warning message')
UserWarning: This is a warning message
```

Since I left the fields for *message* and *module* blank, they were interpreted as matching anything.

25.10.3 Filtering with Patterns

To filter on more complex rules programmatically, use `filterwarnings()`. For example, to filter based on the content of the message text:

```
import warnings

warnings.filterwarnings('ignore', '.*do not.*',)

warnings.warn('Show this message')
warnings.warn('Do not show this message')
```

The pattern contains "`do not`", but the actual message uses "`Do not`". The pattern matches because the regular expression is always compiled to look for case insensitive matches.

```
$ python warnings_filterwarnings_message.py

warnings_filterwarnings_message.py:14: UserWarning: Show this message
  warnings.warn('Show this message')
```

Running this source from the command line:

```
import warnings

warnings.warn('Show this message')
warnings.warn('Do not show this message')
```

yields:

```
$ python -W "ignore:do not:UserWarning::0" warnings_filtering.py

warnings_filtering.py:12: UserWarning: Show this message
  warnings.warn('Show this message')
```

The same pattern matching rules apply to the name of the source module containing the warning call. To suppress all warnings from the `warnings_filtering` module:

```
import warnings

warnings.filterwarnings('ignore',
                        '.*',
                        UserWarning,
                        'warnings_filtering',
                        )

import warnings_filtering
```

Since the filter is in place, no warnings are emitted when `warnings_filtering` is imported:

```
$ python warnings_filterwarnings_module.py
```

To suppress only the warning on line 14 of `warnings_filtering`:

```
import warnings

warnings.filterwarnings('ignore',
                        '.*',
                        UserWarning,
                        'warnings_filtering',
                        14)

import warnings_filtering
```

```
$ python warnings_filterwarnings_lineno.py

/Users/dhellmann/Documents/PyMOTW/src/PyMOTW/warnings/warnings_filtering.py:12: UserWarning: Show thi
  warnings.warn('Show this message')
/Users/dhellmann/Documents/PyMOTW/src/PyMOTW/warnings/warnings_filtering.py:13: UserWarning: Do not s
  warnings.warn('Do not show this message')
```

25.10.4 Repeated Warnings

By default, most types of warnings are only printed the first time they occur in a given location, where location is defined as the combination of module and line number.

```
import warnings

def function_with_warning():
    warnings.warn('This is a warning!')

function_with_warning()
function_with_warning()
function_with_warning()
```

```
$ python warnings_repeated.py

warnings_repeated.py:13: UserWarning: This is a warning!
  warnings.warn('This is a warning!')
```

The "once" action can be used to suppress instances of the same message from different locations.

```
import warnings

warnings.simplefilter('once', UserWarning)

warnings.warn('This is a warning!')
warnings.warn('This is a warning!')
warnings.warn('This is a warning!')
```

```
$ python warnings_once.py

warnings_once.py:14: UserWarning: This is a warning!
  warnings.warn('This is a warning!')
```

Similarly, "module" will suppress repeated messages from the same module, no matter what line number.

25.10.5 Alternate Message Delivery Functions

Normally warnings are printed to *sys.stderr*. You can change that behavior by replacing the `showwarning()` function inside the `warnings` module. For example, if you wanted warnings to go to a log file instead of stderr, you could replace `showwarning()` with a function like this:

```
import warnings
import logging

logging.basicConfig(level=logging.INFO)

def send_warnings_to_log(message, category, filename, lineno, file=None):
    logging.warning(
        '%s:%s: %s:%s' %
        (filename, lineno, category.__name__, message))
    return

old_showwarning = warnings.showwarning
warnings.showwarning = send_warnings_to_log

warnings.warn('This is a warning message')
```

So that when `warn()` is called, the warnings are emitted with the rest of the log messages.

```
$ python warnings_showwarning.py

WARNING:root:warnings_showwarning.py:24: UserWarning:This is a warning message
```

25.10.6 Formatting

If it is OK for warnings to go to stderr, but you don't like the formatting, you can replace `formatwarning()` instead.

```python
import warnings

def warning_on_one_line(message, category, filename, lineno, file=None, line=None):
    return ' %s:%s: %s:%s' % (filename, lineno, category.__name__, message)

warnings.warn('This is a warning message, before')
warnings.formatwarning = warning_on_one_line
warnings.warn('This is a warning message, after')
```

```
$ python warnings_formatwarning.py

warnings_formatwarning.py:15: UserWarning: This is a warning message, before
  warnings.warn('This is a warning message, before')
 warnings_formatwarning.py:17: UserWarning:This is a warning message, after
```

25.10.7 Stack Level in Warnings

You'll notice that by default the warning message includes the source line that generated it, when available. It's not all that useful to see the line of code with the actual warning message, though. Instead, you can tell `warn()` how far up the stack it has to go to find the line the called the function containing the warning. That way users of a deprecated function see where the function is called, instead of the implementation of the function.

```python
import warnings

def old_function():
    warnings.warn(
        'old_function() is deprecated, use new_function() instead',
        stacklevel=2)

def caller_of_old_function():
    old_function()

caller_of_old_function()
```

Notice that in this example `warn()` needs to go up the stack 2 levels, one for itself and one for `old_function()`.

```
$ python warnings_warn_stacklevel.py

warnings_warn_stacklevel.py:18: UserWarning: old_function() is deprecated, use new_function() insteac
  old_function()
```

See also:

warnings (http://docs.python.org/lib/module-warnings.html) Standard library documentation for this module.

PEP 230 (http://www.python.org/dev/peps/pep-0230) Warning Framework `exceptions` Base classes for exceptions and warnings.

CHAPTER

TWENTYSIX

IMPORTING MODULES

26.1 imp – Interface to module import mechanism.

Purpose The imp module exposes the implementation of Python's import statement.

Available In At least 2.2.1

The imp module includes functions that expose part of the underlying implementation of Python's import mechanism for loading code in packages and modules. It is one access point to importing modules dynamically, and useful in some cases where you don't know the name of the module you need to import when you write your code (e.g., for plugins or extensions to an application).

26.1.1 Example Package

The examples below use a package called "example" with `__init__.py`:

```
print 'Importing example package'
```

and module called submodule containing:

```
print 'Importing submodule'
```

Watch for the text from the print statements in the sample output when the package or module are imported.

26.1.2 Module Types

Python supports several styles of modules. Each requires its own handling when opening the module and adding it to the namespace. Some of the supported types and those parameters can be listed by the `get_suffixes()` function.

```
import imp

module_types = { imp.PY_SOURCE:   'source',
                 imp.PY_COMPILED: 'compiled',
                 imp.C_EXTENSION: 'extension',
                 imp.PY_RESOURCE: 'resource',
                 imp.PKG_DIRECTORY: 'package',
                 }

def main():
    fmt = '%10s %10s %10s'
    print fmt % ('Extension', 'Mode', 'Type')
    print '-' * 32
    for extension, mode, module_type in imp.get_suffixes():
        print fmt % (extension, mode, module_types[module_type])

if __name__ == '__main__':
    main()
```

`get_suffixes()` returns a sequence of tuples containing the file extension, mode to use for opening the file, and a type code from a constant defined in the module. This table is incomplete, because some of the importable module or package types do not correspond to single files.

```
$ python imp_get_suffixes.py

 Extension       Mode       Type
--------------------------------
       .so         rb  extension
 module.so         rb  extension
       .py          U     source
      .pyc         rb   compiled
```

26.1.3 Finding Modules

The first step to loading a module is finding it. `find_module()` scans the import search path looking for a package or module with the given name. It returns an open file handle (if appropriate for the type), filename where the module was found, and "description" (a tuple such as those returned by `get_suffixes()`).

```
import imp
from imp_get_suffixes import module_types

print 'Package:'
f, filename, description = imp.find_module('example')
print module_types[description[2]], filename
print

print 'Sub-module:'
f, filename, description = imp.find_module('submodule', [filename])
print module_types[description[2]], filename
if f: f.close()
```

`find_module()` does not pay attention to dotted package names ("example.submodule"), so the caller has to take care to pass the correct path for any nested modules. That means that when importing the submodule from the package, you need to give a path that points to the package directory for `find_module()` to locate the module you're looking for.

```
$ python imp_find_module.py

Package:
package /Users/dhellmann/Documents/PyMOTW/src/PyMOTW/imp/example

Sub-module:
source /Users/dhellmann/Documents/PyMOTW/src/PyMOTW/imp/example/submodule.py
```

If `find_module()` cannot locate the module, it raises an *ImportError*.

```
import imp

try:
    imp.find_module('no_such_module')
```

```
except ImportError, err:
    print 'ImportError:', err
```

```
$ python imp_find_module_error.py

ImportError: No module named no_such_module
```

26.1.4 Loading Modules

Once you have found the module, use `load_module()` to actually import it. `load_module()` takes the full dotted path module name and the values returned by `find_module()` (the open file handle, filename, and description tuple).

```
import imp

f, filename, description = imp.find_module('example')
example_package = imp.load_module('example', f, filename, description)
print 'Package:', example_package

f, filename, description = imp.find_module('submodule',
                                           example_package.__path__)
try:
    submodule = imp.load_module('example.module', f, filename, description)
    print 'Sub-module:', submodule
finally:
    f.close()
```

`load_module()` creates a new module object with the name given, loads the code for it, and adds it to *sys.modules*.

```
$ python imp_load_module.py
Importing example package
Package: <module 'example' from '/Users/dhellmann/Documents/PyMOTW/trunk/PyMOTW/imp/example/__init__
Importing submodule
Sub-module: <module 'example.module' from '/Users/dhellmann/Documents/PyMOTW/trunk/PyMOTW/imp/example
```

If you call `load_module()` for a module which has already been imported, the effect is like calling `reload()` on the existing module object.

```
import imp
import sys

for i in range(2):
    print i,
    try:
        m = sys.modules['example']
    except KeyError:
        print '(not in sys.modules)',
    else:
        print '(have in sys.modules)',
    f, filename, description = imp.find_module('example')
    example_package = imp.load_module('example', f, filename, description)
```

Instead of a creating a new module, the contents of the existing module are simply replaced.

```
$ python imp_load_module_reload.py

0 (not in sys.modules) Importing example package
1 (have in sys.modules) Importing example package
```

See also:

imp (http://docs.python.org/library/imp.html) The standard library documentation for this module.

Modules and Imports Import hooks, the module search path, and other related machinery.

inspect Load information from a module programmatically.

PEP 302 (http://www.python.org/dev/peps/pep-0302) New import hooks.

PEP 369 (http://www.python.org/dev/peps/pep-0369) Post import hooks.

26.2 pkgutil – Package Utilities

Purpose Add to the module search path for a specific package and work with resources included in a package.

Available In 2.3 and later

The pkgutil module includes functions for working with Python packages. extend_path() changes the import path for sub-modules of the package, and get_data() provides access to file resources distributed with the package.

26.2.1 Package Import Paths

The extend_path() function is used to modify the search path for modules in a given package to include other directories in *sys.path*. This can be used to override installed versions of packages with development versions, or to combine platform-specific and shared modules into a single package namespace.

The most common way to call extend_path() is by adding these two lines to the __init__.py inside the packag:

e:

```
import pkgutil
__path__ = pkgutil.extend_path(__path__, __name__)
```

extend_path() scans sys.path for directories that include a subdirectory named for the package given as the second argument. The list of directories is combined with the path value passed as the first argument and returned as a single list, suitable for use as the package import path.

An example package called demopkg includes these files:

```
$ find demopkg1 -name '*.py'
demopkg1/__init__.py
demopkg1/shared.py
```

demopkg1/__init__.py contains:

```
import pkgutil
import pprint

print 'demopkg1.__path__ before:'
pprint.pprint(__path__)
print

__path__ = pkgutil.extend_path(__path__, __name__)

print 'demopkg1.__path__ after:'
```

```
pprint.pprint(__path__)
print
```

The **print** statements shows the search path before and after it is modified, to highlight the difference.

And an `extension` directory, with add-on features for `demopkg`, contains

```
$ find extension -name '*.py'
extension/__init__.py
extension/demopkg1/__init__.py
extension/demopkg1/not_shared.py
```

A simple test program imports the `demopkg1` package:

```
import demopkg1
print 'demopkg1           :', demopkg1.__file__

try:
    import demopkg1.shared
except Exception, err:
    print 'demopkg1.shared    : Not found (%s)' % err
else:
    print 'demopkg1.shared    :', demopkg1.shared.__file__

try:
    import demopkg1.not_shared
except Exception, err:
    print 'demopkg1.not_shared: Not found (%s)' % err
else:
    print 'demopkg1.not_shared:', demopkg1.not_shared.__file__
```

When this test program is run directly from the command line, the `not_shared` module is not found.

Note: The full filesystem paths in these examples have been shortened to emphasize the parts that change.

```
$ python pkgutil_extend_path.py

demopkg1.__path__ before:
['.../PyMOTW/pkgutil/demopkg1']

demopkg1.__path__ after:
['.../PyMOTW/pkgutil/demopkg1']

demopkg1           : .../PyMOTW/pkgutil/demopkg1/__init__.py
demopkg1.shared    : .../PyMOTW/pkgutil/demopkg1/shared.py
demopkg1.not_shared: Not found (No module named not_shared)
```

However, if the `extension` directory is added to the `PYTHONPATH` and the program is run again, different results are produced.

```
$ export PYTHONPATH=extension
$ python pkgutil_extend_path.py
demopkg1.__path__ before:
['.../PyMOTW/pkgutil/demopkg1']

demopkg1.__path__ after:
['.../PyMOTW/pkgutil/demopkg1',
 '.../PyMOTW/pkgutil/extension/demopkg1']
```

```
demopkg1           : .../PyMOTW/pkgutil/demopkg1/__init__.pyc
demopkg1.shared    : .../PyMOTW/pkgutil/demopkg1/shared.pyc
demopkg1.not_shared: .../PyMOTW/pkgutil/extension/demopkg1/not_shared.py
```

The version of `demopkg1` inside the `extension` directory has been added to the search path, so the `not_shared` module is found there.

Extending the path in this manner is useful for combining platform-specific versions of packages with common packages, especially if the platform-specific versions include C extension modules.

Development Versions of Packages

While develop enhancements to a project, it is common to need to test changes to an installed package. Replacing the installed copy with a development version may be a bad idea, since it is not necessarily correct and other tools on the system are likely to depend on the installed package.

A completely separate copy of the package could be configured in a development environment using virtualenv (http://pypi.python.org/pypi/virtualenv), but for small modifications the overhead of setting up a virtual environment with all of the dependencies may be excessive.

Another option is to use `pkgutil` to modify the module search path for modules that belong to the package under development. In this case, however, the path must be reversed so development version overrides the installed version.

Given a package `demopkg2` like this:

```
$ find demopkg2 -name '*.py'
demopkg2/__init__.py
demopkg2/overloaded.py
```

With the function under development located in `demopkg2/overloaded.py`. The installed version contains

```
def func():
    print 'This is the installed version of func().'
```

and `demopkg2/__init__.py` contains

```
import pkgutil

__path__ = pkgutil.extend_path(__path__, __name__)
__path__.reverse()
```

`reverse()` is used to ensure that any directories added to the search path by `pkgutil` are scanned for imports *before* the default location.

This program imports `demopkg2.overloaded` and calls `func()`:

```
import demopkg2
print 'demopkg2           :', demopkg2.__file__

import demopkg2.overloaded
print 'demopkg2.overloaded:', demopkg2.overloaded.__file__

print
demopkg2.overloaded.func()
```

Running it without any special path treatment produces output from the installed version of `func()`.

```
$ python pkgutil_devel.py
demopkg2           : .../PyMOTW/pkgutil/demopkg2/__init__.py
demopkg2.overloaded: .../PyMOTW/pkgutil/demopkg2/overloaded.py
```

A development directory containing

```
$ find develop -name '*.py'
develop/demopkg2/__init__.py
develop/demopkg2/overloaded.py
```

and a modified version of `overloaded`

```python
def func():
    print 'This is the development version of func().'
```

will be loaded when the test program is run with the `develop` directory in the search path.

```
$ export PYTHONPATH=develop
$ python pkgutil_devel.py

demopkg2           : .../PyMOTW/pkgutil/demopkg2/__init__.pyc
demopkg2.overloaded: .../PyMOTW/pkgutil/develop/demopkg2/overloaded.pyc
```

Managing Paths with PKG Files

The first example above illustrated how to extend the search path using extra directories included in the `PYTHONPATH`. It is also possible to add to the search path using `*.pkg` files containing directory names. PKG files are similar to the PTH files used by the `site` module. They can contain directory names, one per line, to be added to the search path for the package.

Another way to structure the platform-specific portions of the application from the first example is to use a separate directory for each operating system, and include a `.pkg` file to extend the search path.

This example uses the same `demopkg1` files, and also includes the following files:

```
$ find os_* -type f
os_one/demopkg1/__init__.py
os_one/demopkg1/not_shared.py
os_one/demopkg1.pkg
os_two/demopkg1/__init__.py
os_two/demopkg1/not_shared.py
os_two/demopkg1.pkg
```

The PKG files are named `demopkg1.pkg` to match the package being extended. They both contain:

```
demopkg
```

This demo program shows the version of the module being imported:

```python
import demopkg1
print 'demopkg1:', demopkg1.__file__

import demopkg1.shared
print 'demopkg1.shared:', demopkg1.shared.__file__

import demopkg1.not_shared
print 'demopkg1.not_shared:', demopkg1.not_shared.__file__
```

A simple run script can be used to switch between the two packages:

```
export PYTHONPATH=os_${1}
echo "PYTHONPATH=$PYTHONPATH"
echo
```

```
python pkgutil_os_specific.py
```

And when run with "one" or "two" as the arguments, the path is adjusted appropriately:

```
$ ./with_os.sh one
PYTHONPATH=os_one

demopkg1.__path__ before:
['.../PyMOTW/pkgutil/demopkg1']

demopkg1.__path__ after:
['.../PyMOTW/pkgutil/demopkg1',
 '.../PyMOTW/pkgutil/os_one/demopkg1',
 'demopkg']

demopkg1           : .../PyMOTW/pkgutil/demopkg1/__init__.pyc
demopkg1.shared    : .../PyMOTW/pkgutil/demopkg1/shared.pyc
demopkg1.not_shared: .../PyMOTW/pkgutil/os_one/demopkg1/not_shared.pyc

$ ./with_os.sh two
PYTHONPATH=os_two

demopkg1.__path__ before:
['.../PyMOTW/pkgutil/demopkg1']

demopkg1.__path__ after:
['.../PyMOTW/pkgutil/demopkg1',
 '.../PyMOTW/pkgutil/os_two/demopkg1',
 'demopkg']

demopkg1           : .../PyMOTW/pkgutil/demopkg1/__init__.pyc
demopkg1.shared    : .../PyMOTW/pkgutil/demopkg1/shared.pyc
demopkg1.not_shared: .../PyMOTW/pkgutil/os_two/demopkg1/not_shared.pyc
```

PKG files can appear anywhere in the normal search path, so a single PKG file in the current working directory could also be used to include a development tree.

Nested Packages

For nested packages, it is only necessary to modify the path of the top-level package. For example, with this directory structure

```
$ find nested -name '*.py'
nested/__init__.py
nested/second/__init__.py
nested/second/deep.py
nested/shallow.py
```

Where `nested/__init__.py` contains

```
import pkgutil

__path__ = pkgutil.extend_path(__path__, __name__)
__path__.reverse()
```

and a development tree like

```
$ find develop/nested -name '*.py'
develop/nested/__init__.py
develop/nested/second/__init__.py
develop/nested/second/deep.py
develop/nested/shallow.py
```

Both the `shallow` and `deep` modules contain a simple function to print out a message indicating whether or not they come from the installed or development version.

This test program exercises the new packages.

```
import nested

import nested.shallow
print 'nested.shallow:', nested.shallow.__file__
nested.shallow.func()

print
import nested.second.deep
print 'nested.second.deep:', nested.second.deep.__file__
nested.second.deep.func()
```

When `pkgutil_nested.py` is run without any path manipulation, the installed version of both modules are used.

```
$ python pkgutil_nested.py
nested.shallow: .../PyMOTW/pkgutil/nested/shallow.pyc
This func() comes from the installed version of nested.shallow

nested.second.deep: .../PyMOTW/pkgutil/nested/second/deep.pyc
This func() comes from the installed version of nested.second.deep
```

When the `develop` directory is added to the path, the development version of both functions override the installed versions.

```
$ PYTHONPATH=develop python pkgutil_nested.py
nested.shallow: .../PyMOTW/pkgutil/develop/nested/shallow.pyc
This func() comes from the development version of nested.shallow

nested.second.deep: .../PyMOTW/pkgutil/develop/nested/second/deep.pyc
This func() comes from the development version of nested.second.deep
```

26.2.2 Package Data

In addition to code, Python packages can contain data files such as templates, default configuration files, images, and other supporting files used by the code in the package. The `get_data()` function gives access to the data in the files in a format-agnostic way, so it does not matter if the package is distributed as an EGG, part of a frozen binary, or regular files on the filesystem.

With a package `pkgwithdata` containing a `templates` directory

```
$ find pkgwithdata -type f

pkgwithdata/__init__.py
pkgwithdata/templates/base.html
```

and `pkgwithdata/templates/base.html` containing

```
<!DOCTYPE HTML PUBLIC "-//IETF//DTD HTML//EN">
<html> <head>
<title>PyMOTW Template</title>
</head>

<body>
<h1>Example Template</h1>

<p>This is a sample data file.</p>

</body>
</html>
```

This program uses `get_data()` to retrieve the template contents and print them out.

```
import pkgutil

template = pkgutil.get_data('pkgwithdata', 'templates/base.html')
print template.encode('utf-8')
```

The arguments to `get_data()` are the dotted name of the package, and a filename relative to the top of the package. The return value is a byte sequence, so it is encoded as UTF-8 before being printed.

```
$ python pkgutil_get_data.py

<!DOCTYPE HTML PUBLIC "-//IETF//DTD HTML//EN">
<html> <head>
<title>PyMOTW Template</title>
</head>

<body>
<h1>Example Template</h1>

<p>This is a sample data file.</p>

</body>
</html>
```

`get_data()` is distribution format-agnostic because it uses the import hooks defined in **PEP 302** (http://www.python.org/dev/peps/pep-0302) to access the package contents. Any loader that provides the hooks can be used, including the ZIP archive importer in `zipfile`.

```
import pkgutil
import zipfile
import sys

# Create a ZIP file with code from the current directory
# and the template using a name that does not appear on the
# local filesystem.
with zipfile.PyZipFile('pkgwithdatainzip.zip', mode='w') as zf:
    zf.writepy('.')
    zf.write('pkgwithdata/templates/base.html',
             'pkgwithdata/templates/fromzip.html',
             )

# Add the ZIP file to the import path.
sys.path.insert(0, 'pkgwithdatainzip.zip')

# Import pkgwithdata to show that it comes from the ZIP archive.
```

```
import pkgwithdata
print 'Loading pkgwithdata from', pkgwithdata.__file__

# Print the template body
print '\nTemplate:'
print pkgutil.get_data('pkgwithdata', 'templates/fromzip.html').encode('utf-8')
```

This example creates a ZIP archive with a copy of the `pkgwithdata` package, including a renamed version of the template file. It then adds the ZIP archive to the import path before using `pkgutil` to load the template and print it.

```
$ python pkgutil_get_data_zip.py

Loading pkgwithdata from pkgwithdatainzip.zip/pkgwithdata/__init__.pyc

Template:
<!DOCTYPE HTML PUBLIC "-//IETF//DTD HTML//EN">
<html> <head>
<title>PyMOTW Template</title>
</head>

<body>
<h1>Example Template</h1>

<p>This is a sample data file.</p>

</body>
</html>
```

See also:

pkgutil (http://docs.python.org/lib/module-pkgutil.html) Standard library documentation for this module.

virtualenv (http://pypi.python.org/pypi/virtualenv) Ian Bicking's virtual environment script.

`distutils` Packaging tools from Python standard library.

Distribute (http://packages.python.org/distribute/) Next-generation packaging tools.

PEP 302 (http://www.python.org/dev/peps/pep-0302) Import Hooks

`zipfile` Create importable ZIP archives.

`zipimport` Importer for packages in ZIP archives.

26.3 zipimport – Load Python code from inside ZIP archives

Purpose Load Python code from inside ZIP archives.

Available In 2.3 and later

The `zipimport` module implements the `zipimporter` class, which can be used to find and load Python modules inside ZIP archives. The `zipimporter` supports the "import hooks" API specified in **PEP 302** (http://www.python.org/dev/peps/pep-0302); this is how Python Eggs work.

You probably won't need to use the `zipimport` module directly, since it is possible to import directly from a ZIP archive as long as that archive appears in your *sys.path*. However, it is interesting to see the features available.

26.3.1 Example

For the examples this week, I'll reuse some of the code from last week's discussion of zipfile to create an example ZIP archive containing some Python modules. If you are experimenting with the sample code on your system, run `zipimport_make_example.py` before any of the rest of the examples. It will create a ZIP archive containing all of the modules in the example directory, along with some test data needed for the code below.

```
import sys
import zipfile

if __name__ == '__main__':
    zf = zipfile.PyZipFile('zipimport_example.zip', mode='w')
    try:
        zf.writepy('.')
        zf.write('zipimport_get_source.py')
        zf.write('example_package/README.txt')
    finally:
        zf.close()
    for name in zf.namelist():
        print name
```

```
$ python zipimport_make_example.py

__init__.pyc
example_package/__init__.pyc
zipimport_find_module.pyc
zipimport_get_code.pyc
zipimport_get_data.pyc
zipimport_get_data_nozip.pyc
zipimport_get_data_zip.pyc
zipimport_get_source.pyc
zipimport_is_package.pyc
zipimport_load_module.pyc
zipimport_make_example.pyc
zipimport_get_source.py
example_package/README.txt
```

26.3.2 Finding a Module

Given the full name of a module, `find_module()` will try to locate that module inside the ZIP archive.

```
import zipimport

importer = zipimport.zipimporter('zipimport_example.zip')

for module_name in [ 'zipimport_find_module', 'not_there' ]:
    print module_name, ':', importer.find_module(module_name)
```

If the module is found, the `zipimporter` instance is returned. Otherwise, `None` is returned.

```
$ python zipimport_find_module.py

zipimport_find_module : <zipimporter object "zipimport_example.zip">
not_there : None
```

26.3.3 Accessing Code

The `get_code()` method loads the code object for a module from the archive.

```
import zipimport

importer = zipimport.zipimporter('zipimport_example.zip')
code = importer.get_code('zipimport_get_code')
print code
```

The code object is not the same as a module object.

```
$ python zipimport_get_code.py

<code object <module> at 0x1002bc2b0, file "./zipimport_get_code.py", line 7>
```

To load the code as a usable module, use `load_module()` instead.

```
import zipimport

importer = zipimport.zipimporter('zipimport_example.zip')
module = importer.load_module('zipimport_get_code')
print 'Name   :', module.__name__
print 'Loader :', module.__loader__
print 'Code   :', module.code
```

The result is a module object as though the code had been loaded from a regular import:

```
$ python zipimport_load_module.py

<code object <module> at 0x1002ea7b0, file "./zipimport_get_code.py", line 7>
Name   : zipimport_get_code
Loader : <zipimporter object "zipimport_example.zip">
Code   : <code object <module> at 0x1002ea7b0, file "./zipimport_get_code.py", line 7>
```

26.3.4 Source

As with the `inspect` module, it is possible to retrieve the source code for a module from the ZIP archive, if the archive includes the source. In the case of the example, only `zipimport_get_source.py` is added to `zipimport_example.zip` (the rest of the modules are just added as the .pyc files).

```
import zipimport

importer = zipimport.zipimporter('zipimport_example.zip')
for module_name in ['zipimport_get_code', 'zipimport_get_source']:
    source = importer.get_source(module_name)
    print '=' * 80
    print module_name
    print '=' * 80
    print source
    print
```

If the source for a module is not available, `get_source()` returns `None`.

```
$ python zipimport_get_source.py

================================================================================
zipimport_get_code
```

```
================================================================================
None

================================================================================
zipimport_get_source
================================================================================
#!/usr/bin/env python
#
# Copyright 2007 Doug Hellmann.
#

"""Retrieving the source code for a module within a zip archive.

"""
#end_pymotw_header

import zipimport

importer = zipimport.zipimporter('zipimport_example.zip')
for module_name in ['zipimport_get_code', 'zipimport_get_source']:
    source = importer.get_source(module_name)
    print '=' * 80
    print module_name
    print '=' * 80
    print source
    print
```

26.3.5 Packages

To determine if a name refers to a package instead of a regular module, use `is_package()`.

```
import zipimport

importer = zipimport.zipimporter('zipimport_example.zip')
for name in ['zipimport_is_package', 'example_package']:
    print name, importer.is_package(name)
```

In this case, `zipimport_is_package` came from a module and the `example_package` is a package.

```
$ python zipimport_is_package.py

zipimport_is_package False
example_package True
```

26.3.6 Data

There are times when source modules or packages need to be distributed with non-code data. Images, configuration files, default data, and test fixtures are just a few examples of this. Frequently, the module `__path__` attribute is used to find these data files relative to where the code is installed.

For example, with a normal module you might do something like:

```
import os
import example_package
data_filename = os.path.join(os.path.dirname(example_package.__file__),
                             'README.txt')
```

```
print data_filename, ':'
print open(data_filename, 'rt').read()
```

The output will look something like this, with the path changed based on where the PyMOTW sample code is on your filesystem.

```
$ python zipimport_get_data_nozip.py

/Users/dhellmann/Documents/PyMOTW/src/PyMOTW/zipimport/example_package/README.txt :
This file represents sample data which could be embedded in the ZIP
archive.  You could include a configuration file, images, or any other
sort of non-code data.
```

If the `example_package` is imported from the ZIP archive instead of the filesystem, that method does not work:

```
import sys
sys.path.insert(0, 'zipimport_example.zip')

import os
import example_package
print example_package.__file__
data_filename = os.path.join(os.path.dirname(example_package.__file__),
                             'README.txt')
print data_filename, ':'
print open(data_filename, 'rt').read()
```

The `__file__` of the package refers to the ZIP archive, and not a directory. So we cannot just build up the path to the `README.txt` file.

```
$ python zipimport_get_data_zip.py

zipimport_example.zip/example_package/__init__.pyc
zipimport_example.zip/example_package/README.txt :
Traceback (most recent call last):
  File "zipimport_get_data_zip.py", line 40, in <module>
    print open(data_filename, 'rt').read()
IOError: [Errno 20] Not a directory: 'zipimport_example.zip/example_package/README.txt'
```

Instead, we need to use the `get_data()` method. We can access `zipimporter` instance which loaded the module through the `__loader__` attribute of the imported module:

```
import sys
sys.path.insert(0, 'zipimport_example.zip')

import os
import example_package
print example_package.__file__
print example_package.__loader__.get_data('example_package/README.txt')
```

```
$ python zipimport_get_data.py

zipimport_example.zip/example_package/__init__.pyc
This file represents sample data which could be embedded in the ZIP
archive.  You could include a configuration file, images, or any other
sort of non-code data.
```

The `__loader__` is not set for modules not imported via `zipimport`.

See also:

zipimport (http://docs.python.org/lib/module-zipimport.html) Standard library documentation for this module.

imp Other import-related functions.

PEP 302 (http://www.python.org/dev/peps/pep-0302) New Import Hooks

pkgutil Provides a more generic interface to `get_data()`.

CHAPTER

TWENTYSEVEN

MISCELANEOUS

27.1 EasyDialogs – Carbon dialogs for Mac OS X

Purpose Provides simple interfaces to Carbon dialogs from Python.

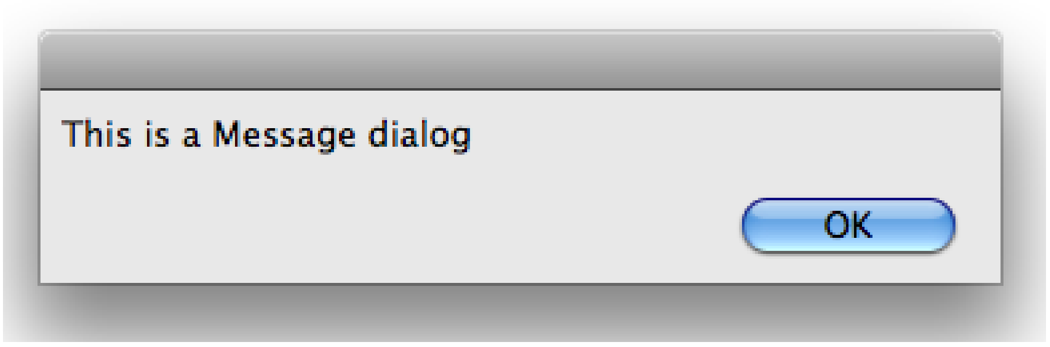
Available In At least 2.0, Macintosh-only (see References below for a Windows implementation)

The EasyDialogs module includes classes and functions for working with simple message and prompt dialogs, as well as stock dialogs for querying the user for file or directory names. The dialogs use the Carbon API. See Apple's Navigation Services Reference (http://developer.apple.com/documentation/Carbon/Reference/Navigation_Services_Ref/Reference/reference.html) for more details about some of the options not covered in detail here.

27.1.1 Messages

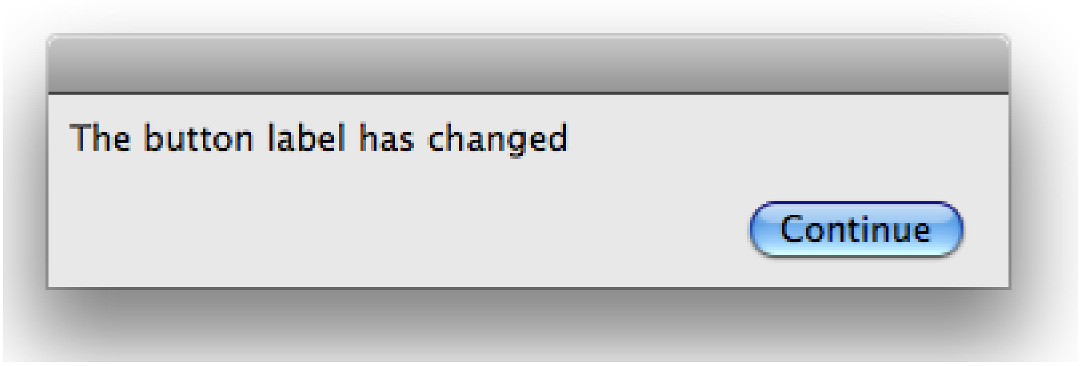
A simple Message function displays modal dialog containing a text message for the user.

```
import EasyDialogs

EasyDialogs.Message('This is a Message dialog')
```


This is a Message dialog

It is easy to change the label of the "OK" button using the ok argument.

```
import EasyDialogs

EasyDialogs.Message('The button label has changed', ok='Continue')
```

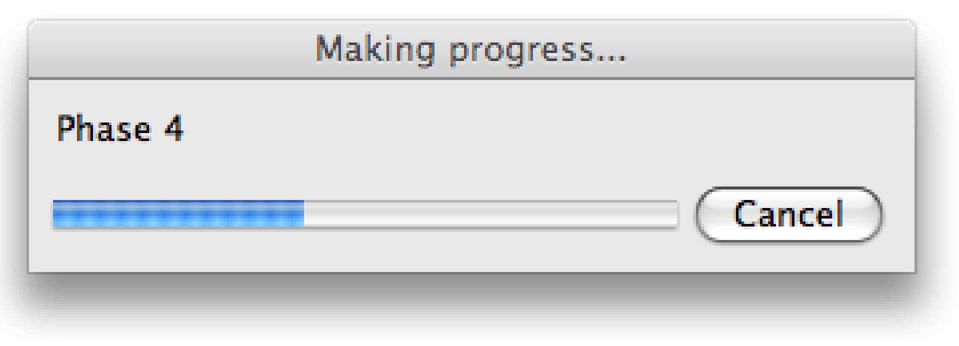


27.1.2 ProgressBar

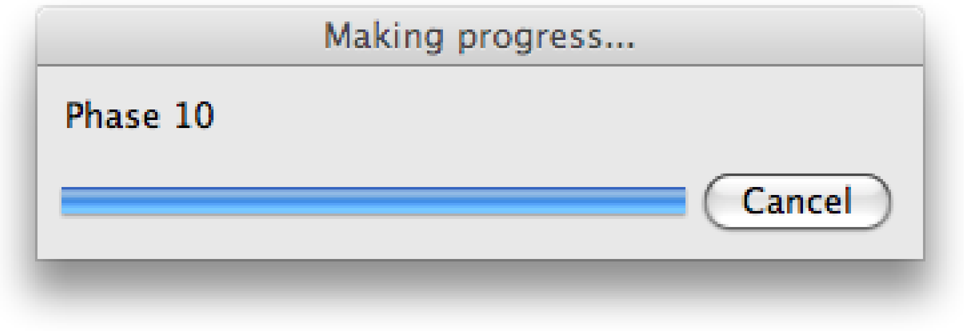
The ProgressBar class manages a modeless dialog with a progress meter. It can operate in determinate (when you know how much work there is to be done) or indeterminate (when you want to show that your app is working, but do not know how much work needs to be done) modes. The constructor takes arguments for the dialog title, the maximum value, and a label to describe the current phase of operation.

In determinate mode, set the maxval argument to the number of steps, amount of data to download, etc. Then use the incr() method to step the progress from 0 to maxval.

```
import EasyDialogs
import time

meter = EasyDialogs.ProgressBar('Making progress...',
                                maxval=10,
                                label='Starting',
                                )
for i in xrange(1, 11):
    phase = 'Phase %d' % i
    print phase
    meter.label(phase)
    meter.inc()
    time.sleep(1)
print 'Done with loop'
time.sleep(1)

del meter
print 'The dialog should be gone now'

time.sleep(1)
```



```
$ python EasyDialogs_ProgressBar.py
Phase 1
Phase 2
Phase 3
Phase 4
Phase 5
Phase 6
Phase 7
Phase 8
Phase 9
Phase 10
Done with loop
```

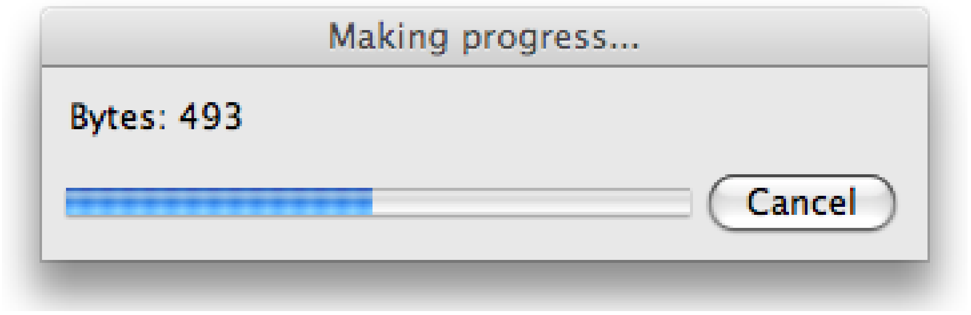


```
The dialog should be gone now
```

Explicitly deleting the ProgressBar instance using `del` removes it from the screen.

If you are measuring progress in uneven steps, use `set()` to change the progress meter instead of `incr()`.

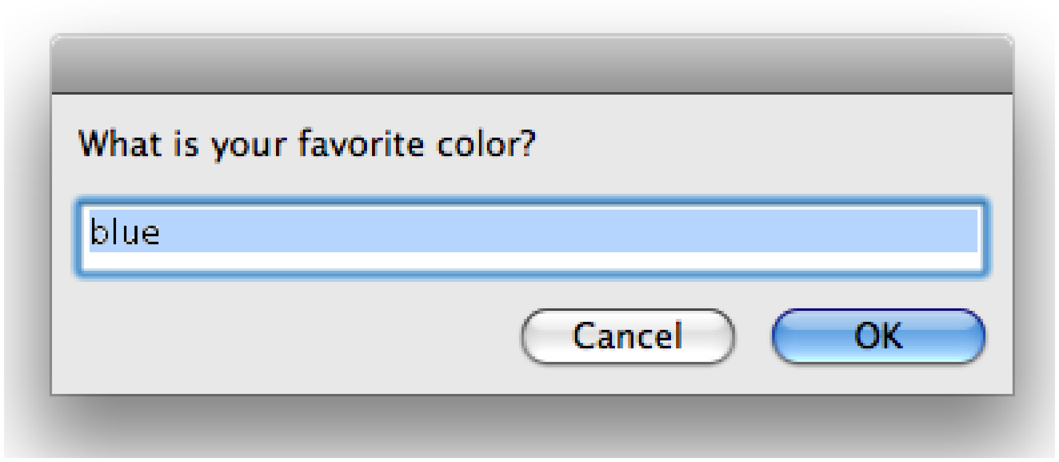
```
import EasyDialogs
import time

meter = EasyDialogs.ProgressBar('Making progress...',
                                maxval=1000,
                                label='Starting',
                                )
for i in xrange(1, 1001, 123):
    msg = 'Bytes: %d' % i
    meter.label(msg)
    meter.set(i)
    time.sleep(1)
```



27.1.3 Simple Prompts

EasyDialogs also lets you ask the user for information. Use AskString to display a modal dialog to prompt the user for a simple string.

```
import EasyDialogs

response = EasyDialogs.AskString('What is your favorite color?', default='blue')
print 'RESPONSE:', response
```


What is your favorite color?

blue

The return value depends on the user's response. It is either the text they enter:

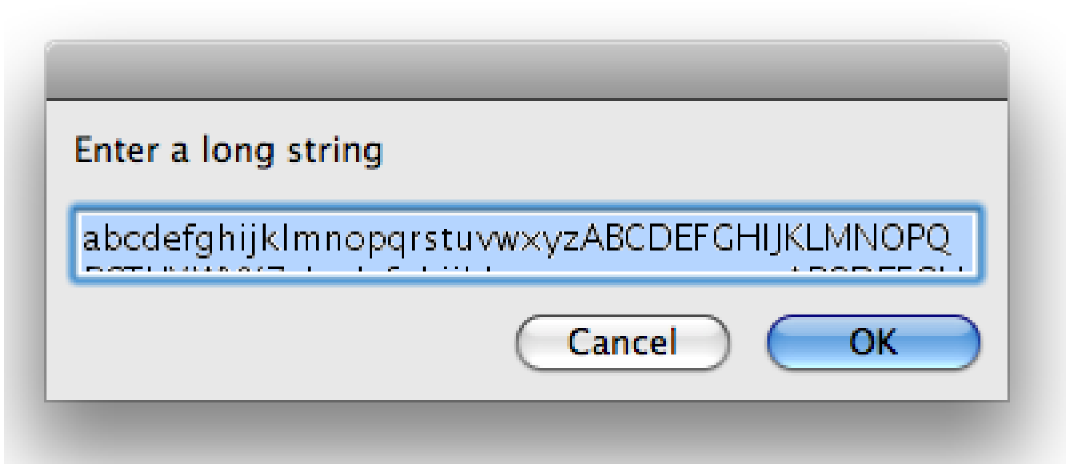
```
$ python EasyDialogs_AskString.py
RESPONSE: blue
```

or None if they press the Cancel button.

```
$ python EasyDialogs_AskString.py
RESPONSE: None
```

The string response has a length limit of 254 characters. If the value entered is longer than that, it is truncated.

```
import EasyDialogs
import string

default = string.ascii_letters * 10
print 'len(default)=', len(default)
response = EasyDialogs.AskString('Enter a long string', default=default)
print 'len(response)=', len(response)
```

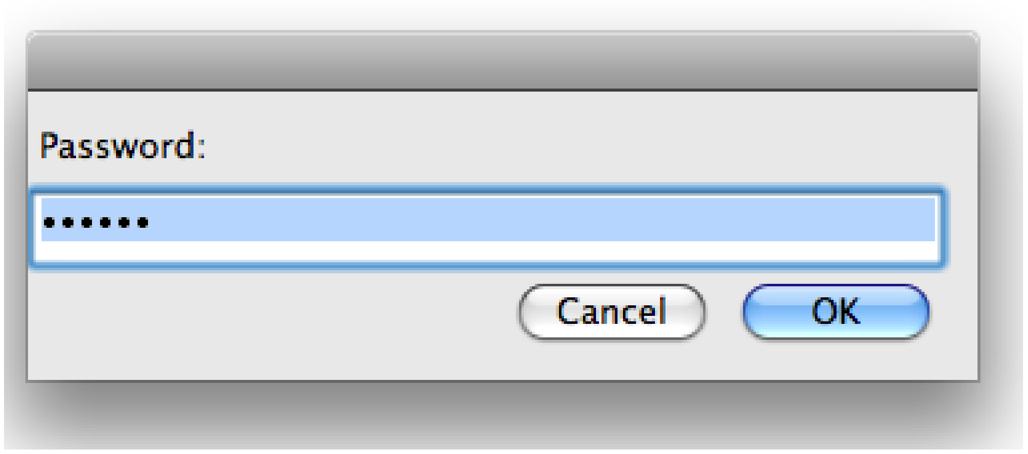


```
$ python EasyDialogs_AskString_too_long.py
len(default)= 520
len(response)= 254
```

27.1.4 Passwords

Use AskPassword to prompt the user for secret values that should not be echoed back to the screen in clear-text.

```
import EasyDialogs

response = EasyDialogs.AskPassword('Password:', default='s3cr3t')
print 'Shh!:', response
```



```
$ python EasyDialogs_AskPassword.py
Shh!: s3cr3t
```

The Ok/Cancel behavior for AskPassword is the same as AskString.

27.1.5 Files and Directories

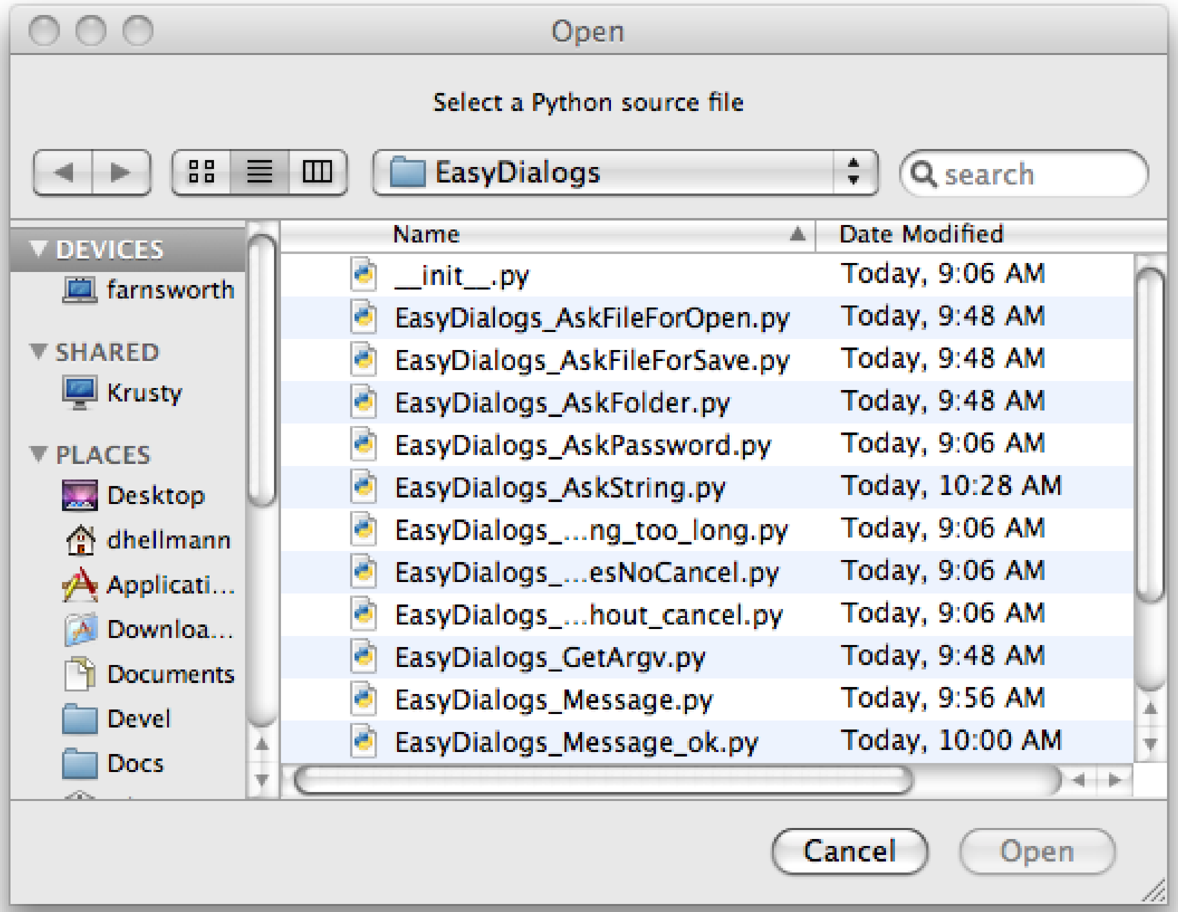
There are special functions for requesting file or directory names. These use the native file selector dialogs, so the user does not have to type in the paths. For example, to ask the user which file to open, use AskFileForOpen.

```
import EasyDialogs
import os

filename = EasyDialogs.AskFileForOpen(
    message='Select a Python source file',
    defaultLocation=os.getcwd(),
    wanted=unicode,
    )

print 'Selected:', filename
```

The wanted=unicode argument tells AskFileForOpen to return the name of the file as a unicode string. The other possible return types include ASCII string, and some Apple data structures for working with file references.

By specifing defaultLocation, this example initializes the dialog to the current working directory. The user is still free to navigate around the filesystem.

Other options to AskFileForOpen let you filter the values displayed, control the type codes of files visible to the user, and interact with the dialog through callbacks. Refer to the module documentation and Apple's reference guide for more details.

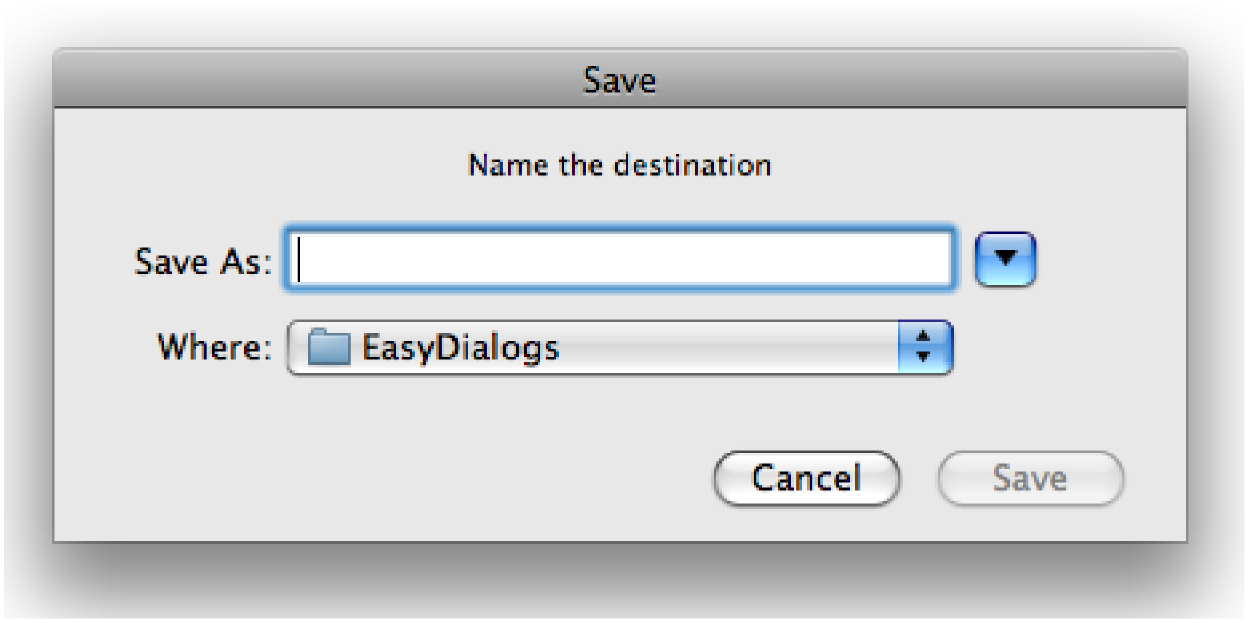


Name	Date Modified
__init__.py	Today, 9:06 AM
EasyDialogs_AskFileForOpen.py	Today, 9:48 AM
EasyDialogs_AskFileForSave.py	Today, 9:48 AM
EasyDialogs_AskFolder.py	Today, 9:48 AM
EasyDialogs_AskPassword.py	Today, 9:06 AM
EasyDialogs_AskString.py	Today, 10:28 AM
EasyDialogs_...ng_too_long.py	Today, 9:06 AM
EasyDialogs_...esNoCancel.py	Today, 9:06 AM
EasyDialogs_...hout_cancel.py	Today, 9:06 AM
EasyDialogs_GetArgv.py	Today, 9:48 AM
EasyDialogs_Message.py	Today, 9:56 AM
EasyDialogs_Message_ok.py	Today, 10:00 AM

```
$ python EasyDialogs_AskFileForOpen.py
Selected: /Users/dhellmann/Documents/PyMOTW/in_progress/EasyDialogs/EasyDialogs_AskFileForOpen.py
```

To prompt the user to provide a new filename when saving a file, use AskFileForSave.

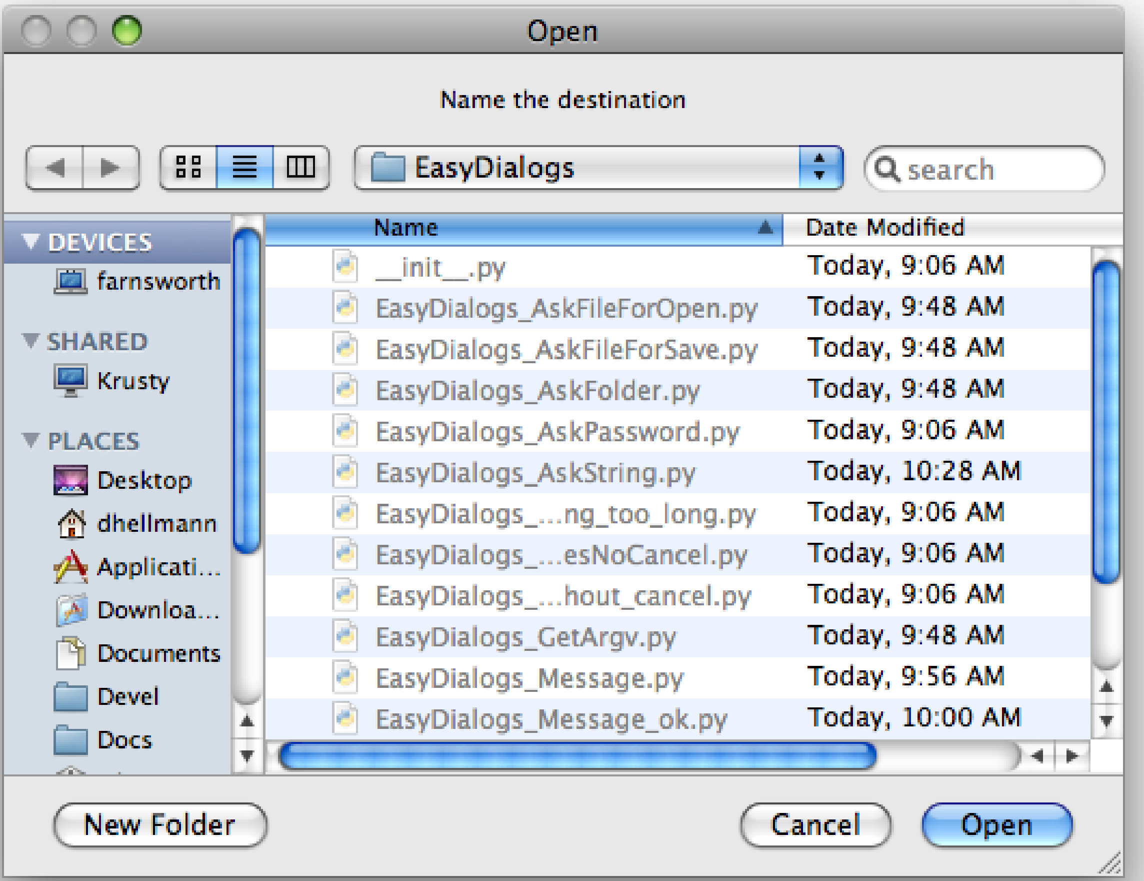
```
import EasyDialogs
import os

filename = EasyDialogs.AskFileForSave(
    message='Name the destination',
    defaultLocation=os.getcwd(),
    wanted=unicode,
    )

print 'Selected:', filename
```



```
$ python EasyDialogs_AskFileForSave.py
Selected: /Users/dhellmann/Documents/PyMOTW/in_progress/EasyDialogs/new_file.py
```

If you need the user to select a directory, existing or new, use AskFolder. The dialog includes a button to let them create a new folder.

```
import EasyDialogs
import os

filename = EasyDialogs.AskFolder(
    message='Name the destination',
    defaultLocation=os.getcwd(),
    wanted=unicode,
    )

print 'Selected:', filename
```



Name	Date Modified
__init__.py	Today, 9:06 AM
EasyDialogs_AskFileForOpen.py	Today, 9:48 AM
EasyDialogs_AskFileForSave.py	Today, 9:48 AM
EasyDialogs_AskFolder.py	Today, 9:48 AM
EasyDialogs_AskPassword.py	Today, 9:06 AM
EasyDialogs_AskString.py	Today, 10:28 AM
EasyDialogs_...ng_too_long.py	Today, 9:06 AM
EasyDialogs_...esNoCancel.py	Today, 9:06 AM
EasyDialogs_...hout_cancel.py	Today, 9:06 AM
EasyDialogs_GetArgv.py	Today, 9:48 AM
EasyDialogs_Message.py	Today, 9:56 AM
EasyDialogs_Message_ok.py	Today, 10:00 AM

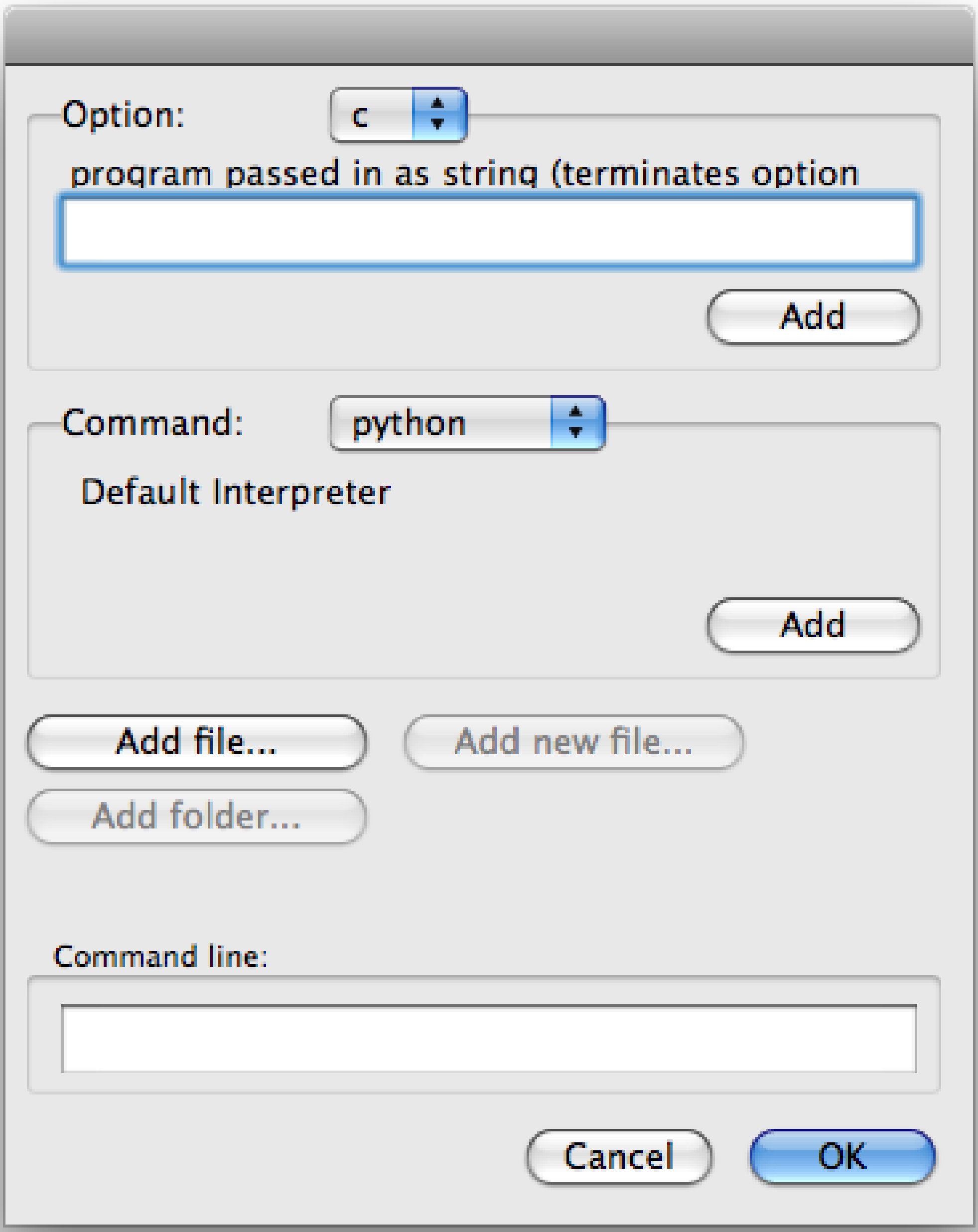
```
$ python EasyDialogs_AskFolder.py
Selected: /Users/dhellmann/Documents/PyMOTW/in_progress/EasyDialogs
```

27.1.6 GetArgv

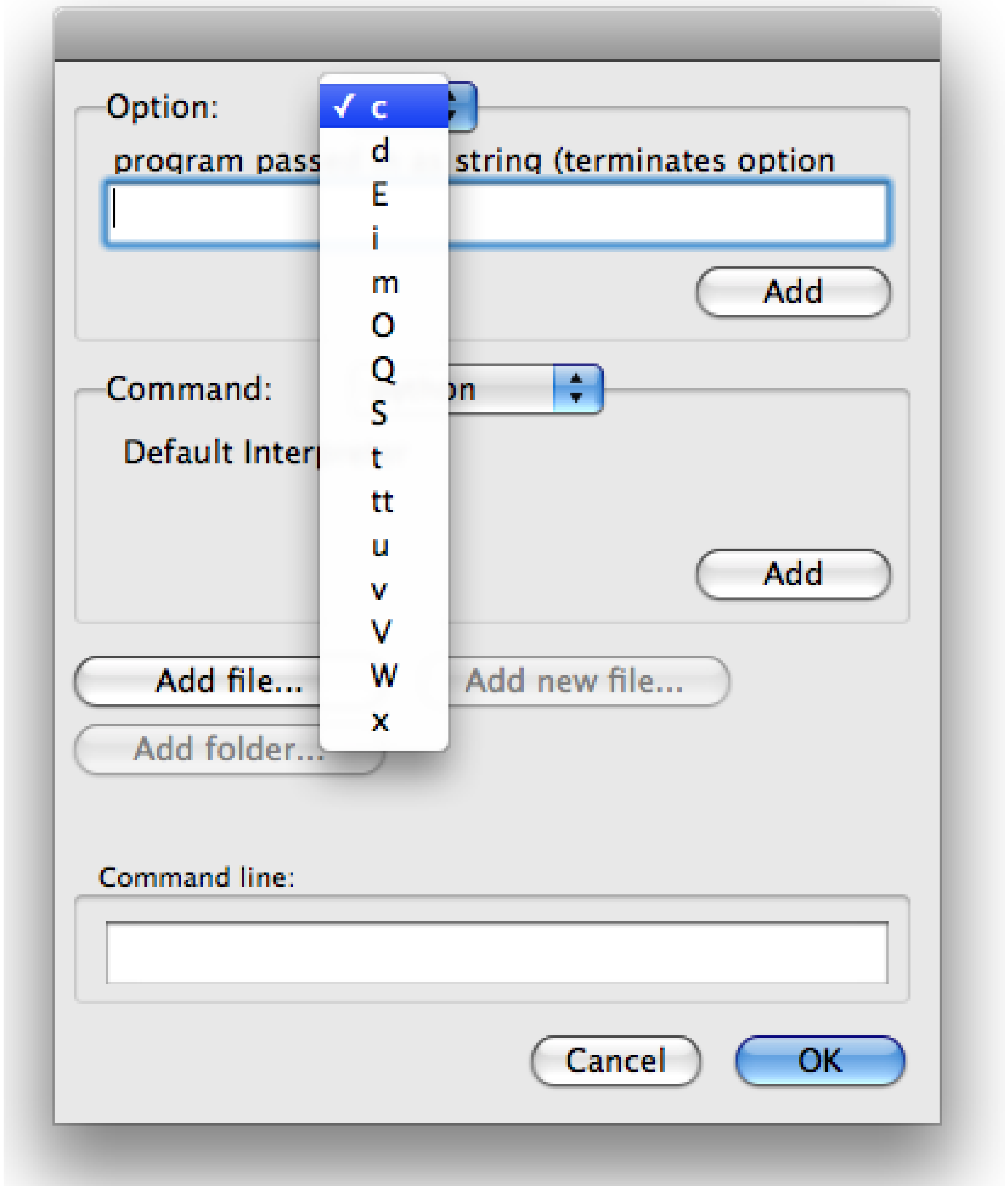
An unusually complex dialog, GetArgv lets the user build a command line string by selecting options from menus. It uses a variation of the getopt syntax to describe the valid options, and returns a list of strings that can be parsed by getopt. In my research this week, I found some scripts that use GetArgv if the user does not specify arguments on the command line.

Let's look at an example that builds a command using the options supported by the Python interpreter.

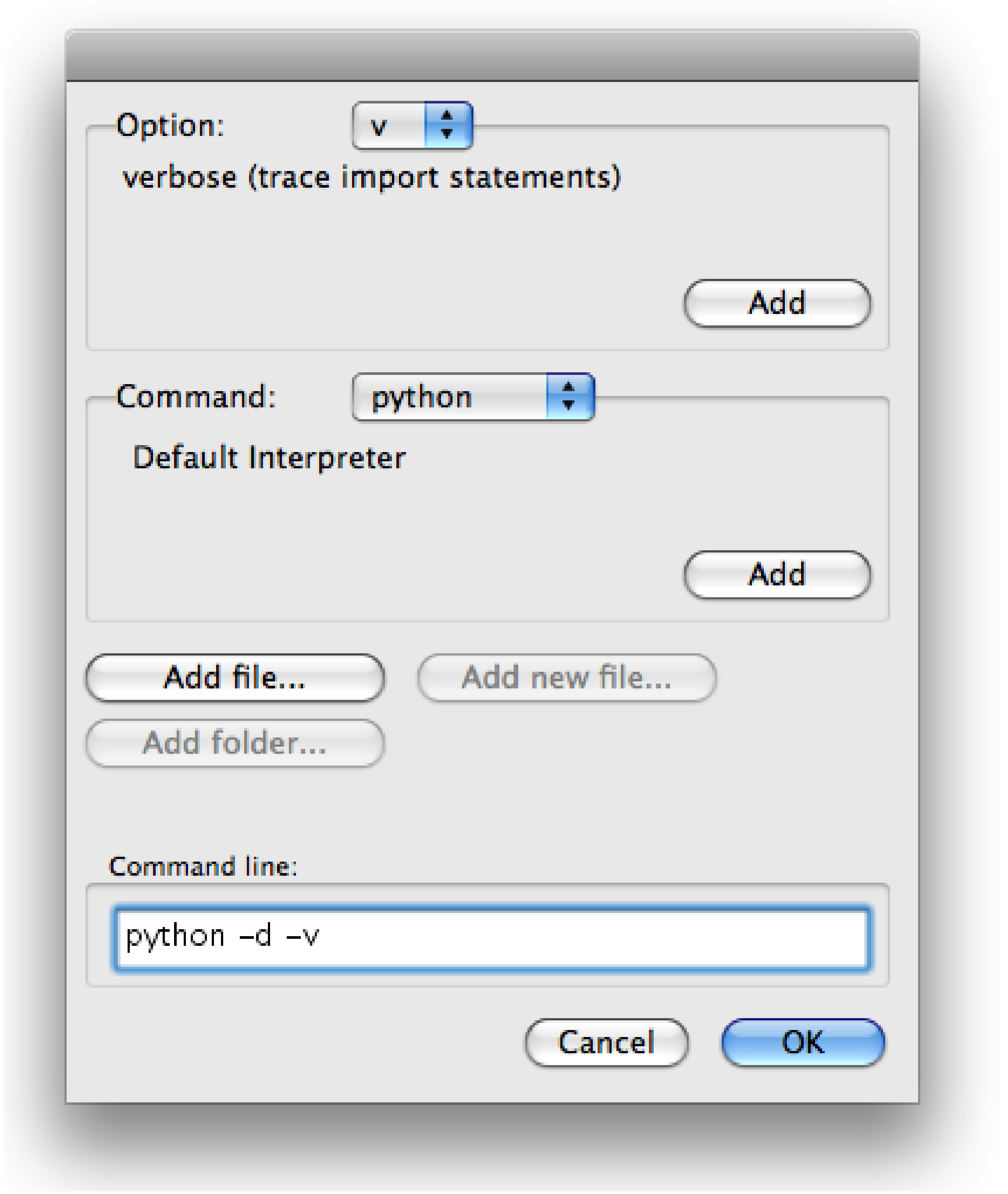
```
import EasyDialogs

arguments = EasyDialogs.GetArgv([
        ('c=', 'program passed in as string (terminates option list)'),
        ('d', 'Debug'),
        ('E', 'Ignore environment variables'),
        ('i', 'Inspect interactively after running'),
        ('m=', 'run library module as a script (terminates option list)'),
        ('O', 'Optimize generated bytecode'),
        ('Q=', 'division options: -Qold (default), -Qwarn, -Qwarnall, -Qnew'),
        ('S', "don't imply 'import site' on initialization"),
        ('t', 'issue warnings about inconsistent tab usage'),
        ('tt', 'issue errors about inconsistent tab usage'),
        ('u', 'unbuffered binary stdout and stderr'),
        ('v', 'verbose (trace import statements)'),
        ('V', 'print the Python version number and exit'),
        ('W=', 'warning control  (arg is action:message:category:module:lineno)'),
        ('x', 'skip first line of source, allowing use of non-Unix forms of #!cmd'),
        ],
        commandlist=[('python', 'Default Interpreter'),
                     ('python2.5', 'Python 2.5'),
                     ('pyhton2.4', 'Python 2.4'),
                     ],
        addoldfile=True,
        addnewfile=False,
        addfolder=False,
        )
print arguments
```



The first argument is a list of tuples containing the option specifier and a text description. The specifier can contain a single letter for simple boolean switches; a letter followed by colon (":") or equals sign ("=") for single letter options that take an argument; several letters for long-form switches ("opt" translates to "–opt"); or several letters followed by colon or equal sign for long options taking an argument. The option description is a string displayed in the dialog.



The dialog is divided into 4 sections. At the top is the list of options you specified. The user can select an option from the list. If the option takes an argument, a text field is displayed so the user can provide a value. The Add button inserts the selected option into the command line field at the bottom of the dialog.

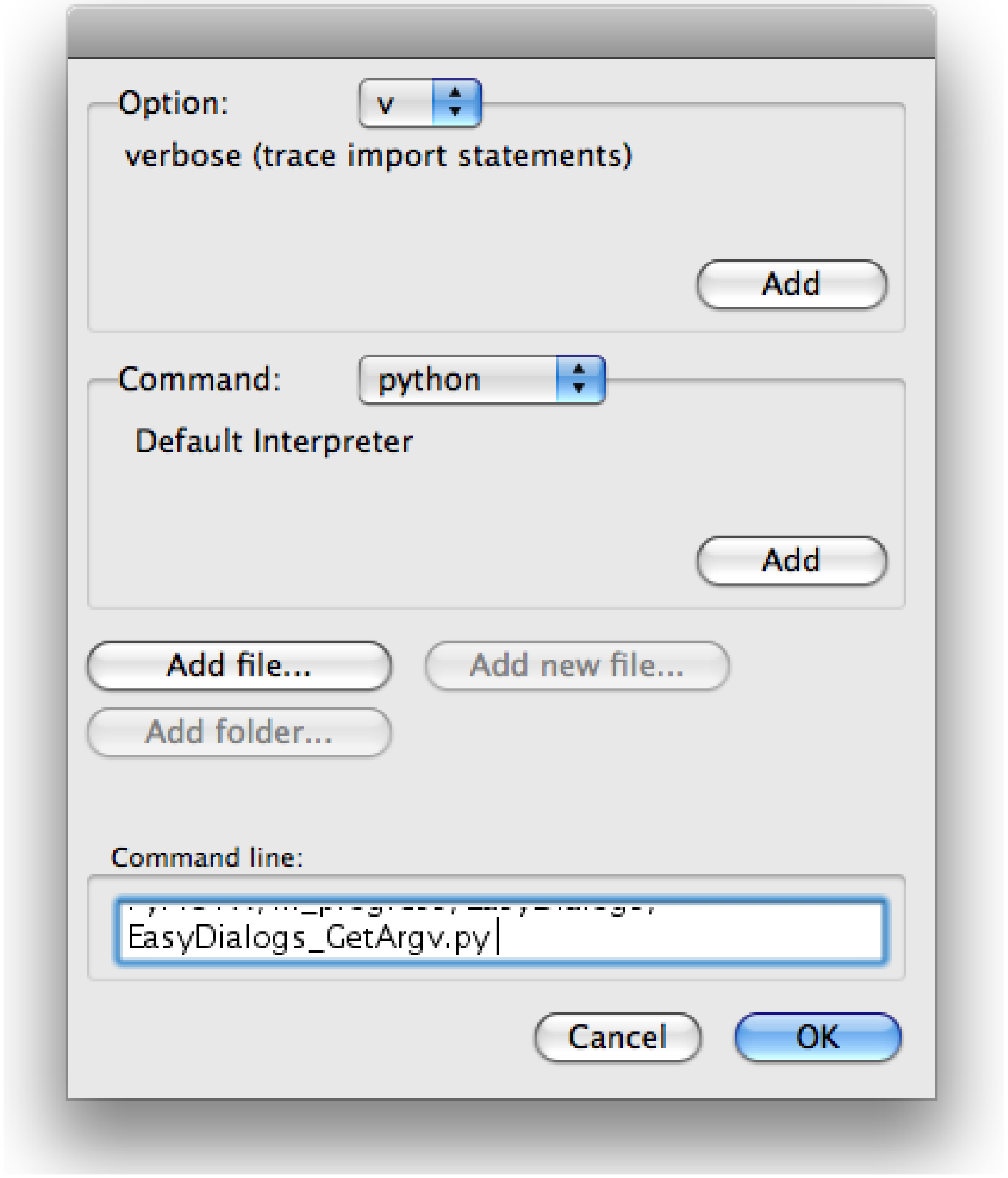


verbose (trace import statements)

Default Interpreter

```
python -d -v
```

The second argument to GetArgv is a list of commands and descriptions. The user can select a command to be included in the argument list from the menu in the middle of the dialog.



The arguments addoldfile, addnewfile, and addfolder control the sensitivity of the buttons in the third section of the dialog. In this example, only the Add file... button is enabled because the Python interpreter does not take directories or missing files as arguments.

At the bottom of the dialog is the command line being constructed by the user. When they press OK, GetArgv returns a list of all of the options that looks like sys.argv.

```
$ python EasyDialogs_GetArgv.py
['python', '-d', '-v', '/Users/dhellmann/Documents/PyMOTW/in_progress/EasyDialogs/EasyDialogs_GetArg
```

See also:

EasyDialogs (http://docs.python.org/library/easydialogs.html) The standard library documentation for this module.

Navigation Services Reference (http://developer.apple.com/documentation/Carbon/Reference/Navigation_Services_Ref/Referen Documentation for Apple's API for working with file objects under Mac OS X.

EasyDialogs for Windows (http://www.averdevelopment.com/python/EasyDialogs.html) A version of this module that runs under Windows.

optparse-gui (http://code.google.com/p/optparse-gui/) A replacement for GetArgv that works with `optparse` instead.

EasyGui (http://easygui.sourceforge.net/) A similar portable library for creating simple graphical user interfaces.

27.2 plistlib – Manipulate OS X property list files

Purpose Read and write OS X property list files

Available In 2.6

`plistlib` provides an interface for working with property list files used under OS X. plist files are typically XML, sometimes compressed. They are used by the operating system and applications to store preferences or other configuration settings. The contents are usually structured as a dictionary containing key value pairs of basic built-in types (unicode strings, integers, dates, etc.). Values can also be nested data structures such as other dictionaries or lists. Binary data, or strings with control characters, can be encoded using the `data` type.

27.2.1 Reading plist Files

OS X applications such as iCal use plist files to store meta-data about objects they manage. For example, iCal stores the definitions of all of your calendars as a series of plist files in the Library directory.

```
<?xml version="1.0" encoding="UTF-8"?>
<!DOCTYPE plist PUBLIC "-//Apple//DTD PLIST 1.0//EN" "http://www.apple.com/DTDs/PropertyList-1.0.dtd
<plist version="1.0">
<dict>
        <key>AlarmFilter</key>
        <true/>
        <key>AlarmsDisabled</key>
        <false/>
        <key>AttachmentFilter</key>
        <true/>
        <key>AutoRefresh</key>
        <true/>
        <key>Checked</key>
        <integer>1</integer>
        <key>Color</key>
        <string>#808000FF</string>
        <key>Enabled</key>
        <true/>
        <key>Key</key>
        <string>4221BCE5-1017-4EE4-B7FF-311A846C600D</string>
        <key>NeedsForcedUpdate</key>
        <false/>
        <key>NeedsRefresh</key>
        <true/>
        <key>Order</key>
        <integer>25</integer>
        <key>RefreshDate</key>
        <date>2009-11-29T16:31:53Z</date>
        <key>RefreshInterval</key>
        <integer>3600</integer>
        <key>SubscriptionTitle</key>
        <string>Athens, GA Weather - By Weather Underground</string>
        <key>SubscriptionURL</key>
        <string>http://ical.wunderground.com/auto/ical/GA/Athens.ics?units=both</string>
        <key>TaskFilter</key>
        <true/>
        <key>Title</key>
        <string>Athens, GA Weather - By Weather Underground</string>
        <key>Type</key>
        <string>Subscription</string>
</dict>
</plist>
```

This sample script finds the calendar defintions, reads them, and prints the titles of any calendars being displayed by iCal (having the property `Checked` set to a true value).

```
import plistlib
import os
import glob

calendar_root = os.path.expanduser('~/Library/Calendars')
calendar_directories = (
    glob.glob(os.path.join(calendar_root, '*.caldav', '*.calendar')) +
    glob.glob(os.path.join(calendar_root, '*.calendar'))
    )

for dirname in calendar_directories:
    info_filename = os.path.join(dirname, 'Info.plist')
    if os.path.isfile(info_filename):
        info = plistlib.readPlist(info_filename)
        if info.get('Checked'):
            print info['Title']
```

The type of the `Checked` property is defined by the plist file, so our script does not need to convert the string to an integer.

```
$ python plistlib_checked_calendars.py
Doug Hellmann
Tasks
Vacation Schedule
EarthSeasons
US Holidays
Athens, GA Weather - By Weather Underground
Birthdays
Georgia Bulldogs Calendar (NCAA Football)
Home
Meetup: Django
Meetup: Python
```

27.2.2 Writing plist Files

If you want to use plist files to save your own settings, use `writePlist()` to serialize the data and write it to the filesystem.

```
import plistlib
import datetime
import tempfile

d = { 'an_int':2,
      'a_bool':False,
      'the_float':5.9,
      'simple_string':'This string has no special characters.',
      'xml_string':'<element attr="value">This string includes XML markup &nbsp;</element>',
      'nested_list':['a', 'b', 'c'],
      'nested_dict':{ 'key':'value' },
      'timestamp':datetime.datetime.now(),
      }

output_file = tempfile.NamedTemporaryFile()
try:
    plistlib.writePlist(d, output_file)
    output_file.seek(0)
    print output_file.read()
finally:
    output_file.close()
```

The first argument is the data structure to write out, and the second is an open file handle or the name of a file.

```
$ python plistlib_write_plist.py

<?xml version="1.0" encoding="UTF-8"?>
<!DOCTYPE plist PUBLIC "-//Apple//DTD PLIST 1.0//EN" "http://www.apple.com/DTDs/PropertyList-1.0.dtd
<plist version="1.0">
<dict>
        <key>a_bool</key>
        <false/>
        <key>an_int</key>
        <integer>2</integer>
        <key>nested_dict</key>
        <dict>
                <key>key</key>
                <string>value</string>
        </dict>
        <key>nested_list</key>
        <array>
                <string>a</string>
                <string>b</string>
                <string>c</string>
        </array>
        <key>simple_string</key>
        <string>This string has no special characters.</string>
        <key>the_float</key>
        <real>5.9</real>
        <key>timestamp</key>
        <date>2013-02-21T06:36:30Z</date>
        <key>xml_string</key>
        <string>&lt;element attr="value"&gt;This string includes XML markup &amp;nbsp;&lt;/element&gt
</dict>
</plist>
```

27.2.3 Binary Property Data

Serializing binary data or strings that may include control characters using a plist is not immune to the typical challenges for an XML format. To work around the issues, plist files can store binary data in base64 format if the object is wrapped with a Data instance.

```
import plistlib

d = { 'binary_data':plistlib.Data('This data has an embedded null. \0'),
      }

print plistlib.writePlistToString(d)
```

This example uses the writePlistToString() to create an in-memory string, instead of writing to a file.

```
$ python plistlib_binary_write.py

<?xml version="1.0" encoding="UTF-8"?>
<!DOCTYPE plist PUBLIC "-//Apple//DTD PLIST 1.0//EN" "http://www.apple.com/DTDs/PropertyList-1.0.dtd
<plist version="1.0">
<dict>
        <key>binary_data</key>
        <data>
        VGhpcyBkYXRhIGhhcyBhbiBlbWJlZGRlZCBudWxsLiAA
        </data>
</dict>
</plist>
```

Binary data is automatically converted to a Data instance when read.

```
import plistlib
import pprint

DATA = """<?xml version="1.0" encoding="UTF-8"?>
<!DOCTYPE plist PUBLIC "-//Apple Computer//DTD PLIST 1.0//EN" "http://www.apple.com/DTDs/PropertyList
<plist version="1.0">
<dict>
        <key>binary_data</key>
        <data>
        VGhpcyBkYXRhIGhhcyBhbiBlbWJlZGRlZCBudWxsLiAA
        </data>
</dict>
</plist>
"""

d = plistlib.readPlistFromString(DATA)

print repr(d['binary_data'].data)
```

The data attribute of the object contains the decoded data.

```
$ python plistlib_binary_read.py

'This data has an embedded null. \x00'
```

See also:

plistlib (http://docs.python.org/library/plistlib.html) The standard library documentation for this module.

plist manual page (http://developer.apple.com/documentation/Darwin/Reference/ManPages/man5/plist.5.html)
Documentation of the plist file format.

Weather Underground (http://www.wunderground.com/) Free weather information, including ICS and RSS feeds.

Convert plist between XML and Binary formats (http://www.macosxhints.com/article.php?story=20050430105126392)
Some plist files are stored in a binary format instead of XML because the binary format is faster to parse using Apple's libraries. Python's plistlib module does not handle the binary format, so you may need to convert binary files to XML using `plutil` before reading them.

Using Python for System Administration (http://docs.google.com/present/view?id=0AW0cyKASCypUZGczODJ6YjdfMjRobW1
Presentation from Nigel Kersten and Chris Adams, including details of using PyObjC to load plists using the native Cocoa API, which transparently handles both the XML and binary formats. See slice 27, especially.

CHAPTER TWENTYEIGHT

HISTORY

Development

- Merge in fixes to the `select` module examples from Michael Schurter.

1.132

- 24 Oct 2010, rewrite `ConfigParser`

1.131

- 17 Oct 2010, `sqlite3`
- Updates to `xml.etree.ElementTree`
- Updates to `resource`
- Updates to `subprocess`
- Updates to `sys`
- Re-generate `platform` example output on more modern systems.
- Updates to `threading`
- Updates to `dircache`

1.130

- 10 Oct 2010, `random`
- Updates to `contextlib`.
- Updates to `logging`.
- Updates to `mmap`.
- Added more details about dialects to `csv`.
- Updates to `difflib`.
- Updates to `multiprocessing`.
- Updates to `optparse`.
- Updates to `pkgutil`.

1.129

- 3 Oct 2010, `select`

1.128.1

- 29 Sept 2010, Corrected the `OrderedDict` equality example.

1.128

- 28 Sept 2010, Updated `collections` to add `OrderedDict` and `Counter`, as well as the *rename* argument to `namedtuple`.

1.127

- 26 Sept 2010, `socket`

1.126

- 19 Sept 2010, `sysconfig`

1.125

- 12 Sept 2010, `pdb`

1.124.1

- 9 Sept 2010, Updated packaging to fix installation errors.

1.124

- 5 Sept 2010, `re`

1.123

- 29 Aug 2010, `codecs`

1.122

- 22 Aug 2010, `math`

1.121

- 15 Aug 2010, `doctest`

1.120

- 8 Aug 2010, `argparse`

1.119

- 11 July 2010, `gc`

1.118.1

- Updates to `locale`

1.118

- Roberto Pauletto's Italian translation has moved to http://robyp.x10hosting.com/
- 27 June 2010, `site`

1.117a

- Added LifoQueue and PriorityQueue examples to `Queue`.
- Completed an editing pass of the entire document, tweaking wording and formatting.

1.117

- Updated `fileinput` example to use `xml.etree.ElementTree`. Added an example to show how to get the filename and line number being processed.

1.116

- 21 Mar 2010, *Creating XML Documents*

- Fixed example in *Abstract Properties* so both the setter and getter work. Thanks to Rune Hansen for pointing out the error in the original version.

1.115

- 14 Mar 2010, *Parsing XML Documents*

1.114

- 7 Mar 2010, `tabnanny`

1.113

- 30 Jan 2010, `cgitb`
- Added reference to presentation about using PyObjC to read/write binary plist files to `plist`.

1.112

- 29 Nov 2009, `plistlib`

1.111.1

- Clarify memory example based on comment from tartley.
- Fix core dump detection in commands_getstatusoutput.py. Thanks to Felix Labrecque for pointing out that it was wrong.

1.111

- 23 Nov 2009, `sys`, continued with *Modules and Imports*

1.110

- 15 Nov 2009, `sys`, continued with *Low-level Thread Support*

1.109

- 8 Nov 2009, `sys`, continued with *Tracing a Program As It Runs*

1.108

- 1 Nov 2009, `sys`, continued with *Exception Handling*

1.107

- 25 Oct 2009, `sys`, continued with *Memory Management and Limits*

1.106

- 18 Oct 2009, `sys`, continued with *Runtime Environment*

1.105

- 12 Oct 2009, `sys` started with *Interpreter Settings*

1.104

- 20 Sept 2009, `resource`

1.103

- 5 Sept 2009, `fractions`

1.102

- 30 Aug 2009, `decimal`

1.101

- 23 Aug 2009, `dis`

1.100

- 9 Aug 2009, `pydoc`
- Add pipes example to `subprocess`.
- Add circular reference example to `pickle`.
- Use the Sphinx text builder to create clean plaintext files for use with motw command line app.
- Use `pydoc` `pager()` to show plaintext help from *motw-cli*.
- Add built-in function `motw()` so that importing PyMOTW into your interactive session makes it easy to get to the examples interactively. See *motw-interactive*.

1.99

- 2 Aug 2009, Add *In-Memory Data Structures* article.

1.98

- Added link to Roberto Pauletto's Italian translation.
- 27 July 2009, Add *Text Processing Tools* article.

1.97

- 19 July 2009, `urllib2`

1.96

- 12 July 2009, *File Access*

1.95

- 5 July 2009, `abc`
- Rearrange packaging to install the HTML files.
- Add `motw` command line app to show PyMOTW article on a given module, similar to pydoc.

1.94

- Moved `run_script()` from pavement.py to sphinxcontrib-paverutils (http://pypi.python.org/pypi/sphinxcontrib-paverutils) 1.1.
- 28 June 2009, `pyclbr`

1.93

- 21 Jun 2009, `robotparser`

1.92

- 14 June 2009, `gettext`
- Added Windows info to `platform`, courtesy of Scott Lyons.
- Added process group example to `subprocess`, courtesy of Scott Leerssen.

1.91

- Add *Data Persistence and Exchange* article.
- Correct link to library table of contents on python.org from about page. Thanks to Tetsuya Morimoto for pointing out the broken link.
- Add information about Tetsuya Morimoto's Japanese translation.
- Add link to jsonpickle on `json` article, courtesy of Sebastien Binet.

- Add time-stamps to HTML output
- Remove extraneous javascript file from web html template to avoid 404 errors

1.90

- 24 May 2009, `json`
- updated daemon process examples in `multiprocessing`

1.89

- 28 April 2009, `multiprocessing` (part 2, communication and MapReduce example)

1.88

- 19 April 2009, `multiprocessing` (part 1, basic usage)
- Upgraded to Python 2.6.2.
- Add options to blog command in pavement.py to let the user specify alternate input and output file names for the blog HTML.
- Added namedtuple example to `collections`.

1.87.1

- Added dialect example to `csv` to show how to parse files with `|`-delimited fields.

1.87

- 5 Apr 2009, `pipes`
- Converted PEP links to use `pep` role.
- Converted RFC references to use `rfc` role.
- Updated examples in `warnings` and `string` to work with changes in Python 2.6.1.

1.86.1

- Updated working environment to use Paver 1.0b1.
- Corrected errors in `*.rst` files identified by update to new version of Paver that doesn't let cog errors slide.
- Added ignore_error option to run_script() in pavement.py so scripts with errors I'm expecting can be quietly ignored.
- Finished converting all articles to use cog, where appropriate.

1.86

- 14 Mar 2009, `asynchat`
- Move to bitbucket.org for DVCS hosting
- Updated description of `uuid4()` in `uuid` based on feedback via O'Reilly blog comment.

1.85

- 1 Mar 2009, `asyncore`
- Continue converting older articles to use cog.
- Fix subprocess examples so they work if the permissions on the "child" scripts haven't been changed from the default way they are installed.

1.84

- 22 Feb 2009, `tarfile`
- Updated DictWriter example in `csv` based on feedback from Trilok Khairnar.
- Cleaned up use of cog in a few older modules

1.83

- 15 Feb 2009, `grp`
- Continue converting older articles to use cog.

1.82

- 8 Feb 2009, `pwd`
- Fix `set_unixfrom()` examples in `mailbox` article based on feedback from Tom Lynn.
- Add this history section

1.81

- 18 Jan 2009, `compileall`

1.80

- 4 Jan 2009, `bz2`

1.79

- 28 Dec 2008, `zlib`.

1.78.1

- Updated `gzip` examples to avoid using built-in names for local variables.

1.78

- 7 Dec 2008, `gzip`.

1.77

- 30 Nov 2008, `readline` and `rlcompleter`

1.76

- 9 Nov 2008, `array`

1.75

- 2 Nov 2008, `struct`.

1.74.1

- Update formatting of several modules to make them more consistent.

1.74

- 19 Oct 2008, `smtpd`.

1.73

- 12 Oct 2008, `trace`

1.72

- 5 Oct 2008, `smtplib`

1.71

- 26 Sept 2008, `mailbox`

1.70.4

- Update formatting of several modules and fix the examples on the `difflib` page.

1.70.3

- 21 Sept 2008 `imaplib`

1.70.2

- 21 Sept 2008 `imaplib`

1.70.1

- 21 Sept 2008 `imaplib` (markup fixed).

1.70

- 21 Sept 2008, `imaplib`.

1.69

- 14 Sept 2008, `anydbm` and related modules.

1.68

- Sept 12, 2008, `exceptions`

1.67.1

- minor changes to accommodate site redesign

1.67

- 31 Aug 2008, overing `profile`, `cProfile`, and `pstats`.

1.66.1

- Fix a logic bug in the code that prints the currently registered signals.

1.66

- 17 Aug 2008, `signal`

1.65

- 10 Aug 2008, adding Sphinx-generated documentation all of the modules covered so far.

1.64

- 3 Aug 2008 `webbrowser`

1.63

- 27 July 2008, `uuid`

1.62

- 20 July 2008 `base64`.

1.61

- 6 July 2008, `xmlrpclib`.

1.60

- 29 June 2008, `SimpleXMLRPCServer`

1.59

- 22 June 2008, `warnings`

1.58

- 15 June 2008, `platform`

1.57

- 8 June 2008, `dircache`.

1.56

- 1 June 2008, `Cookie`

1.55

- 25 May 2008, `contextlib`

1.54

- 18 May 2008, `traceback`.

1.53

- 11 May 2008, `heapq`.

1.52

- 4 May 2008, `cmd`.

1.51

- 27 Apr 2008, `functools`.

1.50

- 20 Apr 2008, `filecmp`.

1.49

- 13 April 2008, `fnmatch`.

1.48

- 4 April 2008, `operator`.

1.47

- 30 March 2008, `urllib`.

1.46

- 23 March 2008, `collections`.

1.45

- PyCon 2008 edition for 16 Mar 2008, `datetime`.

1.44

- 9 Mar 2008, `time`

1.43

- 2 March 2008, `EasyDialogs`.

1.42

- 24 Feb 2008 `imp`.

1.41

- 17 Feb 2008, `pkgutil`.

1.40

- 10 Feb 2008, `tempfile`.

1.39

- 3 Feb 2008, `string`.

1.38

- 26 Jan 2008, `os.path`.

1.37

- 19 Jan 2008, `hashlib`.

1.36

- 13 Jan 2008, `threading`

1.35

- 6 Jan 2008, `weakref`.

1.34

- 30 Dec 2007, `mmap`.

1.33.1

- Correction for release 1.33 for 22 Dec 2007 the `zipimport` module.

1.33

- 22 Dec 2007, `zipimport`.

1.32

- 16 Dec 2007 `zipfile`.

1.31

- 9 Dec 2007, `BaseHTTPServer`

1.30

- Dec 2, 2007 `SocketServer`

1.29

- Nov 25, 2007 `inspect`.

1.28

- Nov 15, 2007 `urlparse`

1.27

- 10 Nov 2007, `pprint`

1.26

- 4 Nov 2007, `shutils`

1.25

- 28 Oct 2007, `commands`

1.24

- 20 Oct 2007, `itertools`

1.23

- Added another `difflib` example based on comments on that post.

1.22

- 14 Oct 2007, `shlex`.

1.21

- 7 Oct 2007, `difflib`.

1.20

- 30 Sept 2007, `copy`

1.19

- 25 Sept 2007, `sched`

1.18

- 20 September 2007, `timeit`

1.17

- 12 Sept 2007, `hmac`

1.16

- 3 Sept 2007, `unittest`

1.15

- 27 Aug, 2007 `optparse`.

1.14

- 20 Aug 2007, `csv`

1.13

- 12 Aug 2007, `getopt`.

1.12

- August 5, 2007, `shelve`

1.11

- July 30, 2007, `glob`

1.10

- July 22, 2007, `calendar`

1.9

- July 15, 2007, `getpass`

1.8

- July 8, 2007, `atexit`

1.7

- July 1, 2007, `subprocess`

1.6

- June 24, 2007, `pickle`

1.5

- June 17, 2007, wrapping up the `os` module.

1.4

- June 10, 2007, `os` module files and directories.

1.3

- June 3, 2007, continuing coverage of `os`

1.2

- May 27, 2007, `os`

1.1

- May 20, 2007, `locale`

1.0

- First packaged release, includes `fileinput`, `ConfigParser`, `Queue`, `StringIO`, `textwrap`, `linecache`, `bisect`, and `logging`.