COMS 3101-3 Programming Languages – Python: Lecture 4

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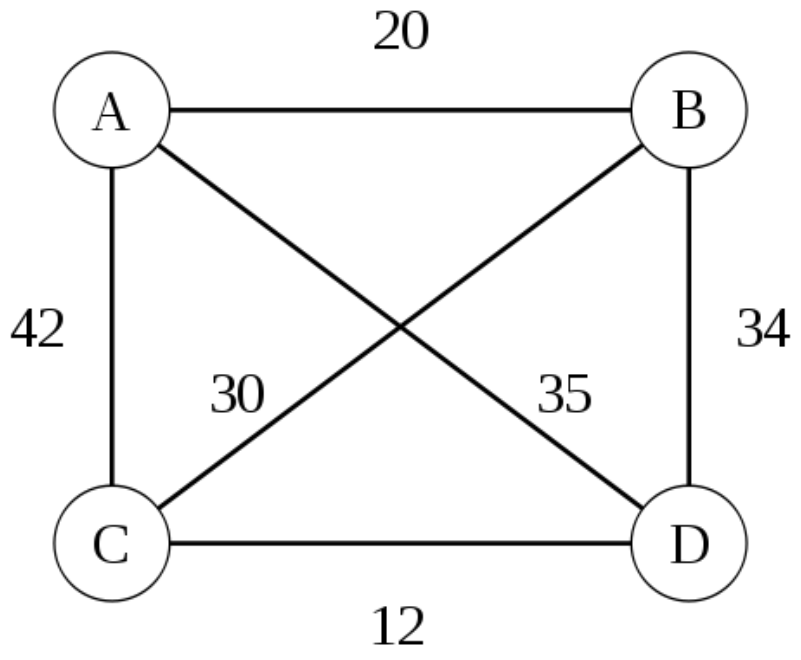
Review

- Advanced functions
  - Map / reduce / filter
- Class
  - Custom type definition
  - Big thing
- Modules and Packages

Assignment 3

- Part3 typo -- fixed
- Part4
  - Advanced sorting (will cover today)
  - Traveling Salesman problem (TSP)



Agenda

- Class Re-cap
- Exception
- Sorting
- Standard Library
  - os
  - sys
  - collection
  - pickle
  - urllib2

CLASS REVIEW

Class Review

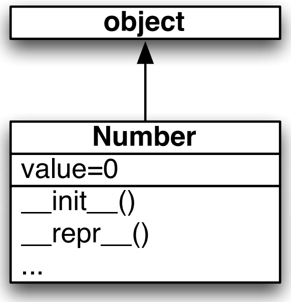
- Support user-defined/custom type
- Blueprint that describes how to build objects
  - Class is an object too
- <u>Objects</u>: instantiated grouping of states(attributes) and behaviors(methods)
- <u>Method</u>: functions associated to the object and can access and manipulate the object's states
- <u>Attributes</u>: data fields of the object for state maintenance

Custom Integer Definition

```
class Number(object):
    def __init__(self, value=0):
        self.value = value

    def __repr__(self):
        return str(self.value)

    def __str__(self):
        return str(self.value)
```



- Class *Number*
  - constructor with single parameter (default = 0)
  - Two special methods overriden

Custom Integer Definition

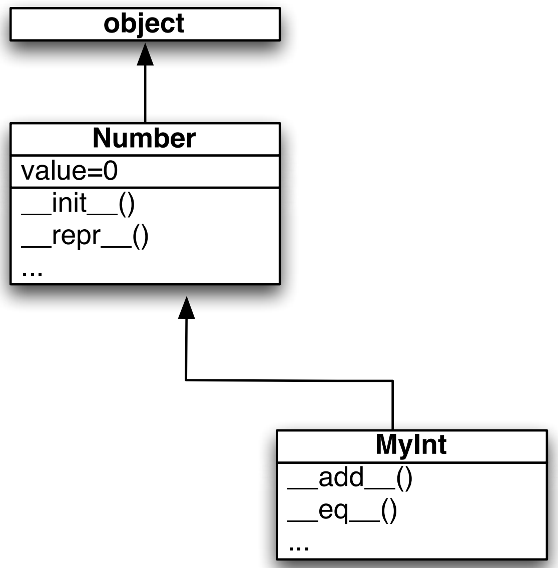
```
class Number(object):
    def __init__(self, value=0):
        self.value = value

    def __repr__(self):
        return str(self.value)

    def __str__(self):
        return str(self.value)
```

```
class MyInt(Number):
    def __add__(self, other):
        return MyInt(self.value + other.value)
    ...
    def __div__(self, other):
        return MyInt(self.value / other.value)

    def __eq__(self, other):
        return self.value == other.value
```



- Single inheritance
  - arithmetic and comparator methods are overridden

Custom Integer Definition

```
class Number(object):
    def __init__(self, value=0):
        self.value = value

    def __repr__(self):
        return str(self.value)

    def __str__(self):
        return str(self.value)
```

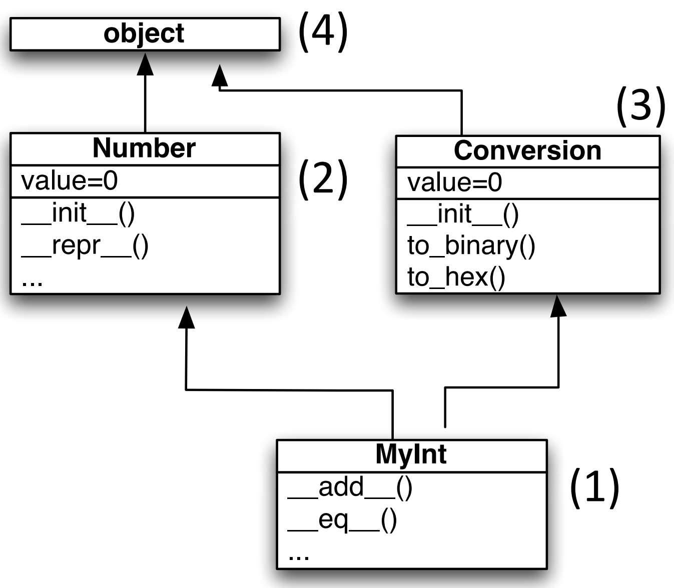
```
class Conversion(object):
    def __init__(self, value=0):
        self.value = value

    def to_binary(self):
        return bin(self.value)

    def to_hex(self):
        return hex(self.value)
```

```
class MyInt(Number):
    def __add__(self, other):
        return MyInt(self.value + other.value)
    ...
    def __div__(self, other):
        return MyInt(self.value / other.value)

    def __eq__(self, other):
        return self.value == other.value
```



- Multiple inheritance
  - Duplicate constructors: __init__()
  - Method resolution order(MRO) applied

EXCEPTIONS

What happens?
if you do something stupid

Example 1: KeyError

```
>>> city2addr={}
>>> city2addr['New York'].append(addr)
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
KeyError: 'New York'
```

Example 2: IndexError

```
>>> lst = range(10)
>>> lst[100]
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
IndexError: list index out of range
```

- Python complains about runtime errors
  - By raising errors (Exceptions)
- Exceptions are objects
  - Built-in exceptions
  - Custom exceptions

Two Error Handling Approaches

- Check before Operation

```
def reverse_seq0(seq):
    if (len(seq)):
        print seq.pop(),
        reverse_seq0(seq)
    else:
        return
```

- Operation first, then handle errors

```
def reverse_seq1(seq):
    try:
        print seq.pop(),
        reverse_seq1(seq)
    except IndexError:
        return
```

- Reverse sequence data type
  - Need to check for empty sequence

Programs are Error Prone

- Syntax errors ← Detected by interpreter
- Incorrect programming behavior(wrong result) ← Testing (later)

  ex) `def hypotenuse(x, y): return` $x^2 - y^2$
- Errors at runtime ← Exception handling
  - `NameError`: referring undefined variables
  - `TypeError`: operations not supported by type (class)
  - `NumericError`: division by zero
  - `IOError`: file not found, cannot write to file …
  - …

Exceptions

- Exception = “Message” object that indicates an error or anomalous condition
- When an error is detected, Python raises an exception
- Exception is propagated through the call hierarchy
- If the exception is not handled and arrives at the top-level:
  - Program terminates
  - Error message and traceback report is printed

Example Error and Traceback

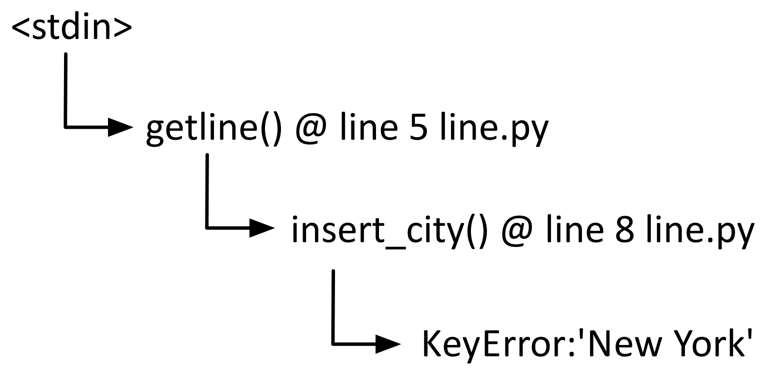
line.py

```
1 citydict={}
2
3 def getline(input):
4   entries = input.split(",")
5   city entries[7]
6   insert_city(city, entries)
7
8 def insert_city(city, entries):
9     citydict[city].append(entries)
```

```
>>> getline(" ... ,New York, ... ")
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
  File "line.py", line 5, in getline
    insert_city(entries[7], entries)
  File "line.py", line 8, in insert_city
    citydict[city].append(entires)
KeyError: 'New York'
```

- `Traceback` contains the path took through the call hierarchy
- Includes module name, function name and line numbers

<Call Hierarchy>



try ... except (1)

- If an error occurs in the block indented below try
  - Execution is interrupted at the point of error
  - Optional except block is executed if exception has the right type
  - Execution is resumed after try ... except block

```
citydict={}

def getline(input):
    entries = input.split()
    city = entries[7]
    try:
        insert_city(city, entries)
    except KeyError, ke:
        print ('caught error', ke)
        citydict[city] = [entries]

def insert_city(city, entries):
    citydict[city].append(entries)
```

```
>>> getline(line)
('caught error', KeyError('New York',))
>>> citydict
{'New York': [['0', '1', '2', '3', '4',
'5', '6', '7', '8', '9']]}
```

try ... except (2)

```
try:
    x = bar(a)
except TypeError:     # Binding the exception
                      # object is optional
    print('caught Type error.')
except ZeroDivisionError , ex:
    print('caught div0 error.')
```

can use multiple except block for different types

```
try:
    x = bar(a)
except (TypeError , ZeroDivisionError):
    print('caught either a type or a div0 error.')
```

can use tuple of exception types

```
try:
    x = bar(a)
except:
    print('caught every exception.')
```

catch all exceptions (use sparingly)

try ...except ... else

- Optional `else` block is run only if `try` block terminates normally
  - When none of `except` blocks are visited
- Avoids unintentionally handling exceptions that occur in the else block

```
try:
    x = bar(a)
    y = 72 / x
except ZeroDivisionError:
    print('caught a div0 error from bar.')
```

Does not distinguish which line causes the error

```
try:
    x = bar(a)
except ZeroDivisionError:
    print('caught a div0 error from bar.')
else:
    try:
        y = 72 / x    # can cause a different
                      # div0 error!
    except ZeroDivisionError:
        print('caught another div0 error.')
```

Handled from different try ... except block

`try ...except ... finally`

- `finally` block is executed no matter what!
  - When the `try` block terminates normally
  - When an exception is caught
  - Even if `break, return, continue` is called or another exception is raised
    - Right place to have clean-up statements

```
def foo(x):
    try:
        y = x[0]
        return y
    except IndexError:
        return 0
    finally:
        print("Done.")
```

```
>>> foo([])
Done.
0
>>> foo([42])
Done.
42
>>> foo(42)
Done.
...
TypeError: 'int' object is
unsubscriptable
```

Raising Exceptions

- Exceptions can be raised if internal errors occur
- Exceptions can be initiated explicitly with `raise`

```
    raise Exception_class, string_message
```

`string_message` is passed to `Exception_class.__init__()`

```
x = raw_input()
if x == "yes":
    foo ()
elif x == "no":
    bar ()
else:
    raise ValueError , \
                    "Expected either 'yes' or 'no'."
```

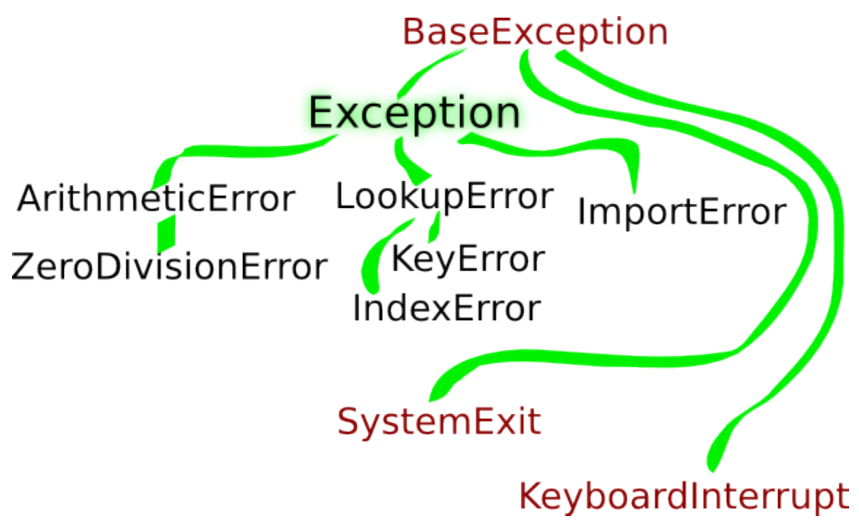
Passing on Exceptions

- Can pass on Exceptions through the call hierarchy after partially handling them

```
def foo(x):
    try:
        y = x[0]
        return y
    except IndexError:
        print("Foo: index 0 did not exist.")
        print("Let someone else deal with it.")
        raise # Re-raise exception
```

Built-in and Custom Exceptions

- List of built-in exceptions: http://docs.python.org/library/exceptions.html
- Can write/define your own exceptions:
  - Exceptions are classes
  - Subclass any of the defined Exceptions (try to be as specific as possible)



```
class EmptyListException(IndexException):
    """ An Exception that indicates that we found an
        empty list.
    """

def foo(x):
    try:
        y = x[0]
        return y
    except EmptyListException , ex:
        sys.stderr.write("Argument list cannot be empty.\n")
        return None
```

Using Exceptions Properly

- Write exception handlers only if you know how to handle the exception
  - i.e., it's easy to back-off or the exception is normal behavior
- Except specific exception classes
  - rather than general ones such as Exception or StandardError (can mask unexpected errors)
- Raise informative exceptions rather than just terminating the program
- Can use exception for control flow (Recall break, continue)
  - From some other languages, this is regarded as a bad practice (Java)

Easier to Ask for Forgiveness than for Permission (EAFP)

```
def reverse_seq1(seq):
    try:
        print seq.pop(),
        reverse_seq1(seq)
    except IndexError:
        return
```

SORTING

Examples are courtesy of Google python tutorial

sorting for `list`

- `list` supports `sort()` method implements stable sort <u>IN-PLACE</u>

```
L.sort(cmp=None, key=None, reverse=False)
```

```
>>> a = [5, 1, 4, 3]
>>> a.sort()
>>> a
[1, 3, 4, 5]
>>> a.sort(reverse=True)
>>> a
[5, 4, 3, 1]
>>> help(a.sort)
```

- You can implement custom sorting by providing comparison function to `key` or `cmp` parameter
  - `cmp` parameter is deprecated

Sorting with `sorted()`

- `sorted()`: takes a sequence data type and returns a new sequence with those elements in sorted order

```
sorted(iterable, cmp=None, key=None, reverse=False)
```

```
>>> a = [5, 1, 4, 3]
>>> b = sorted(a)
>>> a
[5, 1, 4, 3]
>>> b
[1, 3, 4, 5]
```

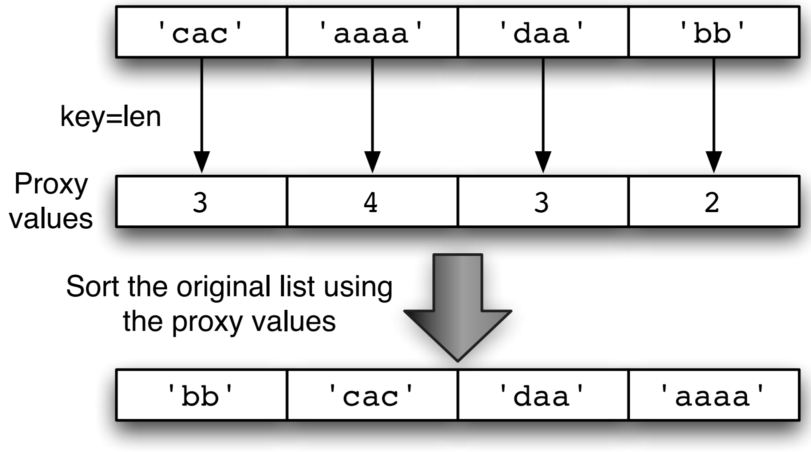
Custom Sorting with key=

- Specify key function for more sophisticated sorting
  - key function take one input return one output

    ex) built-in function len()

```
>>> len
<built-in function len>
```

```
>>> strs = ['cac', 'aaaa', 'daa', 'bb']
>>> print sorted(strs, key=len)
['bb', 'cac', 'daa', 'aaaa']
```

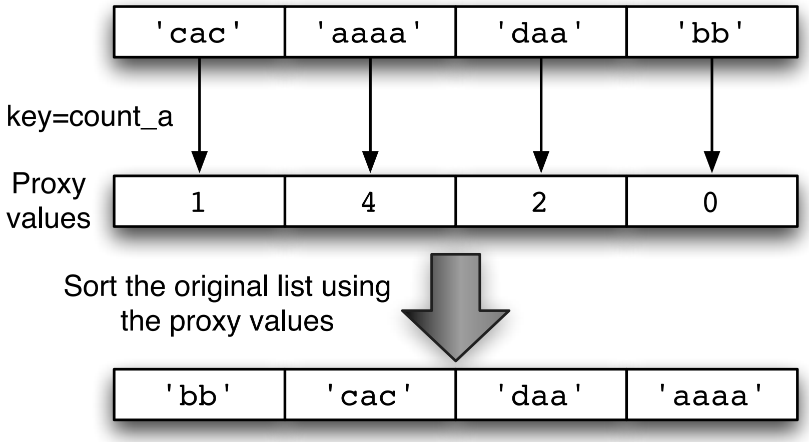


Custom Sorting with key=

- count_a(x) counts the occurrence of 'a' from strings
  - You can generalize functions

```
def count_a(x):
    return x.count('a')
```

```
>>> strs = ['cac', 'aaaa', 'daa', 'bb']
>>> print sorted(strs, key=count_a)
['bb', 'cac', 'daa', 'aaaa']
```



Quiz

- Dictionary data structure
  - grading {name: grade}
  - sort keys by its values

```
>>> grading = {'Kangkook': 59, 'Ethan': 80, 'John': 77, \
               'George': 89, 'Kontaxis': 75}
```

- **Defining a *key* function**

```
>>> def get_value(key):
>>>     return grading[key]

>>> sorted(grading, key=get_value)
['Kangkook', 'Kontaxis', 'John', 'Ethan', 'George’]
```

- **Using *dict.get()* method**

```
>>> sorted(grading, key=grading.get)
['Kangkook', 'Kontaxis', 'John', 'Ethan', 'George’]
```

STANDARD LIBRARY

Standard Library

- So far: structure of the programming language itself
- Python comes with a *'battery included'* philosophy
  - A lot of built-in functionalities
  - Large standard library modules
- Will cover some import / representative modules
- See docs for more

  http://docs.python.org/library/index.html

Some Important Modules (1)

- General Purpose:
  - **sys: Access runtime environment**
  - **collections: More container data-types**
  - itertools: fancy iterators
  - time: Time access and conversions
  - **math: Mathematical functions**
  - subprocess: Spawn child process
- Strings
  - **re: Regular expressions**
- File I/O
  - **os: interact with the operating system**
  - **os.path: pathname operation / browse FS**
  - **csv: read/write comma separated value(CSV) file**
  - shutil: High level file operation
- GUI
  - TKinter: built-in GUI

Some Important Modules (1)

- Internet / Networking
  - **urllib2: Open / access resource by URL**
  - smtplib: email processing
  - **SimpleHTTPServer: simple http request handler**
  - **xmlrpclib: XML-RPC client**
- Debugging / Profiling
  - **logger: built-in logging**
  - **pdb: Python debugger**
  - trace: Trace statement execution
- Development
  - **Pydoc: Document generator and online help system**
  - **unittest: Python unit testing framework**

sys

System(i.e. Python interpreter)-specific parameter and functions

sys Module: IO Stream File Objects

- `sys.stdin`: terminal input
- `sys.stdout`: terminal output
- `sys.stderr`: error stream
  - By default stderr is printed to terminal as well
  - In UNIX/Linux/Mac: can ‘redirect’ different streams to files

sys_inout.py

```
import sys
if __name__=="__main__":
    input = sys.stdin.read()
    sys.stdout.write("stdout: " + input)
    sys.stderr.write("stderr: " + input)
```

```
jikk$ python sys_inout.py
abcd
stdout: abcd
stderr: abcd
jikk$ python sys_inout.py > /tmp/stdout 2> /tmp/stderr
abcd
```

sys Module: path

- `sys.path`: a list of directory locations that determines where Python searches for modules
  - Environment variable **PYTHONPATH** is appended to default path

```
jikk$ export PYTHONPATH="$PYTHONPATH:/Users/jikk/project/”
jikk$ python
Python 2.6.8 (unknown, Jul 31 2012, 14:17:35)
[GCC 4.2.1 Compatible Apple Clang 4.0 ((tags/Apple/clang-421.0.57))]
on darwin
Type "help", "copyright", "credits" or "license" for more
information.
>>> import sys
>>> sys.path
[’’, ’/Library/Python/2.7/site-packages’, ’/Users/jikk/project/’]
```

sys Module: Command Line Arguments

- `sys.argv` is a list of containing command line arguments
  - `sys.argv[0]` is the name of the script
  - all other elements are arguments passed to the script
  - arguments are passed as *string*

test_args.py

```
import sys
if __name__ == "__main__":
    print sys.argv
```

```
jikk$ python test_args.py arg0 arg1
['test_args.py', 'arg0', 'arg1']
```

os

python interface to OS operations

File Operation with ‘os’

- ‘os’ module defines interfaces that enable interactions with operating systems
  - Most frequently used component of standard library
  - Implements majority subset of OS system call API

```
>>> import os
>>> os.system('date')  # OS specific command
Wed Sep 9 22:16:59 EDT 2013
0
```

- ‘os.path’ sub-module defines interfaces for filename manipulation

```
>>> os.path.isdir("/tmp")  # some folder
True
```

os.path Module – manipulate pathnames

- `os.path.abspath(path)`: Returns the absolute pathname for a relative path

```
>>> os.path.abspath('python')
'/opt/local/bin/python'
```

- `os.path.basename(path)`: Returns the absolute pathname for a relative path

```
>>> os.path.basepath('/opt/local/bin/python’)
‘python'
```

- `os.path.getsize(path)`: Returns the size of path in byte

```
>>> os.path.getsize("python")
13404
```

- `os.path.isfile(path)`: Returns True if the path points to a file
- `os.path.isdir(path)`: Returns True if the path points to a directory

os Module – list, walk content of a directory

- `os.listdir(path)` lists files in a directory

```
>>> os.listdir("/tmp")
['.font-unix', '.ICE-unix', ... , android-jikk']
```

- `os.walk(path)` returns generator object
  traverse sub-directories in depth-first fashion

```
>>> w = os.walk('/tmp')
>>> loc = w.next()
>>> while w:
...     print loc
...     loc = w.next()
```

collections

High-Performance Container Datatypes

collections.defaultdict

- A dictionary class that automatically supplies default values for missing keys
- Is initialized with a factory object, that create
  - can be a function or a class object
  - can be a basic type (`list, set, dict, int` initializes to default value)

Counter using `dict`

```
def count_seq(seq):
    seq_dict = {}
    for ent in seq:
        if ent in seq_dict:
            seq_dict[ent] += 1
        else:
            seq_dict[ent] = 1
    return seq_dict

>>> count_chr('sdfs')
{'s': 2, 'd': 1, 'f': 1}
```

Counter using `defaultdict`

```
from collections import defaultdict

def count_seq0(seq):
  seq_dict = defaultdict(int)
  for ent in seq:
    seq_dict[ent] += 1
  return seq_dict

>>> count_chr('sdfs')
defaultdict(<type 'int'>, {'s': 2,
'd': 1, 'f': 1})
```

`collections.Counter`

- Easy interface to count hashable(immutable) objects in collections (often strings)
- Once created, they are dictionaries mapping each object to its count
- Support method `most_common(n)`
- Can be updated with other counters or dictionaries

```
>>> from collections import Counter
>>> c = Counter('banana')
>>> c
Counter({'a': 3, 'n': 2, 'b': 1})
>>> c.most_common(2)
[('a', 3), ('n', 2)]
>>> c.update({'b':1})
>>> c
Counter({'a': 3, 'b': 2, 'n': 2})
>>> c['b']
2
```

pickle

Object serialization / Data persistence

Pickle: Object Serialization

- Provide a convenient way to store Python objects in file and reload them
- Allows saving/reloading program data or transferring them over a network
- Can pickle almost everything
  - All standard data types
  - User defined functions, classes and instances
  - Works on complete object hierarchies
  - Classes need to be defined when un-pickling

```
import pickle
f = open('zip2addr.pickle','w')
pickle.dump(zip2addr, f)
f.close()
```

```
f = open('zip2addr.pickle','r')
zip2addr = pickle.load(f)
f.close()
```

Pickle: Protocols and cPickle

- Normally pickle uses a plaintext ASCII protocol
- Newer protocols available
  - 0: ASCII protocol
  - 1: old binary format (backward compatible)
  - 2: new protocol (≧ Python 2.3, more efficient)
- More efficient reimplementation of Pickle in native C
  - Always use this for large object hierarchies (up to 1000x faster)

```
import cPickle as pickle
f = open('zip2addr.pickle','wb')
zip2addr = pickle.dump(zip2addr, f, protocol=2)
f.close()
```

urllib2

Open / Access resource by URL

urllib2: Fetch URLs

- URL: uniform resource locator
  - Support various Internet protocols: http, ftp, file …
- urllib2 enables
  - fetch internet resources located by URL
  - Interface to modify request headers

```
#URL for file
file://localhost/Users/jikk/jikk_web/index.html

#URL for HTTP
http://www.cs.columbia.edu/~jikk/index.html

#URL for ftp
ftp://user:password@host:port/path
```

urllib2: Getting Contents

- urllib2.Request()
  - returns URL request object that you are making
  - Can specify extra information(meta) associated to the request ex) browser type, cookie …
- urllib2.urlopen()
  - Open connection to the host and return response object

```
#basic usage
import urllib2
req = urllib2.Request("http://www.columbia.edu")
content = urllib2.urlopen(req)
lines = content.readlines()
for line in lines:
    print line
```

urllib2: Download files

- URL response operates as file object
  - Can write its contents to another file object
- `shutil` module provides easier interfaces to manipulate files

```
#downloading large binary file
req = urllib2.urlopen("ftp://ftp.sec.gov/edgar/xbrldata.zip")
output = open("output.zip", "wb")

CHUNK_SIZE=1024
buf = req.read(CHUNK_SIZE)
len(buf)
while len(buf):
    output.write(buf)
    buf = req.read(CHUNK_SIZE)

#copying file using shell utilities(shutil)
import shutil
req = urllib2.urlopen("ftp://ftp.sec.gov/edgar/xbrldata.zip")
output = open("output1.zip", "wb")
shutil.copyfileobj(req, output)
```