Programming in Python

Part #1

Who is using it?

- Google (various projects)
- NASA (several projects)
- NYSE (one of only three languages "on the floor")
- Industrial Light & Magic (everything)
- Yahoo! (Yahoo mail & groups)
- RealNetworks (function and load testing)
- RedHat (Linux installation tools)
- LLNL, Fermilab (steering scientific applications)
- Zope Corporation (content management)
- ObjectDomain (embedded Jython in UML tool)
- Alice project at CMU (accessible 3D graphics)
- More success stories at *www.pythonology.com*

Language properties

- Everything is an object
- Packages, modules, classes, functions
- Exception handling
- Dynamic typing, polymorphism
- Static scoping
- Operator overloading
- Indentation for block structure
    - Otherwise conventional syntax

High-level data types

- Numbers: int, long, float, complex
- Strings
- Lists and dictionaries: containers
- Other types for e.g. binary data, regular expressions
- Extension modules can define new “built-in” data types

Interfaces to...

- XML
  - DOM, expat
  - XMLRPC, SOAP, Web Services
- Relational databases
  - MySQL, PostgreSQL, Oracle , ODBC, Sybase, Informix
- Java (via Jython)
- Objective C
- COM, DCOM (.NET too)
- Many GUI libraries
  - cross-platform
    - Tk, wxWindows, GTK, Qt
  - platform-specific
    - MFC, Mac (classic, Cocoa), X11

Compared to Perl

- Easier to learn
  - very important for infrequent users
- More readable code
- More maintainable code
- Fewer “magical” side effects
- More “safety” guarantees
- Better Java integration

Compared to Java

- Code up to 5 times shorter
  - and more readable
- Dynamic typing
- Multiple inheritance, operator overloading
- Quicker development
  - no compilation phase
  - less typing
- Yes, it may run a bit slower
  - but development is much faster
  - and Python uses less memory (studies show)

Similar (but more so) for C/C++

Jython

- Seamless integration with Java
- Separate implementation
- Implements the same language
- Different set of standard modules
- differences in “gray areas”
  - e.g. some different calls
  - different command line options, etc.

Jython's Java integration

- Interactive
- Compiles directly to Java bytecode
- Import Java classes directly
- Subclass Java classes
  - pass instances back to Java
- Java beans integration
- Can compile into Java class files

Basic Python Tutorial

- shell (introduces numbers, strings, variables)
- lists (arrays), dictionaries (hashes), tuples
- variable semantics
- control structures, functions
- classes & methods
- standard library:
  - files: open(), readline(), read(), readlines(), write(), close(), flush(), seek(), tell(), open() again
  - os, os.path, sys, string, UserDict, StringIO, getopt

Interactive “Shell”

- Great for learning the language
- Great for experimenting with the library
- Great for testing your own modules

- Type statements or expressions at prompt:

```
>>> print "Hello, world"
Hello, world
>>> x = 12**2
>>> x/2
72
>>> # this is a comment
```

Python is Interactive

```
>>> 2**16
65536
>>> 2**20
1048576
>>>import string
>>> string.find("abc", "c")
2
```

Python cares about indentation

```
>>> if isAlpha("a"):
...         print "a character!"
... else:
...         print "not a character!"
...
a character!
>>>
```

Python is case-sensitive, dynamically typed…

```
>>> len("test")
4
>>> LEN("test")
NameError: name 'LEN' is not defined
>>> len("test")>1000
0
>>> len("test")<1000
1
>>> len
<built-in function len>
```

Define functions with def

```
def isAlpha(ch):
    return (len(ch)==1) and \
    (string.find(string.letters,ch)>=0)
def dumpWords(self):
        """
        dumps words and word frequencies
        """
        for word in self.wordList:
            print word,\
                self.dictionary[word]
```

In Python “everything is an object”

- As we saw, including functions

`Type(1)` -> <type int>

`Dir(1)` -> … list of functions on **int**s

Python has good data type support for …

- None -- the ‘null’ value
- Ints
- Float
- Strings (`import string`)
- Lists (AI likes lists…)
- Tuples (non-mutable lists)
- Functions
- Dictionaries (hash tables, AI likes these)

Numbers

- The usual notations and operators
  - 12, 3.14, 0xFF, 0377, (-1+2)*3/4**5, abs(x), 0<x<=5
- C-style shifting & masking
  - 1<<16, x&0xff, x|1, ~x, x^y
- Integer division truncates
  - 1/2 -> 0   # float(1)/2 -> 0.5
- Long (arbitrary precision), complex
  - 2L**100 -> 1267650600228229401496703205376L
  - 1j**2 -> (-1+0j)

Strings

- "hello"+"world" "helloworld" # concatenation
- "hello"*3 "hellohellohello" # repetition
- "hello"[0] "h" # indexing
- "hello"[-1] "o" # (from end)
- "hello"[1:4] "ell" # slicing
- len("hello") 5 # size
- "hello" < "jello" 1 # comparison
- "e" in "hello" 1 # search
- "escapes: \n etc, \033 etc, \xff etc"
- 'single quotes' '''triple quotes''' r"raw strings"

Python lists

```
>>> a=[1,2,3]
>>> b=[a,a,a]
>>> a
[1, 2, 3]
>>> b
[[1, 2, 3], [1, 2, 3], [1, 2, 3]]
>>> a.append(4)
>>> a
[1, 2, 3, 4]
```

Python lists

```
a = [99, "bottles of beer", ["on", "the", "wall"]]
```

- Flexible arrays, *not* Lisp-like linked lists
- Same operators as for strings

```
a+b, a*3, a[0], a[-1], a[1:], len(a)
```

- Item and slice assignment

```
a[0] = 98
a[1:2] = ["bottles", "of", "beer"]
    -> [98, "bottles", "of", "beer", ["on", "the", "wall"]]
del a[-1]          # -> [98, "bottles", "of", "beer"]
```

More list operations

```
>>> a = range(5)                # [0,1,2,3,4]
>>> a.append(5)                 # [0,1,2,3,4,5]
>>> a.pop()                     # [0,1,2,3,4]
5
>>> a.insert(0, 5.5)            # [5.5,0,1,2,3,4]
>>> a.pop(0)                    # [0,1,2,3,4]
5.5
>>> a.reverse()         # [4,3,2,1,0]
>>> a.sort()                    # [0,1,2,3,4]
```

Python dictionaries

```
>>> d={}
>>> d['test'] = 1
>>> d['test']
1
>>> d[3]=100
>>> d[4]
KeyError: 4
>>> d.get(4,0)
0
```

Dictionaries – Hash Tables

- Hash tables, "associative arrays"

```
d = {"duck": "eend", "water": "water"}
```

- Lookup:

```
d["duck"] -> "eend"
d["back"]            # raises KeyError exception
```

- Delete, overwrite :

```
del d["water"]                # {"duck": "eend", "back": "rug"}
d["duck"] = "duik"            # {"duck": "duik", "back": "rug"}
```

More dictionary operations

- Keys, values, items:

```
d.keys() -> ["duck", "back"]
d.values() -> ["duik", "rug"]
d.items() -> [("duck","duik"), ("back","rug")]
```

- Presence check:

```
d.has_key("duck") -> 1; d.has_key("spam") -> 0
```

- Values of any type; keys almost any

```
{"name":"Guido", "age":43, ("hello","world"):1,
    42:"yes", "flag": ["red","white","blue"]}
```

Dictionary details

- Keys must be **immutable**:
  - numbers and strings of immutables
    - these cannot be changed after creation
  - reason is *hashing* (fast lookup technique)
  - **not** lists or other dictionaries
    - these types of objects can be changed "in place"
  - no restrictions on values
- Keys will be listed in **arbitrary order**
  - again, because of hashing

Python Tuples

- Look (sorta) like Scheme/Lisp lists for syntax
- But can’t be changed

```
>>> a=(1,2,3)

>>> a.append(4)

AttributeError: 'tuple' object has no attribute
   'append’
```

Python Tuples

- key = (lastname, firstname)
- point = x, y, z   # parent's optional
- x, y, z = point
- lastname = key[0]
- singleton = (1,)   # trailing comma!
- empty = ()   # parentheses!
- tuples vs. lists; tuples immutable

Variables

- No need to declare
- Need to assign (initialize)
    - use of un-initialized variable raises exception
- Not typed

```
if friendly: greeting = "hello world"
else: greeting = 12**2
print greeting
```

- ***Everything*** is a variable:
    - functions, modules, classes

Reference semantics

- Assignment manipulates references

  x = y **does not make a copy** of y

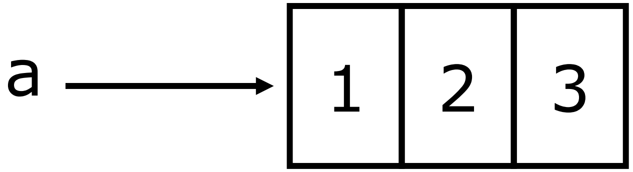
  x = y makes x **reference** the object y references

- Very useful; but beware!
- Example:

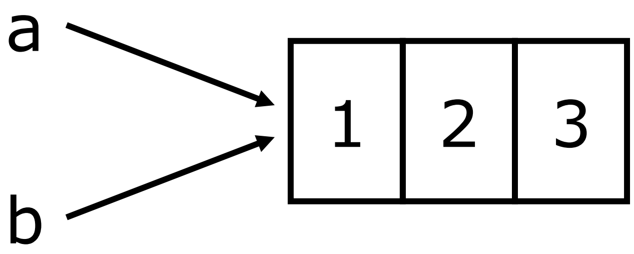
  ```
  >>> a = [1, 2, 3]; b = a
  >>> a.append(4); print b
  [1, 2, 3, 4]
  ```

Changing a shared list

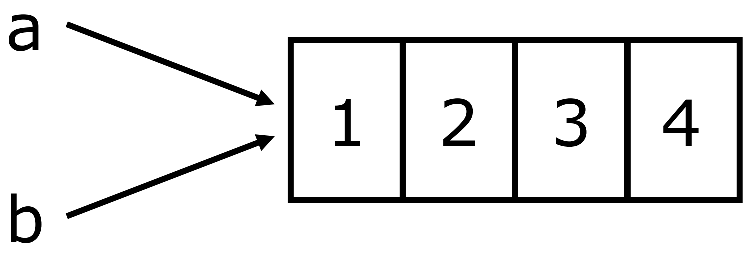
```
a = [1, 2, 3]
```



```
b = a
```



```
a.append(4)
```

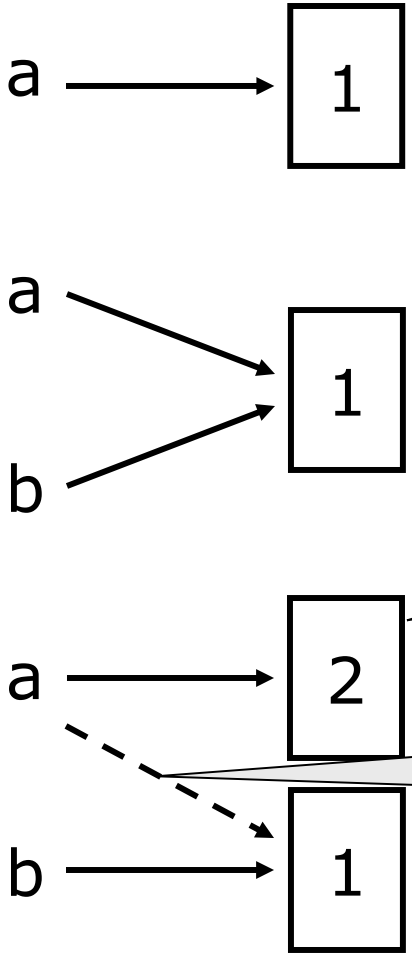


Changing an integer

```
a = 1

b = a

a = a+1
```



new int object created by add operator (1+1)

old reference deleted by assignment (a=...)

Control structures

```
if condition:
    statements
[elif condition:
    statements] ...
[else:
    statements]
```

```
while condition:
    statements

for var in sequence:
    statements

break
continue
```

Grouping indentation

- Python:

```
for i in range(20):
    if i%3 == 0:
        print i
        if i%5 == 0:
            print "Bingo!"
    print "---"
```

- C:

```
for (i = 0; i < 20; i++)
{
    if (i%3 == 0) {
        printf("%d\n", i);
        if (i%5 == 0) {
            printf("Bingo!\n"); }
      }
      printf("---\n");
}
```

```
0
Bingo!
---
---
---
3
---
---
---
6
---
---
---
9
---
---
---
12
---
---
---
15
Bingo!
---
---
---
18
---
---
```

Functions, procedures

```
def name(arg1, arg2, ...):
    "documentation"             # optional
    statements

return                    # from procedure
return expression         # from function
```

Example function

```
def gcd(a, b):
    "greatest common divisor"
    while a != 0:
        a, b = b%a, a                  # parallel assignment
    return b

>>> gcd.__doc__
'greatest common divisor'
>>> gcd(12, 20)
4
```

Classes

```
class name:
    "documentation"
    statements
```

-or-

```
class name(baseclass1, baseclass2, ...):
    ...
```

Typically, *statements* contains method definitions:

```
    def name(self, arg1, arg2, ...):
        ...
```

May also contain *class variable* assignments

You can define classes with class

- The class system changed in Python 2.2, be sure to use the “new style classes,” which inherit from **object**

```
>>> class foo(object):
...        pass
>>> a = foo()
>>> type(a)
<class '__main__.foo'>
```

Creating classes - walk thru

```
class Integer(object):
    """ example class """ # doc string
    # note use of self variable:
    def __init__(self,ivalue): # special name
        self.__ivalue=ivalue # field names
    def getIntValue(self): # read accessor
        return self.__ivalue
    def setIntValue(self,ivalue): #write accessor
        self.__ivalue=ivalue
    # set up attribute
    intValue=property(getIntValue,setIntValue)
```

Example class

```
class Stack:
    "A well-known data structure…"
    def __init__(self):             # constructor
        self.items = []
    def push(self, x):
        self.items.append(x)                # the sky is the limit
    def pop(self):
        x = self.items[-1]                  # what happens if it’s empty?
        del self.items[-1]
        return x
    def empty(self):
        return len(self.items) == 0         # Boolean result
```

Using classes

```
>>> x=Integer(1000)
>>> x.getIntValue()
1000
>>> x.setIntValue(10)
>>> x.intValue
10
>>> x.intValue=500
>>> x.intValue
500
```

Using classes

- To create an instance, simply call the class object:

```
x = Stack()
```

- To use methods of the instance, call using dot notation:

```
x.empty()                               # -> 1
x.push(1)                               # [1]
x.empty()            # -> 0
x.push("hello")               # [1, "hello"]
x.pop()              # -> "hello"       # [1]
```

- To inspect instance variables, use dot notation:

```
x.items                                 # -> [1]
```

Subclassing

```
class FancyStack(Stack):
    "stack with added ability to inspect inferior stack items"

    def peek(self, n):
        "peek(0) returns top; peek(-1) returns item below
    that; etc."
        size = len(self.items)
        assert 0 <= n < size            # test precondition
        return self.items[size-1-n]
```

Subclassing

```
class LimitedStack(FancyStack):
    "fancy stack with limit on stack size"

    def __init__(self, limit):
        self.limit = limit
        FancyStack.__init__(self)                # base class
    constructor

    def push(self, x):
        assert len(self.items) < self.limit
        FancyStack.push(self, x)                 # "super" method call
```

Class & instance variables

```
class Connection:
    verbose = 0                                     # class variable
    def __init__(self, host):
        self.host = host                            # instance variable
    def debug(self, v):
        self.verbose = v                            # make instance variable!
    def connect(self):
        if self.verbose:                            # class or instance
    variable?
            print "connecting to", self.host
```

Modules

- Collection of stuff in *foo*.py file
  - functions, classes, variables
- Importing modules:
  - import string; print string.join(L)
  - from string import join; print join(L)
- Rename after import:
  - import string; s = string; del string

Packages

- Collection of modules in directory
- Must have __init__.py file
- May contain subpackages
- Import syntax:
  - from P.Q.M import foo; print foo()
  - from P.Q import M; print M.foo()
  - import P.Q.M; print P.Q.M.foo()

Catching Exceptions

```
try:
    print 1/x
except ZeroDivisionError, message:
    print "Can’t divide by zero:"
    print message
```

Try-Finally: Cleanup

```
f = open(file)
try:
    process_file(f)
finally:
    f.close()        # always executed
print "OK"                     # executed on success only
```

Raising Exceptions

- raise IndexError
- raise IndexError("k out of range")
- raise IndexError, "k out of range”

-
  ```
  try:
      something
  except:             # catch everything
      print "Oops"
      raise           # reraise
  ```

End of Lecture