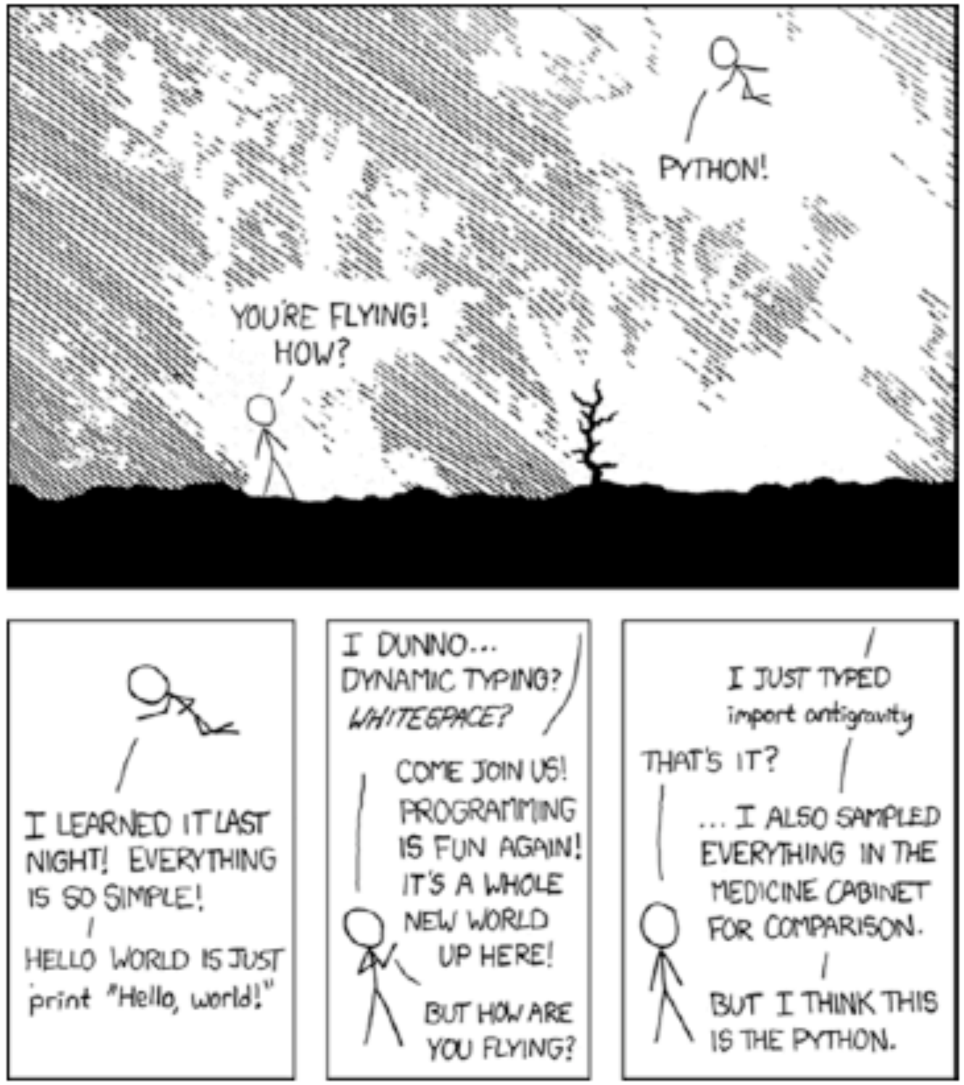
CS3101.3 Python: Lecture 4



source: http://xkcd.com/353/

Last week

- Regular expressions
- Functional programming tools
- Generators
- File handing w/ the os module

This week

- Project guidelines
- Object oriented Python
- Exceptions
- Libraries part I

Course project

Project Proposal

- One page document describing
  - Problem statement / motivation
  - Expected input / output
  - Relevant libraries
  - Anticipated challenges / difficulties
- Timetable
  - Proposal due by the start of next class
  - Final project due by Tues March 2^{nd}
  - Live demo: must be scheduled via Doodle that same week (instructions to follow)
- Demo
  - 10 minute live demo, end to end run
  - If you need special hardware I can meet on campus
- See me if I can help you brainstorm ideas

Previous projects

- Genetic algorithms
- Solar system simulation in MAYA
- Music recommendations via mining Last.fm
- Financial engineering utilities
- Labview interface to monitor equipment
- Sports scheduling, game roster creation
- A webpage for elementary students
- Crypto

Requirements / Grading

- Originality
- Polish
- Technical
  - Design
  - Complexity
  - Execution
  - Library usage
- Documentation
- Effort
- Past questions
  - Line count
  - Interfaces

Object-oriented Python

Resources:

http://docs.python.org/tutorial/classes.html

Object oriented programming

- Object oriented paradigms
  - Classes
  - Instances
  - Inheritance
  - Polymorphism
  - Encapsulation
  - Operator overloading
- Python is a multi-paradigm language
  - You can mix and match procedural and OOP code
  - OOP is great when you need to group together data (state) and behavior (methods)

Class and Instances

- Classes
  - Classes define abstract objects which may be instantiated as instances. Classes are instance factories. Attributes provide data / state; methods provide functionality.
- A *class is a user defined type*
- Classes have *attributes* and *methods*
  - Class attributes are *shared* among instances
  - Instance attributes belong to *specific* instances
- Classes can be *instantiated*
  - Objects of that type are called *instances*
- Calling a class object returns an instances of that class
- Instances
  - Are instantiations of a class, represented by an object in a program.

Example

```
class Boat():
    def __init__(self, name): # the constructor
        self.name = name # an instance attribute
    def greet(self): # self refers to the calling instance
        print ('hi from', self.name)

betty = Boat('betty')
fred = Boat('fred')
betty.greet()
fred.greet()

$python foo.py
hi from betty
hi from fred
```

Attributes

- Attributes represent data which belong to the class or instances
- You can specify attributes inside the body
  - Descriptors (including functions), normal data objects, even other classes (nested classes)
- Attributes are specified by binding a value to an identifier inside or outside the body (binding inside is better for readability)
  - Can be bound at runtime
- The first string literal in the class body is taken to be the docstring
- Implicit attributes:
  - __name__: name of the class
  - __bases__: tuple of base classes
  - __dict__: dictionary object containing the class attributes

Class Attributes vs. Instance Attributes

```
class Boat():
    num_boats = 0
    def __init__(self, name):
        self.name = name
        Boat.num_boats +=1
    def greet(self):
        print ('hi from',
                self.name)

betty = Boat('betty')
betty.greet()
print (Boat.num_boats)
fred = Boat('fred')
fred.greet()
print (Boat.num_boats)
```

```
$python foo.py
hi from betty
1
hi from fred
2
```

Methods: class vs. instance

- Class methods are functions which typically run on data belonging to all classes
- Instance methods typically run on data belonging to a specific instance
- Methods can be defined in class bodies using the def statement
  - Instance method definitions have a mandatory first parameter: *self*
- *self* refers back to the instance which called the method, and is passed by Python automatically behind the scenes
- class c(object):
  - def hello(self):
    - print ('Hello world!')
- Many types of methods can be defined (to be discussed later)

Self

- *self* is an *automatically* received first argument received when *instances* call methods
- *self* provides a reference back to the instance which called the class method
- Instance methods must specify self as their first parameter
- Class methods may be called without instantiating the class
- They do *not* use self as their first parameter

Example

```
class Homer():
     def eat():
        print ('Homer class method')
     def snack(self):
        print ('Homer instance method')

Homer.eat()
h = Homer()
h.snack() # self automatically passed

$python foo.py
Homer class method
Homer instance method
```

Classes and Instances (cont'd)

- Classes in Python are first-class objects
  - They are objects like any other
  - Can be passed as arguments to functions, used as keys in a dictionary, bound to local and global variables, etc.
- Classes work a lot like dictionaries: an instance of a class is a Python object with arbitrarily named attributes you can bind and reference
- Lookup of attributes not found in the instance itself is delegated to the class, which may be delegated to classes it inherits from

Constructors

- Constructor
  - If a class defines or inherits the __*init*__ method, it is implicitly executed when the class is instantiated
- To create an instance, call a class definition as if it were a function
  - myInstance = Foo()
- Calling a class object invokes the __init__ method on the new instance, deferring to the superclass if necessary
- __init__ bind's attributes to the newly created instance
- Built-in function *isinstance(I,C)* returns True if object I is an instance of class C or its subclasses, False otherwise

The Class Statement

- class classname(base-classes):
  - statement(s)
- The class statement does not create any instances of the new classes, it simply defines their attributes and methods
  - __init__ is called *only* when an *instance* is created (and every time)
- base-classes are parents of the class, i.e. the current class derives or inherits from these base classes, is optional
- statement(s) is nonempty and is the class body, will execute immediately when the class statement is called
  - Until the body finishes executing, the class will not be bound to the identifier
- Caution: any executable code not in methods will run when the class definition is parsed

Inheritance

- Inheritance
  - Creating a new (sub) class by extending the functionality of an existing (parent or super) class. Results in the subclass inheriting the attributes and behavior of the parent class
  - Inheritance in Python means that name lookup (for methods and attributes) is extended to the parent classes
  - Python supports multiple inheritance
    - In case of conflicts between attributes or methods, the general rule is the first inherited class wins (left-most first)

Inheritance

```
class Boat():
    def __init__(self, name):
        self.name = name
    def greet(self):
        print ('hi from', self.name)

class Sailboat(Boat):
    def sail(self):
        print ('Wooosh')

b = Sailboat('betty') # the constructor is inherited
b.greet() # greet is inherited
b.sail() # sail is a new method specific to sailboats
```

```
$python foo.py
hi from betty
Wooosh
```

Multiple Inheritance

```
class Sailboat():
    def sail(self):
        print ('Wooosh')

class Cannon():
    def fire(self):
        print ('Boom!')

class PirateShip(Sailboat, Cannon):
    pass

p = PirateShip()
p.sail()
p.fire()
```

```
$ python foo.py
Wooosh
Boom!
```

Method and Attribute Resolution

- Recall the syntax of the class statement
- class classname(base-classes):
  - statement(s)
- Python supports multiple inheritance
  - base-classes can be a comma-delimited list of superclasses
- Method resolution order
  - How does lookup of an attribute name occur?
  - In general: left-to-right, depth first

Composition

```
class Homer():
    def __init__(self):
        self.donuts = []
    def add(self, donut):
        self.donuts.append(donut)
    def stats(self):
        print ('Homer has the
   following donuts')
        for d in self.donuts:
            print ('\t' + d.name)

class Donut():
    def __init__(self, name):
        self.name = name

h = Homer()
h.add(Donut('jelly'))
h.add(Donut('sugar'))
h.stats()
```

```
$ python foo.py
Homer has the following donuts:
   jelly
   sugar
```

Polymorphism (overriding)

- Polymorphism
  - A subclass specializes the behavior of their parent class by overriding (or re-declaring) methods or data
  - Mammals swim (but people and dolphins swim rather differently)
- Polymorphism in python is as simple as re-declaring a method
- Common patterns:
  - Inheritor (does not override a method, makes use of the parent's functionality)
  - Replacer (overrides the method entirely)
  - Extender (calls the parent's method, but adds functionality)
  - Provider (fills in a template method declared by the parent)

Polymorphism example (replacer)

```
class Boat():
    def go(self):
        print ('Generic behavior')

class Sailboat(Boat):
    def go(self):
        print ("Let's go sailing!")

a = Boat()
a.go()
b = Sailboat()
b.go()

$ python foo.py
Generic behavior
Let's go sailing!
```

Overriding Attributes

- When a subclass defines an attribute with the same name as one in a superclass, the subclass' attribute will always be used first
  – Known as the subclass *overriding the definition in the superclass*
- Delegating to superclass (or base) methods
  – Subclasses may call methods in base classes

Exposing functionality

- Python’s philosophy is to expose as much of a class as possible
- Private variables are signified by a leading underscore _
  - Decreases risk of accidental data sharing
  - But a convention that’s up to the programmers to respect
  - A determined programmer can access class private variables

Inspection

```
class Boat():
    '''Class docs'''
    the_sky = 'blue'
    def go(self):
        print ('Generic behavior')

b = Boat()
print (b.__class__.__dict__)
```

```
Python foo.py
{'__module__': '__main__', 'the_sky': 'blue',
  '__dict__': <attribute '__dict__' of 'Boat'
  objects>, 'go': <function go at 0x3b61e0>,
  '__weakref__': <attribute '__weakref__' of 'Boat'
  objects>, '__doc__': 'Class docs'}
```

Operator overloading

- Allows classes to define specific behavior for normal operators (e.g., +, -,*)
- As well as concepts such as iteration, type conversation, equality testing
- Useful if you're developing a package
  - For instance, it makes sense to be able to multiple two vectors with the '*' operator
- Use sparingly and only if obvious

Operator overloading example

```
class Donut():
    def __init__(self, name, quantity):
        self.name = name
        self.quantity = quantity
    def __add__(self, num):
        self.quantity += num
        print ('woohoo!')
        print ('we have %s donuts!' % (self.quantity))

d = Donut('jelly', 1)
d += 8
```

```
python foo.py
woohoo!
we have 9 donuts!
```

Providing iterator functionality

```
class Donut():
    def __init__(self, name):
        self.name = name
    def __getitem__(self, i):
        return self.name[i]

d = Donut('jelly')
print ('Give me a ', end = '')
for char in d:
    print (char + '!', end = ' ')
```

```
python foo.py
Give me a j! e! l! l! y!
```

Factory methods

- A factory is a function which returns an object of a particular class type depending on some condition
- A typical scenario is switching between two almost identical classes depending on the enviornment

Example

```
class c1():
    def run_command(self):
        print ('ready for linux')

class c2():
    def run_command(self):
        print ('ready for windows')

def factory(linux=False):
    if linux:
        return c1()
    else:
        return c2()

x = factory(linux=True)
x.run_command()

$python foo.py
ready for linux
```

The object Type

- Built-in type: object
- Ancestor of all built-in types and new-style classes
- Some special methods are defined:
  - __new__, __init__, __delattr__, __hash__,__repr__, __str__, …

Exceptions

Resources:

http://docs.python.org/tutorial/errors.html

Exceptions

- Difference between errors and exceptions?
  - Errors detected during execution are called *exceptions* and are not unconditionally fatal
- Python's emphasis
  - Use exceptions when and where they make a program simpler, more robust, and more readable
- Special situations are frequently indicated in Python using exceptions
  - e.g., end of iteration is signaled by the StopIteration exception
- OK to use frequently

Stack trace

```
def bug():
    return 1 / 0

print (bug())

$ python f.py
Traceback (most recent call last):
  File "f.py", line 4, in <module>
    print (bug())
  File "f.py", line 2, in bug
    return 1 / 0
```

Exception objects

```
def bug():
    try:
        return 1 / 0
    except ZeroDivisionError as detail:
        print ('Caught a bug!')
        print (type(detail))
        print (detail)

print (bug())

$ python f.py
Caught a bug!
<class 'ZeroDivisionError'>
int division or modulo by zero
None
```

Stop Iteration

```
def count_down(to):
    while to > 0:
        to -= 1
        yield to

f = count_down(3)
while True:
    print(next(f))
```

```
$ python foo.py
2
1
0
Traceback (most recent call last):
  File "z.py", line 8, in <module>
    print(next(f))
StopIteration
```

Stop Iteration

```
def count_down(to):
    while to > 0:
        to -= 1
        yield to

f = count_down(3)
done = False
while not done:
    try:
        print(next(f))
    except StopIteration:
        print('all done')
        done = True
print ('phew')
```

```
$ python foo.py
2
1
0
all done
phew
```

Exceptions

Raising Exceptions

- Exceptions communicate errors and anomalies
- When problems are detected, exceptions are raised / thrown
- Your code can explicitly raise exceptions
- Exceptions are caught by exception handlers
- Exceptions are instances of BaseException

Handling Exceptions

- Handling an exception means accepting the exception object from the propagation mechanism
- If exceptions are uncaught, they terminate the program and result in a stack trace
- Handling exceptions allows programs to deal with errors and anomalies gracefully

The try Statement

- Provides Python's exception handling mechanism
- It is a compound statement with one of these forms:
  - Try clause followed by one or more except clauses (with optional else clause)
  - Try clause followed by finally clause
  - Try clause followed by except clauses and optional else clause, followed by finally clause (Python 2.5+)

Exception propagation

- When an exception is raised normal control flow is superseded by the exception propagation mechanism
- A raised exception is handled by the first try block with a matching except clause
- If an exception is raised without a try clause, or in a try clause without a matching except clause, it propagates up the call stack stack until either being caught, or terminating the program
- You can catch arbitrary deep exceptions produced by function calls

try/except/else

```
Syntax ([] indicate optional code):
try:
   statement(s)
except [expression [, target]]:
   statement(s)
[else:statement(s)]
```

- The body of the except clause is known as an exception handler
- Exception handler executes if expression matches an exception object propagating from the try clause
  - expression is an Exception class or tuple of classes
  - target is an identifier that is bound to the exception object before the handler executes
  - In the case of several except clauses, they are checked in order until one is found with a matching expression
  - List specific cases before general ones

try/except/else (cont'd)

- Last except may lack an expression
  - Known as *bare excepts*
  - Will handle *any* exception that reaches it
  - **Should avoid**; it's sloppy coding
  - Trivia: "On error resume next"
- Exception propagation terminates when it finds a handler with a matching expression
- The optional else clause executes only when the try clause terminates normally (i.e. when no exception is raised) or when it exists with a break, continue or return statement
  - Handlers do not cover exceptions raised in the else clause

Examples

```
>>> try: # try / except example
…       open('/')
…   except IOError:
…       print ('Failed to open file.’)
Failed to open file.

>>> try:
…        open(‘test’, ‘w’)
…        print (‘success’)
…    except IOError:
…        print (‘Failed to create file’)
…     else:
…        print (‘File creation succeeded.’)

<open file 'test', mode 'w' at 0xb770f3e0>
Success
File creation succeeded.
```

Finally

```
Syntax
try:
   statement(s)
finally:
   statement(s)
```

- The finally clause is a clean-up handler
  - It always executes after the try clause, regardless of whether or not an exception is raised (executes even if a return statement is placed w/in the try clause)
  - If an exception propagates from the try clause, the try clause will terminate, the finally clause executes, and the exception continues to propagate
- Specifies code which is guaranteed to run regardless of whether an exception occurs in the try block
- Useful to close database connections, files, etc
  - Wish the user a nice day before crashing

try/except/finally

- From Python 2.5 onward, except clause(s) are allowed with try/finally
- Syntax:

```
try:
    statement(s)
except [expression[, target]]:
    statement(s)
finally:
    statement(s)
```

- Equivalent to:

```
try:
    try:
        statement(s)
    except
        statement(s)
finally:
    statement(s)
```

- If try clause raises an exception, it will be handled using the excepts before the finally clause is executed
- Can you think of some instances where try/except/finally would be useful?

The with statement

- New in Python 2.5 (standard in 2.6+, 3.x)
- Occasionally pops up in an error handling context
- Syntax:
  - with expression [as varname]
    - statement(s)
- Embodies the C++ idiom “resource acquisition is initialization”
- Best explained with an example:
  - with open(‘foo.txt’) as f:
    - statements using file object f
- More information:
  - http://www.python.org/peps/pep-0343.html

Built-in exceptions

- (All of type Exception)
  - BaseException
  - AssertionError
  - AttributeError
  - IOError
  - ImportError
  - IndexError
  - KeyError
  - NotImplementedError
  - TypeError
- See: http://docs.python.org/library/exceptions.html#bltin-exceptions

Assert

```
def homer_dates(x):
    assert(x != 'selma')
    print ('woohoo!')

homer_dates('marge')
woohoo!
```

```
homer_dates('selma’)
Traceback (most recent call last):
  File "q.py", line 6, in <module>
    homer_dates('selma')
  File "q.py", line 2, in homer_dates
    assert(x != 'selma')
AssertionError
```

Defining your own exceptions

```
class HomerError(BaseException):
    '''Protects Homer'''

def homer_dates(x):
    if x == 'selma':
        raise HomerError
    print ('woohoo!')

try:
    homer_dates('marge')
    homer_dates('selma')
except HomerError:
    print ('not gonna happen')
```

```
$python foo.py
woohoo!
not gonna happen
```

Exception Handling Strategies

Look before you leap

Easier to ask forgiveness than permission

Python prefers the second

```
def div(x, y):
  if y == 0:
      raise ZeroDivisionError
```

- Checks diminish readability
- Exceptions are rare, why waste effort up front?

```
def div(x,y):
 try:
     return x / y
 except ZeroDivisionError:
  ...
```

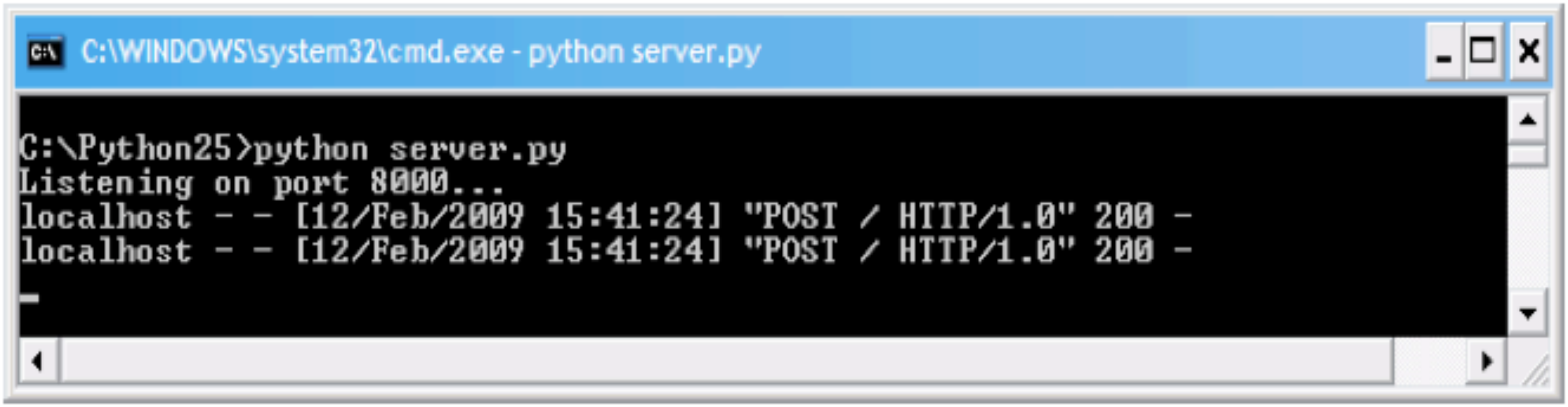
- Emphasizes the common case
- Increases readability

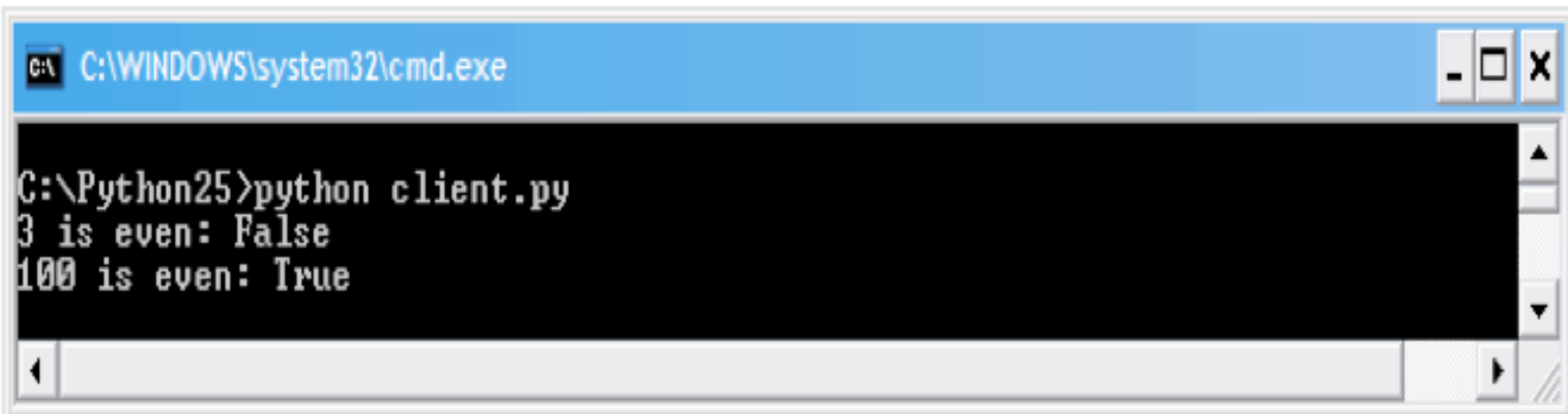
Exceptions wrap up

- Avoid empty except statements
- Use the built-in exceptions before defining your own types
- Use assert as a sanity check
- The stack trace is powerful
- In small scripts, the easiest way to debug is often just to crash and examine it!

Libraries

XML-RPC





Anyone taken Networks? What do you think the line count would be in C?

XML-RPC:

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

Server

```
import xmlrpclib
from SimpleXMLRPCServer import SimpleXMLRPCServer
def is_even(n): return n%2 == 0
server = SimpleXMLRPCServer(("localhost", 8000))
print "Listening on port 8000...“
server.register_function(is_even, "is_even") server.serve_forever()
```

Client

```
import xmlrpclib proxy = xmlrpclib.ServerProxy("http://localhost:8000/")
print proxy.is_even(3)
print proxy.is_even(100)
False
True
```

Finding and installing libraries

http://www.goldb.org/ystockquote.html

All it takes

```
>> import ystockquote
>> ystockquote.get_price('GOOG')

357.95
```

Included Functions

- get_all(symbol)
- get_price(symbol)
- get_change(symbol)
- get_volume(symbol)
- get_avg_daily_volume(symbol)
- get_stock_exchange(symbol)
- get_market_cap(symbol)
- get_book_value(symbol)
- get_ebitda(symbol)
- get_dividend_per_share(symbol)
- ...