COMS 3101-3 Programming Languages – Python: Lecture 6

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Agenda

- Debugging
- Decorators
- Web development

Review

REGULAR EXPRESSION

re.match()

- Correction

```
re.match(pattern, string, flags=0)
    Try to apply the pattern at the start of the string,
    returning a match object, or None if no match was found.
```

- Similar to

```
#re.MULTILINE – regards string as single line input
re.search(^pattern, string, re.MULTIILINE)
```

- To match entire line or string

```
#search for line matches
re.search(^pattern$, string)
re.search(^pattern$, string, re.MULTILINE)
```

Title Element

```
#Basic syntax
<title> this is a title </title>
#pattern
pat = r"<title>(.*)</title>"

#HTML is NOT case-sensitive
<TITLE> this is a title </TITLE>
re.search (..., re.IGNORECASE)

#HTML syntax allows space elements after tag string
<TITLE
> this is a title </TITLE>
pat = r"<title\s*>(.*)</title\s*>”
```

Link element

```
<A Href= 'HTTP://s1.s2.DOMAIN.EDU:80/˜usr/script.cgi?foo=bar&answer=4'>

pat = r"<a\s*href=\s*'(.*)'"

<A Href= "HTTP://s1.s2.DOMAIN.EDU:80/˜usr/script.cgi?foo=bar&answer=4">

pat = "<a\s*href=\s*('(.*)'|\"(.*)\")"

<A Href= "teaching/index.html" target="_blank">

pat = r"<a\s*href=\s*('(.*?)'|\"(.*?)\")"
```

- Pattern applied to real page

```
for m in re.finditer(pat, content, re.IGNORECASE):
    print m.group(1),

"#"
"http://nsl.cs.columbia.edu"
"http://www.columbia.edu"
"http://www.cs.columbia.edu/~angelos"
"projects.html"
...
```

DEBUGGING AND TESTING

Programs are Error Prone

- Syntax errors ←Detected by interpreter
- Errors at runtime ← Exception handling
- Incorrect programming behavior(wrong result)
  - Sometimes works, sometime not

⬆

Debugging and Testing

Debugging Tips for Scalable Project

- Utilize Python Interpreter actively
  - Program should be organized into functions / classes of reasonable sizes
- Log / Trace program behavior
  - Using print() or logging module
- assert() everywhere
- Be familiar with pdb (Python debugger)
- Establish unit testing framework

Debugging with `print`

- Most common way of debugging: Simply print intermediate results
- Prints all relevant information and reference to which part of the program prints
- Better: Write debugging statements to `sys.stderr`
- Comment / uncomment debugging code

```
def mirror(lst):
    ret = []
    for i in range(len(lst)):
        ret.append(lst[-i])
        #print >> sys.stderr, \
        # "mirror: list for i={0}: ".format(i)
        #print >> sys.stderr,"{1}\n".format(lst)
    return lst + ret

x = [1,2,3]
print(mirror(x)) # Expected: [1,2,3,3,2,1]
```

logging module for debugging

- logging module to log errors and debugging messages
- Provides central control over debugging output

```
import logging
logging.basicConfig(level = logging.DEBUG)

def mirror(lst):
  ret = []
  for i in range(len(lst)):
    ret.append(lst[-i - 1])
    logging.debug(“list for i={0}: {1} ".format(i, lst[-i - 1]))
  return lst + ret
```

```
>>> mirror([1,2,3])
DEBUG:root:list for i=0: 3
DEBUG:root:list for i=1: 2
DEBUG:root:list for i=2: 1
[1, 2, 3, 3, 2, 1]
```

logging – Logging Levels

- Can output messages to on different logging levels
  - Output messages of *LEVEL* and above

```
logging.basicConfig(level=logging.LEVEL)
```

Severity

level	function
`logging.CRITICAL`	`logging.critical()`
`logging.ERROR`	`logging.error()`
`logging.WARNING`	`logging.warning()`
`logging.INFO`	`logging.info()`
`logging.DEBUG`	`logging.debug()`

logging – more on logging

- Can output messages to a log file

```
logging.basicConfig(level=logging.DEBUG,
                    filename = ‘bugs.log’)
```

- Config is valid for all modules in a program
  - Only set logfile and level once in main
- Can add and time

```
logging.basicConfig(level=logging.DEBUG,
                      filename=‘bugs.log’,
                      format=‘%(acstime)s %(message)’)
```

- More on logging
  http://docs.python.org/library/logging.html

Python debugger - pdb

- Python provides a built-in debugger (module pdb)
- Allows to execute code line-by-line
- pdb allows access to program state

- Postmortem debugging

```
$ python –m pdb mirror.py
```

- Or launching pdb interactively from Python console

```
>>> from mirror import mirror
>>> import pdb
>>> mirror([1, 2, 3])
Exception!!!
...
>>> pdb.pm()
```

pdb Commands

- b: set breakpoint
- n: next line
- r: return from the function
- l: source code for current file
- c: continue execution until next breakpoint

Trace Generation

- Function call trace
  - What if we want to log function call /return
  - input arguments along with return values
- Recall ‘Closure’
  - Function object that contains some state defined from outside function

```
def func_trace(func):

   # New function object wraps fun
   def new_fun(arg0):

       # Before fun is called
       print “calling with”, arg0

       result = func(arg0) # Call fun

       # After fun is called
       print “return value”, result

       return result

    return new_fun
```

Trace Generation

- func_trace returns wrapper function to func
- Now it only supports function with a single arguments

```
def func_trace(func):

   # New function object wraps fun
   def new_fun(arg0):

       # Before fun is called
       print “calling with”, arg0

        result = func(arg0) # Call fun

       # After fun is called
       print “return value”, result

       return result

    return new_fun
```

```
>>> def inc_one(arg0):
...     return arg0 + 1
...
>>> inc_one(1)
2
>>> inc_one = func_trace(inc_one)
>>> inc_one(1)
calling with 1
return value 2
2
```

Trace Generation: Support arbitrary argument

- *args, **kwargs
  - to support arbitrary combinations of positional and named parameters
  - args: list containing positional parameters
  - kwargs: dictionary containing name, parameter pairs
- *, ** operators are required only when these are again become parameter to call another function

```
def func_trace(func):

  # New function object wraps fun
  def new_fun(*args, **kwargs):

    # Before fun is called
    print “calling with”, args, kwargs

    result = func(*args, **kwargs)

    # After fun is called
    print “return value”, result

    return result

  return new_fun
```

```
>>> def get_tuple(x,y):
...     return x, y
...
>>> get_tuple =
         func_trace(get_tuple)

#Positional parameter
>>> get_tuple(1,2)
calling with (1, 2) {}
return value (1, 2)
(1, 2)

#Named parameter
>>> get_tuple(x=1, y=2)
calling with () {'y': 2, 'x': 1}
return value (1, 2)
(1, 2)
```

Trace Generation: Controlling Trace Output

- Integrate trace output with Python logging infrastructure
- Redirect trace output to logging.* functions

```
import logging
def func_trace(func):

  # New function object wraps fun
  def new_fun(*args, **kwargs):

    # Before fun is called
    logging.Debug(“calling with {0}”\
             “{1}”.format(args, kwargs))

    result = func(*args, **kwargs)

    # After fun is called
    logging.Debug(“return value:” \
                 {0}”. format(result))

    return result

  return new_fun
```

```
>>> import logging
>>>
logging.basicConfig(level=logging.DEBUG)

>>> get_tuple = func_trace(get_tuple)

>>> get_tuple
<function new_fun at 0x10cb820c8>

>>> get_tuple(1,2)
DEBUG:root:Calling with (1, 2) {}
DEBUG:root:return value (1, 2)
(1, 2)
```

Decorators

- Convenient concise way to modify classes, methods and functions
- Are a form of meta-programming (like macros in C, annotation in Java ...)
- Example uses:
  - Log all errors in a function in a special way
  - Acquire and release some resources at entry/exit point
  - Memoize previous computations performed by a function
  - Make sure only a single instance of a class exists (singleton)
  - Make a method ‘static’
  - Make a method a ‘class method’

Decorators - Syntax

- Decorators are callable objects that are applied to functions or classes

```
@dec2
@dec1
def func(arg1, arg2, ...):
    ...
```

- is syntactic sugar for

```
def func(arg1, arg2, ...):
    ...
func = dec2(dec1(func))
```

Decorators can take arguments

- Can call a function to get a decorator

```
@dec(foo1, foo2)
def func(arg1, arg2, ...):
    ...
```

- is syntactic sugar for

```
def func(arg1, arg2, ...):
    ...
func = dec(foo1, foo2)(func)
```

Example built-in decorators - `@staticmethod`

- `@staticmethod` creates a static method
- Static methods do not receive implicit ‘self’ argument
- Can be called on class and instance objects

```
>>> class A(object):
...     @staticmethod
...     def foo(a1):
...          return a1 + 3
...
>>> A.foo(17)
20
>>> A().foo(80)
83
```

`@classmethod` decorator performs in quite similar way, but `@classmethod` requires method to have reference to class object

Decorator: FuncTrace

- Applying FuncTrace using decorator syntax

```
import logging
def func_trace(func):

  # New function object wraps fun
  def new_fun(*args, **kwargs):

    # Before fun is called
    logging.Debug(“calling with {0}”\
             “{1}”.format(args, kwargs))

    result = func(*args, **kwargs)

    # After fun is called
    logging.Debug(“return value:” \
                 {0}”. format(result))

    return result

  return new_fun
```

- Function call syntax

```
def get_tuple (x, y)
    return x,y

get_tuple = func_trace(get_tuple)
```

- Decorator syntax

```
@func_trace
def get_tuple (x, y)
    return x,y
```

Writing Decorators - @memoized

```
>>> @memoize
... def factorial(n):
...     print "#",
...     return 1 if n == 1 else n * factorial(n - 1)
...
>>> factorial(5)
# # # # #
120
>>> factorial(6)
#
720
```

- Memoization: storing previous execution results and return cached value for the same input

Writing Decorators - @memoized

```
# note that this decorator ignores **kwargs
def memoize(func):
    cache =  {}   #cache object

    def memoizer(*args, **kwargs):
        if args not in cache:
            cache[args] = func(*args, **kwargs)
        return cache[args]

    return memoizer
```

- `@memoize` decorator ignores named parameters (**kwargs)
- it doesn’t catch side effects – e.g., print to stdout

Writing Decorators - @singleton

- Singleton pattern
  - Only a single instance of a class exists
  - Instance created at the first time the class is instantiated
  - Subsequence instantiation yields reference to the same instance

```
>>> @singleton
... class A(object):
...     pass
...
>>> x = A()
>>> y = A()
>>> x == y
True
>>> x is y
True
```

Writing Decorators - @singleton

- This is actually cheating (returns a function, not a class)
- Achieves desired behavior
- Rather complete solutions can be found from
  - http://wiki.python.org/moin/PythonDecoratorLibrary

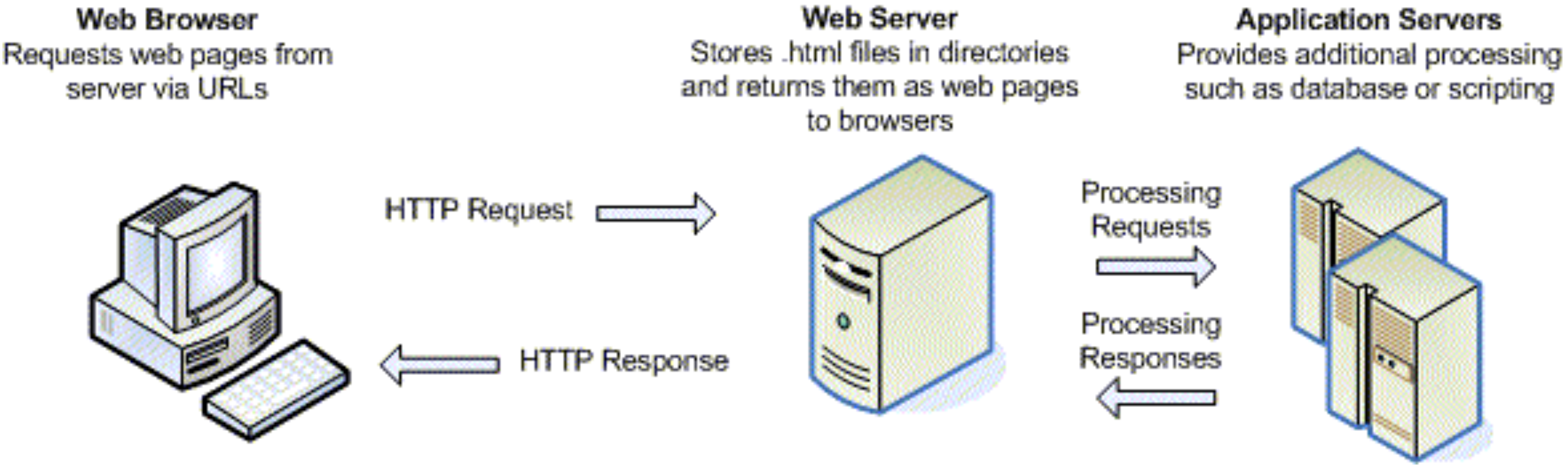
```
def singleton(cls):
  instances = {}

  def getinstance(*args, **kwargs):
    if cls not in instances:
        instances[cls] = cls(*args, **kwargs)
    return instances[cls]

  return getinstance
```

WWW PROGRAMMING WITH PYTHON

A high-level view of the WWW



Web Browser
Requests web pages from server via URLs

HTTP Request

HTTP Response

Web Server
Stores .html files in directories and returns them as web pages to browsers

Processing Requests

Processing Responses

Application Servers
Provides additional processing such as database or scripting

- WWW protocol (HTTP) implemented over TCP/IP
- IP protocol identifies a service with IP address and port numbers
- URL allow you to specify port number

  http://ip_address:port_num/path/to/file

Port #	Default Service
21	ftp
22	ssh
23	telnet
80	http

HyperText Transfer Protocol (HTTP)

- Communication protocol between web client and web server
- Text based protocol
- Two main mathods
  - GET: Client requests a specific resource (web-page, images ...)
    - Possibly pass some short parameter to the server
    - Most common
  - POST: Client submit data to the server and requests some result
    - Upload a file, send a message

Hypertext Markup Protocol – GET

- Client requests page by sending

```
GET /pages/test.html HTTP/1.1
```

- Server responds by providing headers and content

```
HTTP/1.1 200 OK
Date: Wed, 09 Oct 2013 17:45:34 GMT
Server: Apache
X-Powered-By: PHP/5.3.2-1ubuntu4.21
...
Content-Type: text/html

<!DOCTYPE HTML PUBLIC "-//W3C//DTD HTML 4.01 Transitional//EN" "http://
www.w3.org/TR/REC-html40/strict.dtd">
<HTML>
...
</HTML>
```

Hypertext Markup Protocol – GET (error response)

- Client requests page by sending

```
GET /pages/somepage.html HTTP/1.1
```

- Server responds by providing headers and content

```
HTTP /1.1 404 Not Found
Date: Wed, 29 Feb 2012 22:40:01 EST Server: Apache/2.2.9 (Debian)
...

Content-Type: text/html; charset=UTF-8

<!DOCTYPE HTML PUBLIC "-//W3C//DTD HTML 4.01 Transitional//EN" "http://
www.w3.org/TR/REC- html40/strict.dtd">

<html>
<body>
     <h1> Page not found on this server. </h1>
</body>
</html>
```

Low-level networking – writing servers with the sockets module

- Sockets are network endpoint associated with a specific port on a specific machine(IP address)
- Initialize a socket instance of appropriate type and bind it to address and port

```
s = socket.socket(socket.AF_INET, socket.SOCK_STREAM)
s.bind('0.0.0.0', 8080)
```

- Server sockets are in listening state (must specify number of maximum requests in queue)

```
s.listen(5)
```

- Socket blocks and waits for a connection request. Returns a new connection socket that can be read and written

```
connection, address = s.accept()
```

Low-level networking – writing servers with the sockets module

- Once a connection is established, we can recv from and send to it

```
conn, addr = s.accept()
while True:
    data = conn.recv(1024)
    if not data:
        break
    # Echo the data back to the client.
    conn.send(data)
socket.close()
```

- Can get a file object too

```
f = conn.makefile(’rw’)
l = f.readline()
f.write("Foo\n")
# Need to call flush or close to send data!
f.flush()
```

A minimal Web Server in Python

```
import socket
import os.path

s = socket.socket(socket.AF_INET , socket.SOCK_STREAM)
s.bind(('0.0.0.0', 8080))
s.listen(1) # Set socket to 'listening' state

while True:
    conn, addr = s.accept()
    cfile = conn.makefile('rw')
    l = cfile.readline()

    print "RECV:", l

    if l.startswith("GET "):
        pathname = os.path.join("jikk_web/", l.split()[1][1:])

    try:
        cfile.write('HTTP/1.0 200 OK\n\n')
        cfile.write(open(pathname ,'r').read())
    except IOError:
        cfile.write('HTTP/1.0 404 Not Found\n\n')
        cfile.write('Not found!')
    finally:
        cfile.close()
        conn.close()
```

BaseHTTPServer

- Standard library support for static webserver
- Merged to http.server in Python 3
  - 2to3 tool will automatically fix it

```
#running webserver from command line

jikk$ python -m BaseHTTPServer
Serving HTTP on 0.0.0.0 port 8000 ...
```

- To implement protocol you need to extend `BaseHTTPRequestHandler` class

Web Development

Develop user applications that run on the web

- Client-based code that runs on the client
  - Java, JavaScript, Flash, Silverlight ...
  - Python compiled to JavaScript
- Server-based code
  - Static web page: HTML
  - Dynamic web page generation
    - Common Gateway Interface
  - Web frameworks
    - For Python: Django, Zope, Pylons, TurboGears, web2py, Flask

Common Gateway Interface (CGI)

- CGI: method for web servers to delegate generation of web pages to a program
  - Server sets up environment for the script and runs script
  - HTTP POST method can be used to provide stdin for script
  - HTTP GET can pass query string to the script (from HTML forms)
  - Server returns program stdout to the client
- Normally CGI requires some web-server configuration

Python CGI scripts

- Fort test purpose, we can use a stndard library CGI capable web server
  - CGI script (often) live in cgi-bin/ subdirectory

```
$ python –m CGIHTTPServer
```

cgi-bin/cgi0.py

```
#!/usr/bin/python

response = '''
<html> <body>
<h1> Hello World </h1> </body>
</html>'''

print response
```

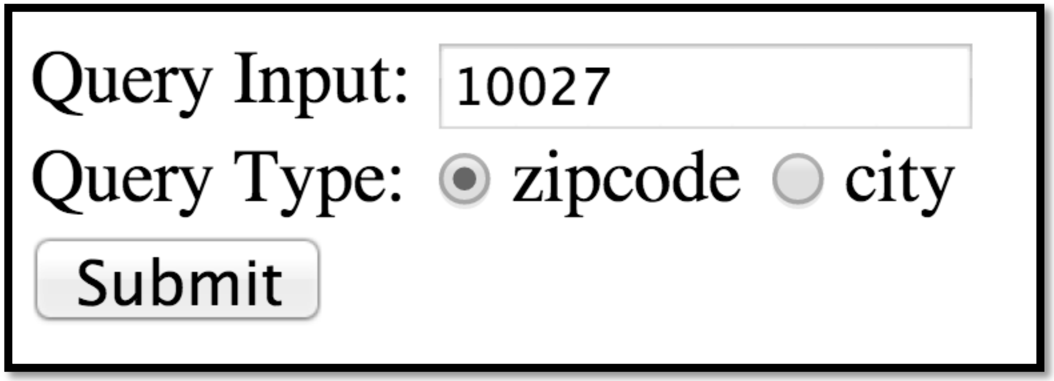
- Now we can browse to http://localhost:8000/cgi-bin/cgi0.py

HTML Forms and Query Strings

```
<form name="query" action="query.py" method= "GET">

Query Input: <input type="text" name="Input" /><br/>
Query Type:
<input type="radio" name="input" VALUE="z"/>zipcode
<input type="radio" name="input" VALUE="c"/>city <br/>
<input type="submit" value="Submit"/>

</form>
```



Query Input: 10027

Query Type: ● zipcode ○ city

- When ‘submit’ is pressed, the browser uses the http GET method to send request

  `query.py?Input=10027&input=z`
- *attribute/value pairs* attached to script name (after ? separated by &)

cgi module

- Needed to access passed attribute/value pairs in the CGI script

```
#!/usr/bin/python
import cgi
form = cgi.FieldStorage()

def make_msg(qtype):
    if qtype == "z":
        return "Input is a zipcode"
    elif qtype == "c":
        return "Input is a city name"
    else:
        return "Invalid"

qtype = form.getvalue("qtype")
msg = make_msg(qtype)

print('''
<html> <body> {0}:  {1}<br>
<a href="../query.html"> back </a> </body > </html >
'''.format(form.getvalue("input"), msg))
```

cgi module (2)

- Also support attribute/value pairs passed by POST method
- Message will not be visible from URL, it is delivered as a separate message
- cgi.FieldStorage takes care of reading and processing data

```
<html ><body >
<form action="cgi-bin/comment.py" method="post">
comment:<br>
<textarea name="comment" cols="40" rows="4">Text here
</textarea>
<br>
<input type="submit" value="Submit"/>
</form>
</body></html>
```

```
#!/usr/bin/python
import cgi
form = cgi.FieldStorage()
print('''Content -Type: text/html
<html> <body> Comment: {0}</body></html>
'''.format(form.getvalue("comment")))
```

cgitb module

- If a CGI script contains errors, it may crash
- Possibly prints exceptions to a server log file
- No output sent back to the client
- cgitb module sends pretty debugging output back to client

```
import cgitb
cgitb.enable()
```

- Nice for debugging purposes! Don’t use on public websites!

Drawbacks of CGI

- Need to run a new process every time to generate a single web page
  - Think about what happens with thousands of user requests!
- Hard to represent state in a web application
  - Need to save information and re-read it
- Some security issues unless webserver is well configured and scripts are written with care

Credits

- Many thanks to Daniel Bauer
  - For his wonderful work on class materials!
- I referred a lot from his material
  - For this classes' material and homeworks