Python Network Programming

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Section 0

Introduction

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Support Files

- Course exercises:

http://www.dabeaz.com/python/pythonnetwork.zip

- This zip file should be downloaded and extracted someplace on your machine
- All of your work will take place in the the "PythonNetwork" folder

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Python Networking

- Network programming is a major use of Python
- Python standard library has wide support for network protocols, data encoding/decoding, and other things you need to make it work
- Writing network programs in Python tends to be substantially easier than in C/C++

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This Course

- This course focuses on the essential details of network programming that all Python programmers should probably know
  - Low-level programming with sockets
  - High-level client modules
  - How to deal with common data encodings
  - Simple web programming (HTTP)
  - Simple distributed computing

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Standard Library

- We will only cover modules supported by the Python standard library
- These come with Python by default
- Keep in mind, much more functionality can be found in third-party modules
- Will give links to notable third-party libraries as appropriate

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Prerequisites

- You should already know Python basics
- However, you don't need to be an expert on all of its advanced features (in fact, none of the code to be written is highly sophisticated)
- You should have some prior knowledge of systems programming and network concepts

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Section 1

Network Fundamentals

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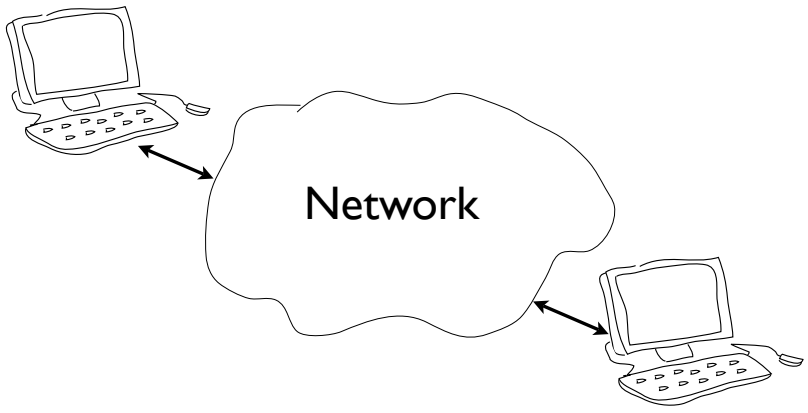
The Problem

- Communication between computers



- It's just sending/receiving bits

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Two Main Issues

- Addressing
  - Specifying a remote computer and service
- Data transport
  - Moving bits back and forth

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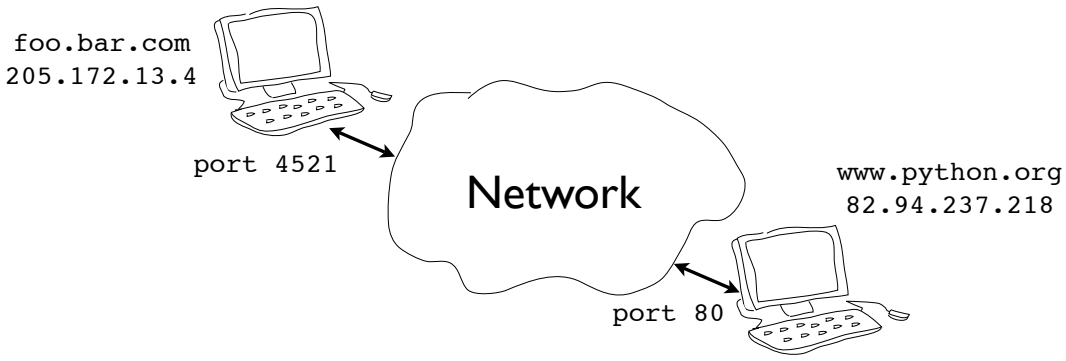
Network Addressing

- Machines have a hostname and IP address
- Programs/services have port numbers



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Standard Ports

- Ports for common services are preassigned

```
21          FTP
22          SSH
23          Telnet
25          SMTP (Mail)
80          HTTP (Web)
110         POP3 (Mail)
119         NNTP (News)
443         HTTPS (web)
```

- Other port numbers may just be randomly assigned to programs by the operating system

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Using netstat

- Use 'netstat' to view active network connections

```
shell % netstat -a
Active Internet connections (servers and established)
Proto Recv-Q Send-Q Local Address           Foreign Address
tcp        0      0 *:imaps                 *:*
tcp        0      0 *:pop3s                 *:*
tcp        0      0 localhost:mysql         *:*
tcp        0      0 *:pop3                  *:*
tcp        0      0 *:imap2                 *:*
tcp        0      0 *:8880                  *:*
tcp        0      0 *:www                   *:*
tcp        0      0 192.168.119.139:domain  *:*
tcp        0      0 localhost:domain        *:*
tcp        0      0 *:ssh                   *:*
...
```

- Note: Must execute from the command shell on both Unix and Windows

Connections

- Each endpoint of a network connection is always represented by a host and port #
- In Python you write it out as a tuple (host,port)

```
("www.python.org",80)
("205.172.13.4",443)
```

- In almost all of the network programs you'll write, you use this convention to specify a network address

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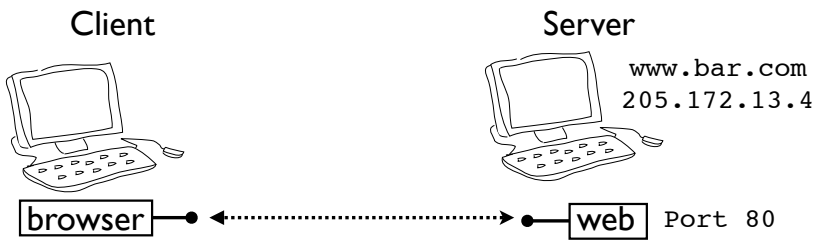
Client/Server Concept

- Each endpoint is a running program
- Servers wait for incoming connections and provide a service (e.g., web, mail, etc.)
- Clients make connections to servers



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Request/Response Cycle

- Most network programs use a request/ response model based on messages
- Client sends a request message (e.g., HTTP)

```
GET /index.html HTTP/1.0
```

- Server sends back a response message

```
HTTP/1.0 200 OK
Content-type: text/html
Content-length: 48823

<HTML>
...
```

- The exact format depends on the application

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Using Telnet

- As a debugging aid, telnet can be used to directly communicate with many services

```
telnet hostname portnum
```

- Example:

type this and press return a few times →

```
shell % telnet www.python.org 80
Trying 82.94.237.218...
Connected to www.python.org.
Escape character is '^]'.
GET /index.html HTTP/1.0

HTTP/1.1 200 OK
Date: Mon, 31 Mar 2008 13:34:03 GMT
Server: Apache/2.2.3 (Debian) DAV/2 SVN/1.4.2
mod_ssl/2.2.3 OpenSSL/0.9.8c
...
```

Data Transport

- There are two basic types of communication
- Streams (TCP): Computers establish a connection with each other and read/write data in a continuous stream of bytes---like a file. This is the most common.
- Datagrams (UDP): Computers send discrete packets (or messages) to each other. Each packet contains a collection of bytes, but each packet is separate and self-contained.

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Sockets

- Programming abstraction for network code
- Socket: A communication endpoint

- Supported by socket library module
- Allows connections to be made and data to be transmitted in either direction

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Socket Basics

- To create a socket

```
import socket
s = socket.socket(addr_family, type)
```

- Address families

```
socket.AF_INET      Internet protocol (IPv4)
socket.AF_INET6     Internet protocol (IPv6)
```

- Socket types

```
socket.SOCK_STREAM  Connection based stream (TCP)
socket.SOCK_DGRAM   Datagrams (UDP)
```

- Example:

```
from socket import *
s = socket(AF_INET,SOCK_STREAM)
```

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Socket Types

- Almost all code will use one of following

```
from socket import *

s = socket(AF_INET, SOCK_STREAM)
s = socket(AF_INET, SOCK_DGRAM)
```

- Most common case: TCP connection

```
s = socket(AF_INET, SOCK_STREAM)
```

Using a Socket

- Creating a socket is only the first step

```
s = socket(AF_INET, SOCK_STREAM)
```

- Further use depends on application
- Server
  - Listen for incoming connections
- Client
  - Make an outgoing connection

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TCP Client

- How to make an outgoing connection

```
from socket import *
s = socket(AF_INET,SOCK_STREAM)
s.connect(("www.python.org",80))        # Connect
s.send("GET /index.html HTTP/1.0\n\n")  # Send request
data = s.recv(10000)                    # Get response
s.close()
```

- s.connect(addr) makes a connection

```
s.connect(("www.python.org",80))
```

- Once connected, use send(),recv() to transmit and receive data
- close() shuts down the connection

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Exercise 1.1

Time : 10 Minutes

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Server Implementation

- Network servers are a bit more tricky
- Must listen for incoming connections on a well-known port number
- Typically run forever in a server-loop
- May have to service multiple clients

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TCP Server

- A simple server

```
from socket import *
s = socket(AF_INET,SOCK_STREAM)
s.bind(("",9000))
s.listen(5)
while True:
    c,a = s.accept()
    print "Received connection from", a
    c.send("Hello %s\n" % a[0])
    c.close()
```

- Send a message back to a client

```
% telnet localhost 9000
Connected to localhost.
Escape character is '^]'.
Hello 127.0.0.1
Connection closed by foreign host.
%
```

Server message

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TCP Server

- Address binding

```
from socket import *
s = socket(AF_INET,SOCK_STR
s.bind(("",9000))
s.listen(5)
while True:
    c,a = s.accept()
    print "Received connection from", a
    c.send("Hello %s\n" % a[0])
    c.close()
```

binds the socket to a specific address

- Addressing

binds to localhost

```
s.bind(("",9000))
s.bind(("localhost",9000))
s.bind(("192.168.2.1",9000))
s.bind(("104.21.4.2",9000))
```

If system has multiple IP addresses, can bind to a specific address

TCP Server

- Start listening for connections

```
from socket import *
s = socket(AF_INET,SOCK_STREAM)
s.bind(("",9000))
s.listen(5)
while True:
    c,a = s.accept()
    print "Received connection from", a
    c.send("Hello %s\n" % a[0])
    c.close()
```

Tells operating system to start listening for connections on the socket

- s.listen(*backlog*)
- backlog is # of pending connections to allow
- Note: not related to max number of clients

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TCP Server

- Accepting a new connection

```
from socket import *
s = socket(AF_INET,SOCK_STREAM)
s.bind(("",9000))
s.listen(5)
while True:
    c,a = s.accept()
    print "Received connection from", a
    c.send("Hello %s\n" % a[0])
    c.close()
```

Accept a new client connection

- s.accept() blocks until connection received
- Server sleeps if nothing is happening

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TCP Server

- Client socket and address

```
from socket import *
s = socket(AF_INET,SOCK_STREAM)
s.bind(("",9000))
s.listen(5)
while True:
    c,a = s.accept()
    print "Received connection from", a
    c.send("Hello %s\n" % a[0])
    c.close()
```

Accept returns a pair (client_socket,addr)

`<socket._socketobject object at 0x3be30>`

This is a new socket that's used for data

`("104.23.11.4",27743)`

This is the network/port address of the client that connected

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TCP Server

- Sending data

```
from socket import *
s = socket(AF_INET,SOCK_STREAM)
s.bind(("",9000))
s.listen(5)
while True:
    c,a = s.accept()
    print "Received connection from", a
    c.send("Hello %s\n" % a[0])
    c.close()
```

Send data to client

Note: Use the client socket for transmitting data. The server socket is only used for accepting new connections.

TCP Server

- Closing the connection

```
from socket import *
s = socket(AF_INET,SOCK_STREAM)
s.bind(("",9000))
s.listen(5)
while True:
    c,a = s.accept()
    print "Received connection from", a
    c.send("Hello %s\n" % a[0])
    c.close()
```

Close client connection

- Note: Server can keep client connection alive as long as it wants
- Can repeatedly receive/send data

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TCP Server

- Waiting for the next connection

```
from socket import *
s = socket(AF_INET,SOCK_STREAM)
s.bind(("",9000))
s.listen(5)
while True:
    c,a = s.accept()
    print "Received connection from", a
    c.send("Hello %s\n" % a[0])
    c.close()
```

Wait for next connection

- Original server socket is reused to listen for more connections
- Server runs forever in a loop like this

Exercise 1.2

Time : 20 Minutes

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Advanced Sockets

- Socket programming is often a mess
- Huge number of options
- Many corner cases
- Many failure modes/reliability issues
- Will briefly cover a few critical issues

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Partial Reads/Writes

- Be aware that reading/writing to a socket may involve partial data transfer
- send() returns actual bytes sent
- recv() length is only a maximum limit

```
>>> len(data)
1000000
>>> s.send(data)
37722
>>>

>>> data = s.recv(10000)
>>> len(data)
6420
>>>
```

Sent partial data

Received less than max

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Partial Reads/Writes

- Be aware that for TCP, the data stream is continuous---no concept of records, etc.

```
# Client
...
s.send(data)
s.send(moredata)
...


# Server
...
data = s.recv(maxsize)
...
```

This recv() may return data from both of the sends combined or less data than even the first send

- A lot depends on OS buffers, network bandwidth, congestion, etc.

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Sending All Data

- To wait until all data is sent, use sendall()

```
s.sendall(data)
```

- Blocks until all data is transmitted
- For most normal applications, this is what you should use
- Exception :You don't use this if networking is mixed in with other kinds of processing (e.g., screen updates, multitasking, etc.)

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End of Data

- How to tell if there is no more data?
- recv() will return empty string

```
>>> s.recv(1000)
''
>>>
```

- This means that the other end of the connection has been closed (no more sends)

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Data Reassembly

- Receivers often need to reassemble messages from a series of small chunks
- Here is a programming template for that

```
fragments = []                # List of chunks
while not done:
     chunk = s.recv(maxsize)  # Get a chunk
     if not chunk:
         break                # EOF. No more data
     fragments.append(chunk)

# Reassemble the message
message = "".join(fragments)
```

- Don't use string concat (+=). It's slow.

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Timeouts

- Most socket operations block indefinitely
- Can set an optional timeout

```
s = socket(AF_INET, SOCK_STREAM)
...
s.settimeout(5.0)    # Timeout of 5 seconds
...
```

- Will get a timeout exception

```
>>> s.recv(1000)
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
socket.timeout: timed out
>>>
```

- Disabling timeouts

```
s.settimeout(None)
```

Non-blocking Sockets

- Instead of timeouts, can set non-blocking

```
>>> s.setblocking(False)
```

- Future send(),recv() operations will raise an exception if the operation would have blocked

```
>>> s.setblocking(False)
>>> s.recv(1000)
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
socket.error: (35, 'Resource temporarily unavailable')
>>> s.recv(1000)
'Hello World\n'
>>>
```

No data available

Data arrived

- Sometimes used for polling

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Socket Options

- Sockets have a large number of parameters
- Can be set using s.setsockopt()
- Example: Reusing the port number

```
>>> s.bind(("",9000))
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
  File "<string>", line 1, in bind
socket.error: (48, 'Address already in use')
>>> s.setsockopt(socket.SOL_SOCKET,
...               socket.SO_REUSEADDR, 1)
>>> s.bind(("",9000))
>>>
```

- Consult reference for more options

Sockets as Files

- Sometimes it is easier to work with sockets represented as a "file" object

```
f = s.makefile()
```

- This will wrap a socket with a file-like API

```
f.read()
f.readline()
f.write()
f.writelines()
for line in f:
    ...
f.close()
```

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Sockets as Files

- Commentary : From personal experience, putting a file-like layer over a socket rarely works as well in practice as it sounds in theory.
- Tricky resource management (must manage both the socket and file independently)
- It's easy to write programs that mysteriously "freeze up" or don't operate quite like you would expect.

Exercise 1.3

Time : 15 Minutes

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Odds and Ends

- Other supported socket types
  - Datagram (UDP) sockets
  - Unix domain sockets
  - Raw sockets/Packets
- Sockets and concurrency
- Useful utility functions

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UDP : Datagrams

- Data sent in discrete packets (Datagrams)
- No concept of a "connection"
- No reliability, no ordering of data
- Datagrams may be lost, arrive in any order
- Higher performance (used in games, etc.)

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UDP Server

- A simple datagram server

```
from socket import *
s = socket(AF_INET,SOCK_DGRAM)

s.bind(("",10000))

while True:
    data, addr = s.recvfrom(maxsize)

    resp = "Get off my lawn!"
    s.sendto(resp,addr)
```

Create datagram socket

Bind to a specific port

Wait for a message

Send response (optional)

- No "connection" is established
- It just sends and receives packets

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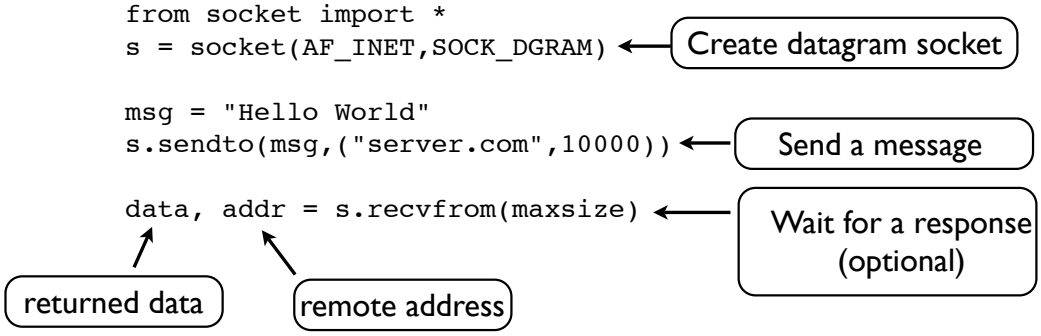
UDP Client

- Sending a datagram to a server

```
from socket import *
s = socket(AF_INET,SOCK_DGRAM)

msg = "Hello World"
s.sendto(msg,("server.com",10000))

data, addr = s.recvfrom(maxsize)
```



- Key concept: No "connection"
- You just send a data packet

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Unix Domain Sockets

- Available on Unix based systems. Sometimes used for fast IPC or pipes between processes
- Creation:

```
s = socket(AF_UNIX, SOCK_STREAM)
s = socket(AF_UNIX, SOCK_DGRAM)
```

- Address is just a "filename"

```
s.bind("/tmp/foo")          # Server binding
s.connect("/tmp/foo")       # Client connection
```

- Rest of the programming interface is the same

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Raw Sockets

- If you have root/admin access, can gain direct access to raw network packets
- Depends on the system
- Example: Linux packet sniffing

```
s = socket(AF_PACKET, SOCK_DGRAM)
s.bind(("eth0",0x0800))   # Sniff IP packets

while True:
    msg,addr = s.recvfrom(4096)  # get a packet
    ...
```

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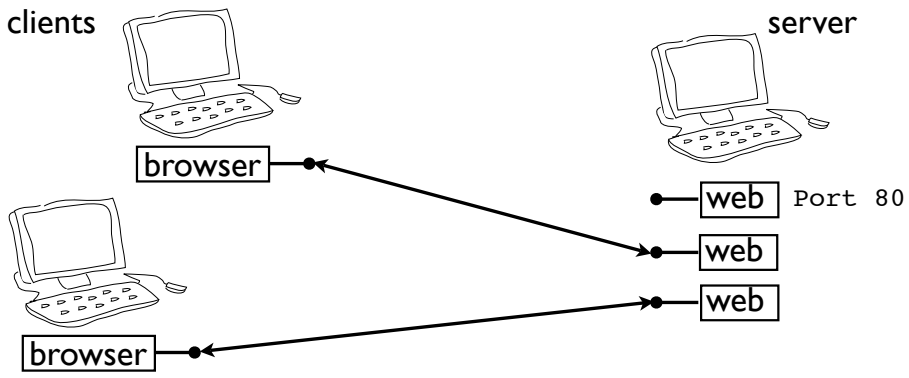
Sockets and Concurrency

- Servers usually handle multiple clients



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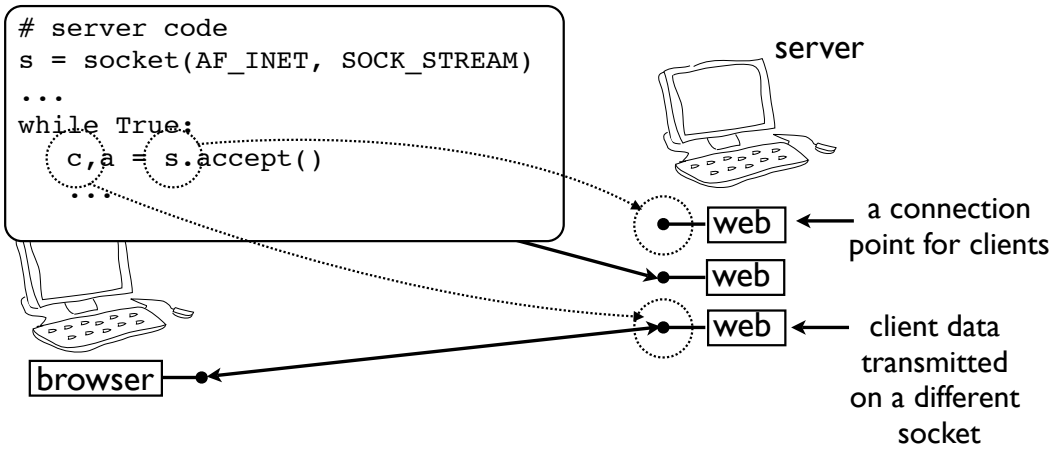
Sockets and Concurrency

- Each client gets its own socket on server



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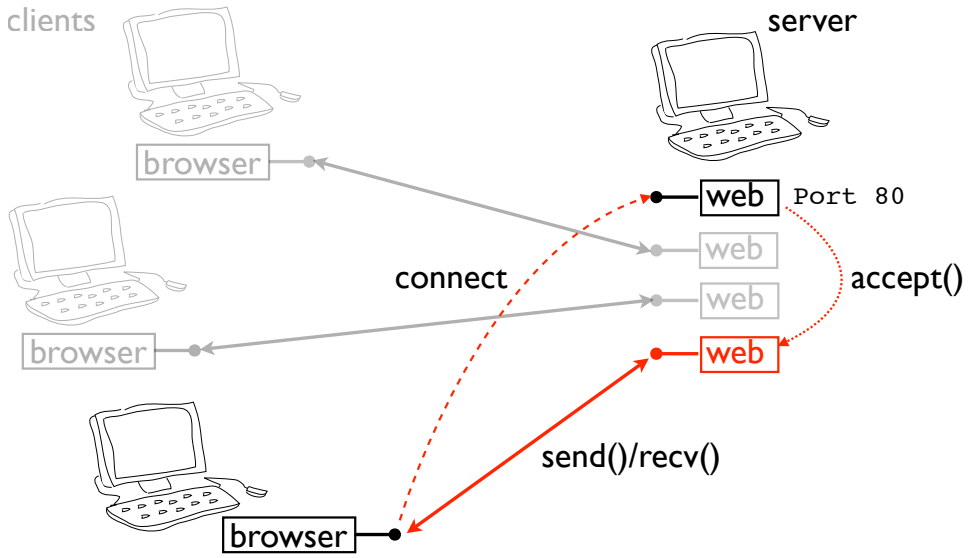
Sockets and Concurrency

- New connections make a new socket



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Sockets and Concurrency

- To manage multiple clients,
  - Server must always be ready to accept new connections
  - Must allow each client to operate independently (each may be performing different tasks on the server)
- Will briefly outline the common solutions

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Threaded Server

- Each client is handled by a separate thread

```
import threading
from socket import *

def handle_client(c):
    ... whatever ...
    c.close()
    return

s = socket(AF_INET,SOCK_STREAM)
s.bind(("",9000))
s.listen(5)
while True:
    c,a = s.accept()
    t = threading.Thread(target=handle_client,
                         args=(c,))
```

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Forking Server (Unix)

- Each client is handled by a subprocess

```
import os
from socket import *
s = socket(AF_INET,SOCK_STREAM)
s.bind(("",9000))
s.listen(5)
while True:
    c,a = s.accept()
    if os.fork() == 0:
        # Child process.  Manage client
        ...
        c.close()
        os._exit(0)
    else:
        # Parent process. Clean up and go
        # back to wait for more connections
        c.close()
```

- Note: Omitting some critical details

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Asynchronous Server

- Server handles all clients in an event loop

```
import select
from socket import *
s = socket(AF_INET,SOCK_STREAM)
...
clients = []  # List of all active client sockets
while True:
    # Look for activity on any of my sockets
    input,output,err = select.select(s+clients,
                                     clients, clients)
    # Process all sockets with input
    for i in input:
        ...
    # Process all sockets ready for output
    for o in output:
        ...
```

- Frameworks such as Twisted build upon this

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Utility Functions

- Get the hostname of the local machine

```
>>> socket.gethostname()
'foo.bar.com'
>>>
```

- Get the IP address of a remote machine

```
>>> socket.gethostbyname("www.python.org")
'82.94.237.218'
>>>
```

- Get name information on a remote IP

```
>>> socket.gethostbyaddr("82.94.237.218")
('dinsdale.python.org', [], ['82.94.237.218'])
>>>
```

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Omissions

- socket module has hundreds of obscure socket control options, flags, etc.
- Many more utility functions
- IPv6 (Supported, but new and hairy)
- Other socket types (SOCK_RAW, etc.)
- More on concurrent programming (covered in advanced course)

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Discussion

- It is often unnecessary to directly use sockets
- Other library modules simplify use
- However, those modules assume some knowledge of the basic concepts (addresses, ports, TCP, UDP, etc.)
- Will see more in the next few sections...

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Section 2

Client Programming

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Overview

- Python has library modules for interacting with a variety of standard internet services
- HTTP, FTP, SMTP, NNTP, XML-RPC, etc.
- In this section we're going to look at how some of these library modules work
- Main focus is on the web (HTTP)

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urllib Module

- A high level module that allows clients to connect a variety of internet services
  - HTTP
  - HTTPS
  - FTP
  - Local files
- Works with typical URLs on the web...

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urllib Module

- Open a web page: urlopen()

```
>>> import urllib
>>> u = urllib.urlopen("http://www.python/org/index.html")
>>> data = u.read()
>>> print data
<!DOCTYPE html PUBLIC "-//W3C//DTD XHTML ...
...
>>>
```

- urlopen() returns a file-like object
- Read from it to get downloaded data

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urllib protocols

- Supported protocols

```
u = urllib.urlopen("http://www.foo.com")
u = urllib.urlopen("https://www.foo.com/private")
u = urllib.urlopen("ftp://ftp.foo.com/README")
u = urllib.urlopen("file:///Users/beazley/blah.txt")
```

- Note: HTTPS only supported if Python configured with support for OpenSSL

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HTML Forms

- One use of urllib is to automate forms

- Example HTML source for the form

```
<FORM ACTION="/subscribe" METHOD="POST">
Your name: <INPUT type="text" name="name" size="30"><br>
Your email: <INPUT type="text" name="email" size="30"><br>
<INPUT type="submit" name="submit-button" value="Subscribe">
```

HTML Forms

- Within the form, you will find an action and named parameters for the form fields

```
<FORM ACTION="/subscribe" METHOD="POST">
Your name: <INPUT type="text" name="name" size="30"><br>
Your email: <INPUT type="text" name="email" size="30"><br>
<INPUT type="submit" name="submit-button" value="Subscribe">
```

- Action (a URL)

```
http://somedomain.com/subscribe
```

- Parameters:

```
name
email
```

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Web Services

- Another use of urllib is to access web services
  - Downloading maps
  - Stock quotes
  - Email messages
- Most of these are controlled and accessed in the same manner as a form
- There is a particular request and expected set of parameters for different operations

Parameter Encoding

- urlencode()
- Takes a dictionary of fields and creates a URL-encoded string of parameters

```
fields = {
   'name' : 'Dave',
   'email' : 'dave@dabeaz.com'
}

parms = urllib.urlencode(fields)
```

- Sample result

```
>>> parms
'name=Dave&email=dave%40dabeaz.com'
>>>
```

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Sending Parameters

- Case 1 : GET Requests

```
<FORM ACTION="/subscribe" METHOD="GET">
Your name: <INPUT type="text" name="name" size="30"><br>
Your email: <INPUT type="text" name="email" size="30"><br>
<INPUT type="submit" name="submit-button" value="Subscribe">
```

- Example code:

```
fields = { ... }
parms = urllib.urlencode(fields)
u = urllib.urlopen("http://somedomain.com/subscribe?"+parms)
```

You create a long URL by concatenating the request with the parameters

```
http://somedomain.com/subscribe?name=Dave&email=dave%40dabeaz.com
```

Sending Parameters

- Case 2 : POST Requests

```
<FORM ACTION="/subscribe" METHOD="POST">
Your name: <INPUT type="text" name="name" size="30"><br>
Your email: <INPUT type="text" name="email" size="30"><br>
<INPUT type="submit" name="submit-button" value="Subscribe">
```

- Example code:

```
fields = { ... }
parms = urllib.urlencode(fields)
u = urllib.urlopen("http://somedomain.com/subscribe", parms)
```

Parameters get uploaded separately as part of the request body

```
POST /subscribe HTTP/1.0
...
name=Dave&email=dave%40dabeaz.com
```

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Response Data

- To read response data, treat the result of urlopen() as a file object

```
>>> u = urllib.urlopen("http://www.python.org")
>>> data = u.read()
>>>
```

- Be aware that the response data consists of the raw bytes transmitted
- If there is any kind of extra encoding (e.g., Unicode), you will need to decode the data with extra processing steps.

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Response Headers

- HTTP headers are retrieved using .info()

```
>>> u = urllib.urlopen("http://www.python.org")
>>> headers = u.info()
>>> headers
<httplib.HTTPMessage instance at 0x1118828>
>>> headers.keys()
['content-length', 'accept-ranges', 'server',
'last-modified', 'connection', 'etag', 'date',
'content-type']
>>> headers['content-length']
'13597'
>>> headers['content-type']
'text/html'
>>>
```

- A dictionary-like object

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Response Status

- urlopen() ignores HTTP status codes (i.e., errors are silently ignored)
- Can manually check the response code

```
u = urllib.urlopen("http://www.python.org/java")
if u.code == 200:
    # success
    ...
elif u.code == 404:
    # Not found!
    ...
elif u.code == 403:
    # Forbidden
    ...
```

- Unfortunately a little clumsy (fixed shortly)

Exercise 2.1

Time : 15 Minutes

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urllib Limitations

- urllib only works with simple cases
- Does not support cookies
- Does not support authentication
- Does not report HTTP errors gracefully
- Only supports GET/POST requests

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urllib2 Module

- urllib2 - The sequel to urllib
- Builds upon and expands urllib
- Can interact with servers that require cookies, passwords, and other details
- Better error handling (uses exceptions)
- Is the preferred library for modern code

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urllib2 Example

- urllib2 provides urlopen() as before

```
>>> import urllib2
>>> u = urllib2.urlopen("http://www.python.org/index.html")
>>> data = u.read()
>>>
```

- However, the module expands functionality in two primary areas
  - Requests
  - Openers

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urllib2 Requests

- Requests are now objects

```
>>> r = urllib2.Request("http://www.python.org")
>>> u = urllib2.urlopen(r)
>>> data = u.read()
```

- Requests can have additional attributes added
- User data (for POST requests)
- Customized HTTP headers

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Requests with Data

- Create a POST request with user data

```
data = {
   'name' : 'dave',
   'email' : 'dave@dabeaz.com'
}

r = urllib2.Request("http://somedomain.com/subscribe",
                    urllib.urlencode(data))
u = urllib2.urlopen(r)
response = u.read()
```

- Note :You still use urllib.urlencode() from the older urllib library

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Request Headers

- Adding/Modifying client HTTP headers

```
headers = {
   'User-Agent' : 'Mozilla/4.0 (compatible; MSIE 7.0;
Windows NT 5.1; .NET CLR 2.0.50727)'
}

r = urllib2.Request("http://somedomain.com/",
                    headers=headers)
u = urllib2.urlopen(r)
response = u.read()
```

- This can be used if you need to emulate a specific client (e.g., Internet Explorer, etc.)

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urllib2 Error Handling

- HTTP Errors are reported as exceptions

```
>>> u = urllib2.urlopen("http://www.python.org/perl")
Traceback...
urllib2.HTTPError: HTTP Error 404: Not Found
>>>
```

- Catching an error

```
try:
   u = urllib2.urlopen(url)
except urllib2.HTTPError,e:
   code = e.code      # HTTP error code
```

- Note: urllib2 automatically tries to handle redirection and certain HTTP responses

urllib2 Openers

- The function urlopen() is an "opener"
- It knows how to open a connection, interact with the server, and return a response.
- It only has a few basic features---it does not know how to deal with cookies and passwords
- However, you can make your own opener objects with these features enabled

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urllib2 build_opener()

- build_opener() makes an custom opener

```
# Make a URL opener with cookie support
opener = urllib2.build_opener(
            urllib2.HTTPCookieProcessor()
)
u = opener.open("http://www.python.org/index.html")
```

- Can add a set of new features from this list

```
CacheFTPHandler
HTTPBasicAuthHandler
HTTPCookieProcessor
HTTPDigestAuthHandler
ProxyHandler
ProxyBasicAuthHandler
ProxyDigestAuthHandler
```

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Example : Login Cookies

```
fields = {
    'txtUsername' : 'dave',
    'txtPassword' : '12345',
    'submit_login' : 'Log In'
}
opener = urllib2.build_opener(
           urllib2.HTTPCookieProcessor()
         )
request = urllib2.Request(
      "http://somedomain.com/login.asp",
      urllib.urlencode(fields))

# Login
u = opener.open(request)
resp = u.read()

# Get a page, but use cookies returned by initial login
u = opener.open("http://somedomain.com/private.asp")
resp = u.read()
```

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Discussion

- urllib2 module has a huge number of options
- Different configurations
- File formats, policies, authentication, etc.
- Will have to consult reference for everything

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Exercise 2.2

Time : 15 Minutes

Password: guido456

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Limitations

- urllib and urllib2 are useful for fetching files
- However, neither module provides support for more advanced operations
- Examples:
  - Uploading to an FTP server
  - File-upload via HTTP Post
  - Other HTTP methods (e.g., HEAD, PUT)

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ftplib

- A module for interacting with FTP servers
- Example : Capture a directory listing

```
>>> import ftplib
>>> f = ftplib.FTP("ftp.gnu.org","anonymous",
...                "dave@dabeaz.com")
>>> files = []
>>> f.retrlines("LIST",files.append)
'226 Directory send OK.'
>>> len(files)
15
>>> files[0]
'-rw-r--r--    1 0    0       1765 Feb 20 16:47 README'
>>>
```

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Upload to a FTP Server

```
host     = "ftp.foo.com"
username = "dave"
password = "1235"
filename = "somefile.dat"

import ftplib
ftp_serv = ftplib.FTP(host,username,password)

# Open the file you want to send
f = open(filename,"rb")

# Send it to the FTP server
resp = ftp_serv.storbinary("STOR "+filename, f)

# Close the connection
ftp_serv.close()
```

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httplib

- A module for implementing the client side of an HTTP connection

```
import httplib
c = httplib.HTTPConnection("www.python.org",80)
c.putrequest("HEAD","/tut/tut.html")
c.putheader("Someheader","Somevalue")
c.endheaders()

r = c.getresponse()
data = r.read()
c.close()
```

- Low-level control over HTTP headers, methods, data transmission, etc.

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smtplib

- A module for sending email messages

```
import smtplib
serv = smtplib.SMTP()
serv.connect()

msg = """\
From: dave@dabeaz.com
To: bob@yahoo.com
Subject: Get off my lawn!

Blah blah blah"""

serv.sendmail("dave@dabeaz.com",['bob@yahoo.com'],msg)
```

- Useful if you want to have a program send you a notification, send email to customers, etc.

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Exercise 2.3

Time : 15 Minutes

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Section 3

Internet Data Handling

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Overview

- If you write network clients, you will have to worry about a variety of common file formats
- CSV, HTML, XML, JSON, etc.
- In this section, we briefly look at library support for working with such data

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CSV Files

- Comma Separated Values

```
Elwood,Blues,"1060 W Addison,Chicago 60637",110
McGurn,Jack,"4902 N Broadway,Chicago 60640",200
```

- Parsing with the CSV module

```
import csv
f = open("schmods.csv","r")
for row in csv.reader(f):
    # Do something with items in row
    ...
```

- Understands quoting, various subtle details

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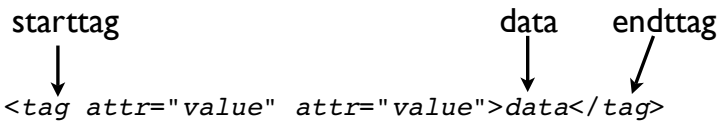
Parsing HTML

- Suppose you want to parse HTML (maybe obtained via urlopen)
- Use the HTMLParser module
- A library that processes HTML using an "event-driven" programming style

Parsing HTML

- Define a class that inherits from HTMLParser and define a set of methods that respond to different document features

```
from HTMLParser import HTMLParser
class MyParser(HTMLParser):
    def handle_starttag(self,tag,attrs):
        ...
    def handle_data(self,data):
        ...
    def handle_endtag(self,tag):
        ...
```



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Running a Parser

- To run the parser, you create a parser object and feed it some data

```
# Fetch a web page
import urllib
u = urllib.urlopen("http://www.example.com")
data = u.read()

# Run it through the parser
p = MyParser()
p.feed(data)
```

- The parser will scan through the data and trigger the various handler methods

HTML Example

- An example: Gather all links

```
from HTMLParser import HTMLParser
class GatherLinks(HTMLParser):
    def __init__(self):
        HTMLParser.__init__(self)
        self.links = []
    def handle_starttag(self,tag,attrs):
        if tag == 'a':
           for name,value in attrs:
               if name == 'href':
                   self.links.append(value)
```

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HTML Example

- Running the parser

```
>>> parser = GatherLinks()
>>> import urllib
>>> data = urllib.urlopen("http://www.python.org").read()
>>> parser.feed(data)
>>> for x in parser.links:
...      print x
/search/
/about
/news/
/doc/
/download/
...
>>>
```

XML Parsing with SAX

- The event-driven style used by HTMLParser is sometimes used to parse XML
- Basis of the SAX parsing interface
- An approach sometimes seen when dealing with large XML documents since it allows for incremental processing

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Brief XML Refresher

- XML documents use structured markup

```
<contact>
  <name>Elwood Blues</name>
  <address>1060 W Addison</address>
  <city>Chicago</city>
  <zip>60616</zip>
</contact>
```

- Documents made up of elements

```
<name>Elwood Blues</name>
```

- Elements have starting/ending tags
- May contain text and other elements

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SAX Parsing

- Define a special handler class

```
import xml.sax

class MyHandler(xml.sax.ContentHandler):
    def startDocument(self):
        print "Document start"
    def startElement(self,name,attrs):
        print "Start:", name
    def characters(self,text):
        print "Characters:", text
    def endElement(self,name):
        print "End:", name
```

- In the class, you define methods that capture elements and other parts of the document

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SAX Parsing

- To parse a document, you create an instance of the handler and give it to the parser

```
# Create the handler object
hand = MyHandler()

# Parse a document using the handler
xml.sax.parse("data.xml",hand)
```

- This reads the file and calls handler methods as different document elements are encountered (start tags, text, end tags, etc.)

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Exercise 3.1

Time : 15 Minutes

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XML and ElementTree

- xml.etree.ElementTree module is one of the easiest ways to parse XML
- Lets look at the highlights

etree Parsing Basics

- Parsing a document

```
from xml.etree.ElementTree import parse
doc = parse("recipe.xml")
```

- This builds a complete parse tree of the entire document
- To extract data, you will perform various kinds of queries on the document object

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etree Parsing Basics

- A mini-reference for extracting data
- Finding one or more elements

```
elem  = doc.find("title")
for elem in doc.findall("ingredients/item"):
    statements
```

- Element attributes and properties

```
elem.tag                    # Element name
elem.text                   # Element text
elem.get(aname [,default])  # Element attributes
```

Obtaining Elements

```
<?xml version="1.0" encoding="iso-8859-1"?>
<recipe>
  <title>Famous Guacamole</title>
  <description>
    A southwest favorite!
  </description>
  <ingredients>
      <item num="2">La
      <item num="1">To
      <item num="1/2"
      <item num="1" un
      <item num="1">Ja
      <item num="1" un
      <item num="3" un
      <item num="6" un
  </ingredients>
  <directions>
    Combine all ingredients and hand whisk to desired consistency.
    Serve and enjoy with ice-cold beers.
  </directions>
</recipe>
```

```
doc = parse("recipe.xml")
desc_elem = doc.find("description")
desc_text = desc_elem.text
```

or

```
doc = parse("recipe.xml")
desc_text = doc.findtext("description")
```

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Iterating over Elements

```
<?xml version="1.
<recipe>
  <title>Famous G
   <description>
     A southwest
   </description>
   <ingredients>
      <item num="2">Large avocados, chopped</item>
      <item num="1">Tomato, chopped</item>
      <item num="1/2" units="C">White onion, chopped</item>
      <item num="1" units="tbl">Fresh squeezed lemon juice</item>
      <item num="1">Jalapeno pepper, diced</item>
      <item num="1" units="tbl">Fresh cilantro, minced</item>
      <item num="3" units="tsp">Sea Salt</item>
      <item num="6" units="bottles">Ice-cold beer</item>
   </ingredients>
   <directions>
     Combine all ingredients and hand whisk to desired consistency.
     Serve and enjoy with ice-cold beers.
   </directions>
</recipe>
```

```
doc = parse("recipe.xml")
for item in doc.findall("ingredients/item"):
      statements
```

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Element Attributes

```
<?xml version="1.0" encoding="iso-8859-1"?>
<recipe>
  <title>Famous Guacamole</title>
   <description>
     A southwest favorite!
   </description>
   <ingredients>
```

```
for item in doc.findall("ingredients/item"):
    num   = item.get("num")
    units = item.get("units")
```

```
      <item num="1" units="tbl">Fresh cilantro, minced</item>
      <item num="3" units="tsp">Sea Salt</item>
      <item num="6" units="bottles">Ice-cold beer</item>
   </ingredients>
   <directions>
     Combine all ingredients and hand whisk to desired consistency.
     Serve and enjoy with ice-cold beers.
   </directions>
</recipe>
```

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Search Wildcards

- Specifying a wildcard for an element name

```
items = doc.findall("*/item")
items = doc.findall("ingredients/*")
```

- The * wildcard only matches a single element
- Use multiple wildcards for nesting

```
<?xml version="1.0"?>
<top>
    <a>
       <b>
          <c>text</c>
       </b>
    </a>
</top>
```

```
c = doc.findall("*/*/c")
c = doc.findall("a/*/c")
c = doc.findall("*/b/c")
```

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Search Wildcards

- Wildcard for multiple nesting levels (//)

```
items = doc.findall("//item")
```

- More examples

```
<?xml version="1.0"?>
<top>
    <a>
       <b>
          <c>text</c>
       </b>
    </a>
</top>
```

```
c = doc.findall("//c")
c = doc.findall("a//c")
```

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cElementTree

- There is a C implementation of the library that is significantly faster

```
import xml.etree.cElementTree
doc = xml.etree.cElementTree.parse("data.xml")
```

- For all practical purposes, you should use this version of the library given a choice
- Note : The C version lacks a few advanced customization features, but you probably won't need them

Tree Modification

- ElementTree allows modifications to be made to the document structure
- To add a new child to a parent node

```
node.append(child)
```

- To insert a new child at a selected position

```
node.insert(index,child)
```

- To remove a child from a parent node

```
node.remove(child)
```

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Tree Output

- If you modify a document, it can be rewritten
- There is a method to write XML

```
doc = xml.etree.ElementTree.parse("input.xml")
# Make modifications to doc
...
# Write modified document back to a file
f = open("output.xml","w")
doc.write(f)
```

- Individual elements can be turned into strings

```
s = xml.etree.ElementTree.tostring(node)
```

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Iterative Parsing

- An alternative parsing interface

```
from xml.etree.ElementTree import iterparse
parse = iterparse("file.xml", ('start','end'))

for event, elem in parse:
    if event == 'start':
         # Encountered an start <tag ...>
         ...
    elif event == 'end':
         # Encountered an end </tag>
         ...
```

- This sweeps over an entire XML document
- Result is a sequence of start/end events and element objects being processed

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Iterative Parsing

- If you combine iterative parsing and tree modification together, you can process large XML documents with almost no memory overhead
- Programming interface is significantly easier to use than a similar approach using SAX
- General idea : Simply throw away the elements no longer needed during parsing

Iterative Parsing

- Programming pattern

```
from xml.etree.ElementTree import iterparse
parser = iterparse("file.xml",('start','end'))

for event,elem in parser:
    if event == 'start':
        if elem.tag == 'parenttag':
            parent = elem
    if event == 'end':
        if elem.tag == 'tagname':
            # process element with tag 'tagname'
            ...
            # Discard the element when done
            parent.remove(elem)
```

- The last step is the critical part

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Exercise 3.2

Time : 15 Minutes

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JSON

- Javascript Object Notation
- A data encoding commonly used on the web when interacting with Javascript
- Sometime preferred over XML because it's less verbose and faster to parse
- Syntax is almost identical to a Python dict

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Sample JSON File

```
{
  "recipe" : {
      "title" : "Famous Guacomole",
      "description" : "A southwest favorite!",
      "ingredients" : [
           {"num": "2", "item":"Large avocados, chopped"},
           {"num": "1/2", "units":"C", "item":"White onion, chopped"},
           {"num": "1", "units":"tbl", "item":"Fresh squeezed lemon juice"},
           {"num": "1", "item":"Jalapeno pepper, diced"},
           {"num": "1", "units":"tbl", "item":"Fresh cilantro, minced"},
           {"num": "3", "units":"tsp", "item":"Sea Salt"},
           {"num": "6", "units":"bottles","item":"Ice-cold beer"}
       ],
      "directions" : "Combine all ingredients and hand whisk to desired
consistency. Serve and enjoy with ice-cold beers."
  }
}
```

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Processing JSON Data

- Parsing a JSON document

```
import json
doc = json.load(open("recipe.json"))
```

- Result is a collection of nested dict/lists

```
ingredients = doc['recipe']['ingredients']
for item in ingredients:
     # Process item
     ...
```

- Dumping a dictionary as JSON

```
f = open("file.json","w")
json.dump(doc,f)
```

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Exercise 3.3

Time : 15 Minutes

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Section 4

Web Programming Basics

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Introduction

- The web is (obviously) so pervasive, knowing how to write simple web-based applications is basic knowledge that all programmers should know about
- In this section, we cover the absolute basics of how to make a Python program accessible through the web

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Overview

- Some basics of Python web programming
- HTTP Protocol
- CGI scripting
- WSGI (Web Services Gateway Interface)
- Custom HTTP servers

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Disclaimer

- Web programming is a huge topic that could span an entire multi-day class
- It might mean different things
  - Building an entire website
  - Implementing a web service
- Our focus is on some basic mechanisms found in the Python standard library that all Python programmers should know about

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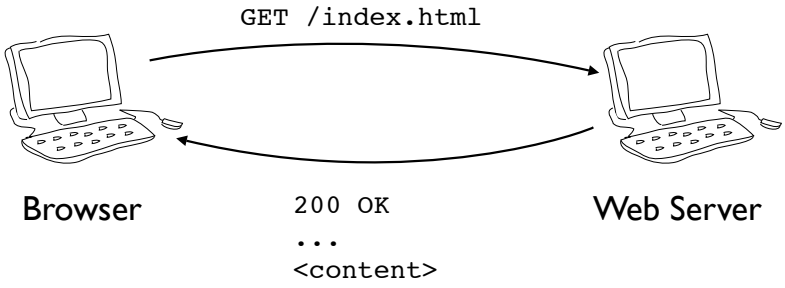
HTTP Explained

- HTTP is the underlying protocol of the web
- Consists of requests and responses



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HTTP Client Requests

- Client (Browser) sends a request

```
GET /index.html HTTP/1.1
Host: www.python.org
User-Agent: Mozilla/5.0 (Macintosh; U; Intel Mac OS X; en-U
Accept: text/xml,application/xml,application/xhtml+xml,text
Accept-Language: en-us,en;q=0.5
Accept-Encoding: gzip,deflate
Accept-Charset: ISO-8859-1,utf-8;q=0.7,*;q=0.7
Keep-Alive: 300
Connection: keep-alive
<blank line>
```

- Request line followed by headers that provide additional information about the client

HTTP Responses

- Server sends back a response

```
HTTP/1.1 200 OK
Date: Thu, 26 Apr 2007 19:54:01 GMT
Server: Apache/2.0.54 (Debian GNU/Linux) DAV/2 SVN/1.1.4 mo
Last-Modified: Thu, 26 Apr 2007 18:40:24 GMT
Accept-Ranges: bytes
Content-Length: 14315
Connection: close
Content-Type: text/html

<HTML>
...
```

- Response line followed by headers that further describe the response contents

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HTTP Protocol

- There are a small number of request types

```
GET
POST
HEAD
PUT
```

- There are standardized response codes

```
200 OK
403 Forbidden
404 Not Found
501 Not implemented
...
```

- But, this isn't an exhaustive tutorial

Content Encoding

- Content is described by these header fields:

```
Content-type:
Content-length:
```

- Example:

```
Content-type: image/jpeg
Content-length: 12422
```

- Of these, Content-type is the most critical
- Length is optional, but it's polite to include it if it can be determined in advance

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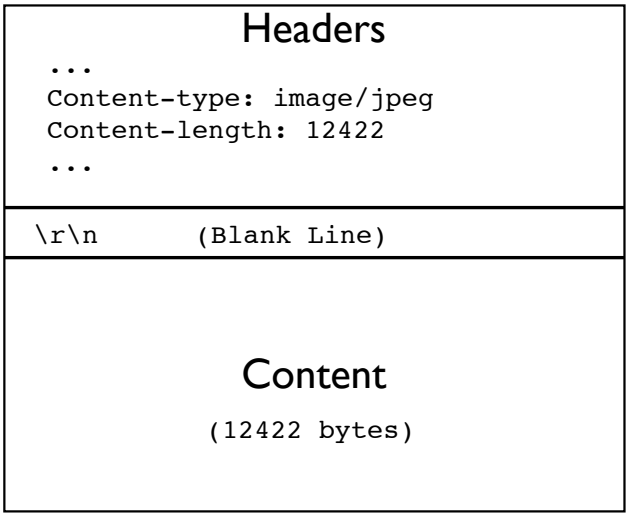
Payload Packaging

- Responses must follow this formatting



Exercise 4.1

Time : 10 Minutes

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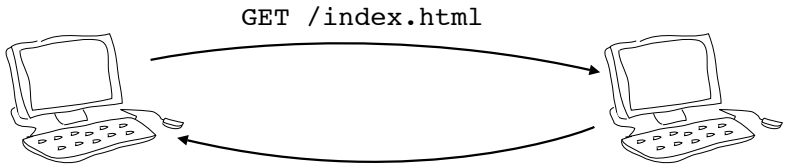
Role of Python

- Most web-related Python programming pertains to the operation of the server



Firefox
Safari
Internet Explorer
etc.

Web Server

```
Apache
Python
MySQL
etc.
```

- Python scripts used on the server to create, manage, or deliver content back to clients

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Typical Python Tasks

- Static content generation. One-time generation of static web pages to be served by a standard web server such as Apache.
- Dynamic content generation. Python scripts that produce output in response to requests (e.g., form processing, CGI scripting).

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Content Generation

- It is often overlooked, but Python is a useful tool for simply creating static web pages
- Example : Taking various pages of content, adding elements, and applying a common format across all of them.
- Web server simply delivers all of the generated content as normal files

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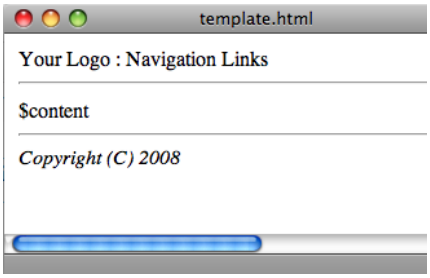
Example : Page Templates

- Create a page "template" file

```
<html>
  <body>
    <table width=700>
      <tr><td>
      Your Logo : Navigation Links
      <hr>
      </td></tr>
      <tr><td>
      $content
      <hr>
      <em>Copyright (C) 2008</em>
      </td></tr>
    </table>
  </body>
</html>
```

Note the special $variable



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Example : Page Templates

- Use template strings to render pages

```
from string import Template

# Read the template string
pagetemplate = Template(open("template.html").read())

# Go make content
page = make_content()

# Render the template to a file
f = open(outfile,"w")
f.write(pagetemplate.substitute(content=page))
```

- Key idea : If you want to change the appearance, you just change the template

Commentary

- Using page templates to generate static content is extremely common
- For simple things, just use the standard library modules (e.g., string.Template)
- For more advanced applications, there are numerous third-party template packages

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Exercise 4.2

Time : 10 Minutes

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HTTP Servers

- Python comes with libraries that implement simple self-contained web servers
- Very useful for testing or special situations where you want web service, but don't want to install something larger (e.g., Apache)
- Not high performance, sometimes "good enough" is just that

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A Simple Web Server

- Serve files from a directory

```
from BaseHTTPServer import HTTPServer
from SimpleHTTPServer import SimpleHTTPRequestHandler
import os
os.chdir("/home/docs/html")
serv = HTTPServer(("",8080),SimpleHTTPRequestHandler)
serv.serve_forever()
```

- This creates a minimal web server
- Connect with a browser and try it out

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Exercise 4.3

Time : 10 Minutes

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A Web Server with CGI

- Serve files and allow CGI scripts

```
from BaseHTTPServer import HTTPServer
from CGIHTTPServer import CGIHTTPRequestHandler
import os
os.chdir("/home/docs/html")
serv = HTTPServer(("",8080),CGIHTTPRequestHandler)
serv.serve_forever()
```

- Executes scripts in "/cgi-bin" and "/htbin" directories in order to create dynamic content

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CGI Scripting

- Common Gateway Interface
- A common protocol used by existing web servers to run server-side scripts, plugins
- Example: Running Python, Perl, Ruby scripts under Apache, etc.
- Classically associated with form processing, but that's far from the only application

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CGI Example

- A web-page might have a form on it

Your name:
Your email:
Subscribe

- Here is the underlying HTML code

```
<FORM ACTION="/cgi-bin/subscribe.py" METHOD="POST">
Your name: <INPUT type="text" name="name" size="30"><br>
Your email: <INPUT type="text" name="email" size="30"><br>
<INPUT type="submit" name="submit-button" value="Subscribe">
```

Specifies a CGI program on the server

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CGI Example

- Forms have submitted fields or parameters

```
<FORM ACTION="/cgi-bin/subscribe.py" METHOD="POST">
Your name: <INPUT type="text" name="name" size="30"><br>
Your email: <INPUT type="text" name="email" size="30"><br>
<INPUT type="submit" name="submit-button" value="Subscribe">
```

- A request will include both the URL (cgi-bin/subscribe.py) along with the field values

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CGI Example

- Request encoding looks like this:

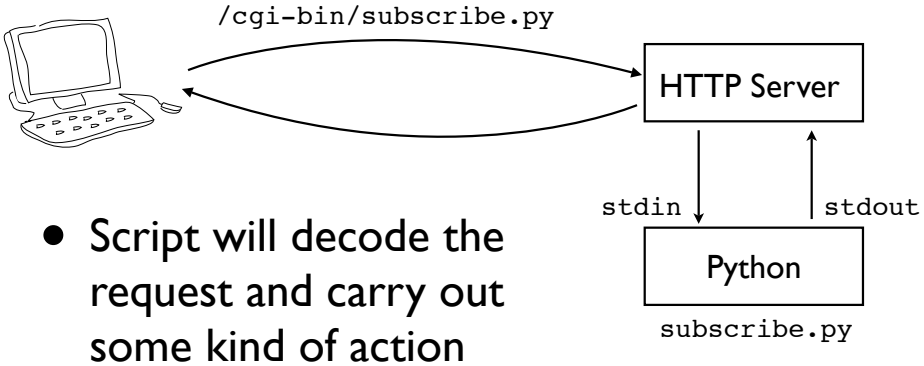
Request →
```
POST /cgi-bin/subscribe.py HTTP/1.1
User-Agent: Mozilla/5.0 (Macintosh; U; Intel Mac OS
Accept: text/xml,application/xml,application/xhtml
Accept-Language: en-us,en;q=0.5
...
```

Query String →
```
name=David+Beazley&email=dave%40dabeaz.com&submit-
button=Subscribe HTTP/1.1
```

- Request tells the server what to run
- Query string contains encoded form fields

CGI Mechanics

- CGI was originally implemented as a scheme for launching processing scripts as a subprocess to a web server



- Script will decode the request and carry out some kind of action

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Classic CGI Interface

- Server populates environment variables with information about the request

```
import os
os.environ['SCRIPT_NAME']
os.environ['REMOTE_ADDR']
os.environ['QUERY_STRING']
os.environ['REQUEST_METHOD']
os.environ['CONTENT_TYPE']
os.environ['CONTENT_LENGTH']
os.environ['HTTP_COOKIE']
...
```

- stdin/stdout provide I/O link to server

```
sys.stdin         # Read to get data sent by client
sys.stdout        # Write to create the response
```

CGI Query Variables

- For GET requests, an env. variable is used

```
query = os.environ['QUERY_STRING']
```

- For POST requests, you read from stdin

```
if os.environ['REQUEST_METHOD'] == 'POST':
    size = int(os.environ['CONTENT_LENGTH'])
    query = sys.stdin.read(size)
```

- This yields the raw query string

```
name=David+Beazley&email=dave
%40dabeaz.com&submit-button=Subscribe
```

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cgi Module

- A utility library for decoding requests
- Major feature: Getting the passed parameters

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

← Parse parameters

```
# Get various field values
name  = form.getvalue('name')
email = form.getvalue('email')
```

- All CGI scripts start like this
- FieldStorage parses the incoming request into a dictionary-like object for extracting inputs

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CGI Responses

- CGI scripts respond by simply printing response headers and the raw content

```
name = form.getvalue('name')
email = form.getvalue('email')
... do some kind of processing ...

# Output a response
print "Status: 200 OK"
print "Content-type: text/html"
print
print "<html><head><title>Success!</title></head><body>"
print "Hello %s, your email is %s" % (name,email)
print "</body>"
```

- Normally you print HTML, but any kind of data can be returned (for web services, you might return XML, JSON, etc.)

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Note on Status Codes

- In CGI, the server status code is set by including a special "Status:" header field

```
import cgi
form = cgi.FieldStorage()
name = form.getvalue('name')
email = form.getvalue('email')
...
print "Status: 200 OK"
print "Content-type: text/html"
print
print "<html><head><title>Success!</title></head><body>"
print "Hello %s, your email is %s" % (name,email)
print "</body>"
```

- This is a special server directive that sets the response status

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CGI Commentary

- There are many more minor details (consult a reference on CGI programming)
- The basic idea is simple
  - Server runs a script
  - Script receives inputs from environment variables and stdin
  - Script produces output on stdout
- It's old-school, but sometimes it's all you get

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Exercise 4.4

Time : 25 Minutes

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WSGI

- Web Services Gateway Interface (WSGI)
- This is a standardized interface for creating Python web services
- Allows one to create code that can run under a wide variety of web servers and frameworks as long as they also support WSGI (and most do)
- So, what is WSGI?

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WSGI Interface

- WSGI is an application programming interface loosely based on CGI programming
- In CGI, there are just two basic features
  - Getting values of inputs (env variables)
  - Producing output by printing
- WSGI takes this concept and repackages it into a more modular form

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WSGI Example

- With WSGI, you write an "application"
- An application is just a function (or callable)

```
def hello_app(environ, start_response):
    status = "200 OK"
    response_headers = [ ('Content-type','text/plain')]
    response = []

    start_response(status,response_headers)
    response.append("Hello World\n")
    response.append("You requested :"+environ['PATH_INFO]')
    return response
```

- This function encapsulates the handling of some request that will be received

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WSGI Applications

- Applications always receive just two inputs

```
def hello_app(environ, start_response):
    status = "200 OK"
    response_headers = [ ('Content-type','text/plain')]
    response = []

    start_response(status,response_headers)
    response.append("Hello World\n")
    response.append("You requested :"+environ['PATH_INFO]')
    return response
```

- environ - A dictionary of input parameters
- start_response - A callable (e.g., function)

WSGI Environment

- The environment contains CGI variables

```
def hello_app(environ, start_response):
    status = "200 OK"
    response_headers = [ ('Content-type','text/plain')]
```

```
environ['REQUEST_METHOD']
environ['SCRIPT_NAME']
environ['PATH_INFO']
environ['QUERY_STRING']
environ['CONTENT_TYPE']
environ['CONTENT_LENGTH']
environ['SERVER_NAME']
...
```

```
['PATH_INFO]')
```

- The meaning and values are exactly the same as in traditional CGI programs

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WSGI Environment

- Environment also contains some WSGI variables

```
def hello_app(environ, start_response):
    status = "200 OK"
    response_headers = [ ('Content-type','text/plain')]
```

```
environ['wsgi.input']
environ['wsgi.errors']
environ['wsgi.url_scheme']
environ['wsgi.multithread']
environ['wsgi.multiprocess']
...
```

```
['PATH_INFO]')
```

- wsgi.input - A file-like object for reading data
- wsgi.errors - File-like object for error output

Processing WSGI Inputs

- Parsing of query strings is similar to CGI

```
import cgi
def sample_app(environ,start_response):
    fields = cgi.FieldStorage(environ['wsgi.input'],
                              environ=environ)
    # fields now has the CGI query variables
    ...
```

- You use FieldStorage() as before, but give it extra parameters telling it where to get data

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WSGI Responses

- The second argument is a function that is called to initiate a response

```
def hello_app(environ, start_response):
    status = "200 OK"
    response_headers = [ ('Content-type','text/plain')]
    response = []

    start_response(status,response_headers)
    response.append("Hello World\n")
    response.append("You requested :"+environ['PATH_INFO]')
    return response
```

- You pass it two parameters
  - A status string (e.g., "200 OK")
  - A list of (header, value) HTTP header pairs

WSGI Responses

- start_response() is a hook back to the server
- Gives the server information for formulating the response (status, headers, etc.)
- Prepares the server for receiving content data

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WSGI Content

- Content is returned as a sequence of byte strings

```
def hello_app(environ, start_response):
    status = "200 OK"
    response_headers = [ ('Content-type','text/plain')]
    response = []

    start_response(status,response_headers)
    response.append("Hello World\n")
    response.append("You requested :"+environ['PATH_INFO]')
    return response
```

- Note: This differs from CGI programming where you produce output using print.

WSGI Content Encoding

- WSGI applications must always produce bytes
- If working with Unicode, it must be encoded

```
def hello_app(environ, start_response):
    status = "200 OK"
    response_headers = [ ('Content-type','text/html')]

    start_response(status,response_headers)
    return [u"That's a spicy Jalape\u00f1o".encode('utf-8')]
```

- This is a little tricky--if you're not anticipating Unicode, everything can break if a Unicode string is returned (be aware that certain modules such as database modules may do this)

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WSGI Deployment

- The main point of WSGI is to simplify deployment of web applications
- You will notice that the interface depends on no third party libraries, no objects, or even any standard library modules
- That is intentional. WSGI apps are supposed to be small self-contained units that plug into other environments

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WSGI Deployment

- Running a simple stand-alone WSGI server

```
from wsgiref import simple_server
httpd = simple_server.make_server("",8080,hello_app)
httpd.serve_forever()
```

- This runs an HTTP server for testing
- You probably wouldn't deploy anything using this, but if you're developing code on your own machine, it can be useful

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WSGI and CGI

- WSGI applications can run on top of standard CGI scripting (which is useful if you're interfacing with traditional web servers).

```
#!/usr/bin/env python
# hello.py

def hello_app(environ,start_response):
    ...

import wsgiref.handlers
wsgiref.handlers.CGIHandler().run(hello_app)
```

Exercise 4.5

Time : 20 Minutes

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Customized HTTP

- Can implement customized HTTP servers
- Use BaseHTTPServer module
- Define a customized HTTP handler object
- Requires some knowledge of the underlying HTTP protocol

Customized HTTP

- Example: A Hello World Server

```
from BaseHTTPServer import BaseHTTPRequestHandler,HTTPServer

class HelloHandler(BaseHTTPRequestHandler):
    def do_GET(self):
        if self.path == '/hello':
            self.send_response(200,"OK")
            self.send_header('Content-type','text/plain')
            self.end_headers()
            self.wfile.write("""<HTML>
               <HEAD><TITLE>Hello</TITLE></HEAD>
               <BODY>Hello World!</BODY></HTML>""")

serv = HTTPServer(("",8080),HelloHandler)
serv.serve_forever()
```

- Defined a method for "GET" requests

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Customized HTTP

- A more complex server

```
from BaseHTTPServer import BaseHTTPRequestHandler,HTTPServer

class MyHandler(BaseHTTPRequestHandler):
    def do_GET(self):
        ...
    def do_POST(self):
        ...
    def do_HEAD(self):
        ...
    def do_PUT(self):
        ...

serv = HTTPServer(("",8080),MyHandler)
serv.serve_forever()
```

Redefine the behavior of the server by defining code for all of the standard HTTP request types

- Can customize everything (requires work)

Exercise 4.6

Time : 15 Minutes

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Web Frameworks

- Python has a huge number of web frameworks
  - Zope
  - Django
  - Turbogears
  - Pylons
  - CherryPy
  - Google App Engine
- Frankly, there are too many to list here..

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Web Frameworks

- Web frameworks build upon previous concepts
- Provide additional support for
  - Form processing
  - Cookies/sessions
  - Database integration
  - Content management
- Usually require their own training course

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Commentary

- If you're building small self-contained components or middleware for use on the web, you're probably better off with WSGI
- The programming interface is minimal
- The components you create will be self-contained if you're careful with your design
- Since WSGI is an official part of Python, virtually all web frameworks will support it

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Section 5

Advanced Networking

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Overview

- An assortment of advanced networking topics
- The Python network programming stack
- Concurrent servers
- Distributed computing
- Multiprocessing

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Problem with Sockets

- In part 1, we looked at low-level programming with sockets
- Although it is possible to write applications based on that interface, most of Python's network libraries use a higher level interface
- For servers, there's the SocketServer module

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SocketServer

- A module for writing custom servers
- Supports TCP and UDP networking
- The module aims to simplify some of the low-level details of working with sockets and put to all of that functionality in one place

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SocketServer Example

- To use SocketServer, you define handler objects using classes
- Example: A time server

```
import SocketServer
import time

class TimeHandler(SocketServer.BaseRequestHandler):
    def handle(self):
        self.request.sendall(time.ctime()+"\n")

serv = SocketServer.TCPServer(("",8000),TimeHandler)
serv.serve_forever()
```

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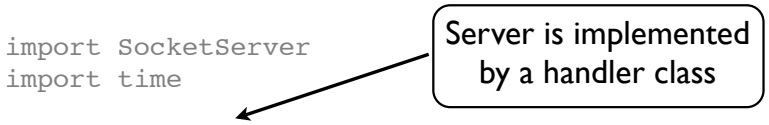
SocketServer Example

- Handler Class




```
import SocketServer
import time

class TimeHandler(SocketServer.BaseRequestHandler):
    def handle(self):
        self.request.sendall(time.ctime()+"\n")

serv = SocketServer.TCPServer(("",8000),TimeHandler)
serv.serve_forever()
```

SocketServer Example

- Handler Class

Must inherit from BaseRequestHandler

```
import SocketServer
import time

class TimeHandler(SocketServer.BaseRequestHandler):
    def handle(self):
        self.request.sendall(time.ctime())

serv = SocketServer.TCPServer(("",8000),TimeHandler)
serv.serve_forever()
```

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SocketServer Example

- handle() method

Define handle() to implement the server action

```
import SocketServer
import time

class TimeHandler(SocketServer.BaseRequestHandler):
    def handle(self):
        self.request.sendall(time.ctime())

serv = SocketServer.TCPServer(("",8000),TimeHandler)
serv.serve_forever()
```

SocketServer Example

- Client socket connection

```
import SocketServer
import time

class TimeHandler(SocketServer.BaseRequestHandler):
    def handle(self):
        self.request.sendall(time.ctime())

serv = SocketS                          8000),TimeHandler)
serv.serve_for
```

Socket object for client connection

- This is a bare socket object

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SocketServer Example

- Creating and running the server

```
import SocketServer
import time

class TimeHandler(SocketS                    ndler):
    def handle(self):
        self.request.sendall(time.ctime())

serv = SocketServer.TCPServer(("",8000),TimeHandler)
serv.serve_forever()
```

Creates a server and connects a handler

Runs the server forever

Execution Model

- Server runs in a loop waiting for requests
- On each connection, the server creates a new instantiation of the handler class
- The handle() method is invoked to handle the logic of communicating with the client
- When handle() returns, the connection is closed and the handler instance is destroyed

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Exercise 5.1

Time : 15 Minutes

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Big Picture

- A major goal of SocketServer is to simplify the task of plugging different server handler objects into different kinds of server implementations
- For example, servers with different implementations of concurrency, extra security features, etc.

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Concurrent Servers

- SocketServer supports different kinds of concurrency implementations

```
TCPServer          - Synchronous TCP server (one client)
ForkingTCPServer   - Forking server (multiple clients)
ThreadingTCPServer - Threaded server (multiple clients)
```

- Just pick the server that you want and plug the handler object into it

```
serv = SocketServer.ForkingTCPServer(("",8000),TimeHandler)
serv.serve_forever()

serv = SocketServer.ThreadingTCPServer(("",8000),TimeHandler)
serv.serve_forever()
```

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Server Mixin Classes

- SocketServer defines these mixin classes

```
ForkingMixIn
ThreadingMixIn
```

- These can be used to add concurrency to other server objects (via multiple inheritance)

```
from BaseHTTPServer import HTTPServer
from SimpleHTTPServer import SimpleHTTPRequestHandler
from SocketServer import ThreadingMixIn

class ThreadedHTTPServer(ThreadingMixIn, HTTPServer):
    pass

serv = ThreadedHTTPServer(("",8080),
                          SimpleHTTPRequestHandler)
```

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Server Subclassing

- SocketServer objects are also subclassed to provide additional customization
- Example: Security/Firewalls

```
class RestrictedTCPServer(TCPServer):
     # Restrict connections to loopback interface
     def verify_request(self,request,addr):
         host, port = addr
         if host != '127.0.0.1':
             return False
         else:
             return True

serv = RestrictedTCPServer(("",8080),TimeHandler)
serv.serve_forever()
```

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Exercise 5.2

Time : 15 Minutes

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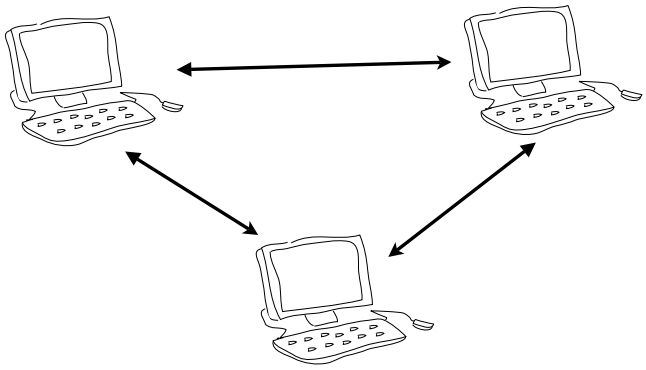
Distributed Computing

- It is relatively simple to build Python applications that span multiple machines or operate on clusters



Discussion

- Keep in mind: Python is a "slow" interpreted programming language
- So, we're not necessarily talking about high performance computing in Python (e.g., number crunching, etc.)
- However, Python can serve as a very useful distributed scripting environment for controlling things on different systems

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XML-RPC

- Remote Procedure Call
- Uses HTTP as a transport protocol
- Parameters/Results encoded in XML
- Supported by languages other than Python

Simple XML-RPC

- How to create a stand-alone server

```
from SimpleXMLRPCServer import SimpleXMLRPCServer

def add(x,y):
    return x+y

s = SimpleXMLRPCServer(("",8080))
s.register_function(add)
s.serve_forever()
```

- How to test it (xmlrpclib)

```
>>> import xmlrpclib
>>> s = xmlrpclib.ServerProxy("http://localhost:8080")
>>> s.add(3,5)
8
>>> s.add("Hello","World")
"HelloWorld"
>>>
```

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Simple XML-RPC

- Adding multiple functions

```
from SimpleXMLRPCServer import SimpleXMLRPCServer

s = SimpleXMLRPCServer(("",8080))
s.register_function(add)
s.register_function(foo)
s.register_function(bar)
s.serve_forever()
```

- Registering an instance (exposes all methods)

```
from SimpleXMLRPCServer import SimpleXMLRPCServer

s = SimpleXMLRPCServer(("",8080))
obj = SomeObject()
s.register_instance(obj)
s.serve_forever()
```

XML-RPC Commentary

- XML-RPC is extremely easy to use
- Almost too easy--you might get the perception that it's extremely limited or fragile
- I have encountered a lot of major projects that are using XML-RPC for distributed control
- Users seem to love it (I concur)

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XML-RPC and Binary

- One wart of caution...
- XML-RPC assumes all strings are UTF-8 encoded Unicode
- Consequence: You can't shove a string of raw binary data through an XML-RPC call
- For binary: must base64 encode/decode
- base64 module can be used for this

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Exercise 5.3

Time : 15 Minutes

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Serializing Python Objects

- In distributed applications, you may want to pass various kinds of Python objects around (e.g., lists, dicts, sets, instances, etc.)
- Libraries such as XML-RPC support simple data types, but not anything more complex
- However, serializing arbitrary Python objects into byte-strings is quite simple

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pickle Module

- A module for serializing objects
- Serializing an object onto a "file"

```
import pickle
...
pickle.dump(someobj,f)
```

- Unserializing an object from a file

```
someobj = pickle.load(f)
```

- Here, a file might be a file, a pipe, a wrapper around a socket, etc.

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Pickling to Strings

- Pickle can also turn objects into byte strings

```
import pickle
# Convert to a string
s = pickle.dumps(someobj, protocol)
...
# Load from a string
someobj = pickle.loads(s)
```

- This can be used if you need to embed a Python object into some other messaging protocol or data encoding

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Example

- Using pickle with XML-RPC

```
# addserv.py
import pickle

def add(px,py):
    x = pickle.loads(px)
    y = pickle.loads(py)
    return pickle.dumps(x+y)

from SimpleXMLRPCServer import SimpleXMLRPCServer
serv = SimpleXMLRPCServer(("",15000))
serv.register_function(add)
serv.serve_forever()
```

- Notice: All input arguments and return values are encoded/decoded with pickle

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Example

- Passing Python objects from the client

```
>>> import pickle
>>> import xmlrpclib
>>> serv = xmlrpclib.ServerProxy("http://localhost:15000")
>>> a = [1,2,3]
>>> b = [4,5]
>>> r = serv.add(pickle.dumps(a),pickle.dumps(b))
>>> c = pickle.loads(r)
>>> c
[1, 2, 3, 4, 5]
>>>
```

- Again, all input and return values are processed through pickle

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Miscellaneous Comments

- Pickle is really only useful if used in a Python-only environment
- Would not use if you need to communicate to other programming languages
- There are also security concerns
- Never use pickle with untrusted clients (malformed pickles can be used to execute arbitrary system commands)

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Exercise 5.4

Time : 15 Minutes

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multiprocessing

- Python 2.6/3.0 include a new library module (multiprocessing) that can be used for different forms of distributed computation
- It is a substantial module that also addresses interprocess communication, parallel computing, worker pools, etc.
- Will only show a few network features here

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Connections

- Creating a dedicated connection between two Python interpreter processes
- Listener (server) process

```
from multiprocessing.connection import Listener
serv = Listener(("",16000),authkey="12345")
c = serv.accept()
```

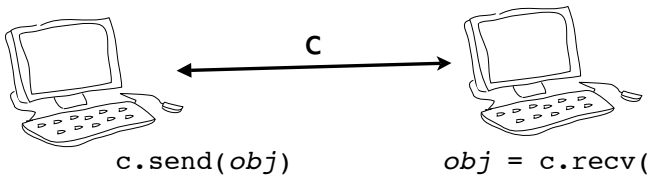
- Client process

```
from multiprocessing.connection import Client
c = Client(("servername",16000),authkey="12345")
```

- On surface, looks similar to a TCP connection

Connection Use

- Connections allow bidirectional message passing of arbitrary Python objects



- Underneath the covers, everything routes through the pickle module
- Similar to a network connection except that you just pass objects through it

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Example

- Example server using multiprocessing

```
# addserv.py

def add(x,y):
    return x+y

from multiprocessing.connection import Listener
serv = Listener(("",16000),authkey="12345")
c = serv.accept()
while True:
    x,y = c.recv()        # Receive a pair
    c.send(add(x,y))      # Send result of add(x,y)
```

- Note: Omitting a variety of error checking/ exception handling

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Example

- Client connection with multiprocessing

```
>>> from multiprocessing.connection import Client
>>> client = Client(("",16000),authkey="12345")
>>> a = [1,2,3]
>>> b = [4,5]
>>> client.send((a,b))
>>> c = client.recv()
>>> c
[1, 2, 3, 4, 5]
>>>
```

- Even though pickle is being used underneath the covers, you don't see it here

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Commentary

- Multiprocessing module already does the work related to pickling, error handling, etc.
- Can use it as the foundation for something more advanced
- There are many more features of multiprocessing not shown here (e.g., features related to distributed objects, parallel processing, etc.)

Commentary

- Multiprocessing is a good choice if you're working strictly in a Python environment
- It will be faster than XML-RPC
- It has some security features (authkey)
- More flexible support for passing Python objects around

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What about...

- CORBA? SOAP? Others?
- There are third party libraries for this
- Honestly, most Python programmers aren't into big heavyweight distributed object systems like this (too much trauma)
- However, if you're into distributed objects, you should probably look at the Pyro project (http://pyro.sourceforge.net)

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Network Wrap-up

- Have covered the basics of network support that's bundled with Python (standard lib)
- Possible directions from here...
  - Concurrent programming techniques (often needed for server implementation)
  - Parallel computing (scientific computing)
  - Web frameworks

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Exercise 5.5

Time : 15 Minutes

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