Python Workshop
File Input/Output

Mike Fienen

U.S. Geological Survey
Wisconsin Water Science Center, Middleton, Wisconsin USA

USGS National Groundwater Workshop, August 2012

Outline

Overview

- Much of what is useful to do in Python is reading files, manipulating the data, and writing out results in another format
- Python and Numpy provide ways to read and write ASCII and binary files
- We will focus on ASCII files

Reading and Writing with Strings

- The simplest way to write information to a string is using `str`

```
>>>a = 5.4
>>>str(a)
'5.4'
```

- We typically want more control. Two main ways to do it. Old school (`%`) and new school (`format`)
- Formatted input and output are a key difference between Python 2.X and 3.X

Writing Strings the Old School Way (%)

- The general syntax is to make a string with conversion types for variables. For example:

```
>>>outstr = 'I have %21.1f kg of %s and %d bins of %s' %(3.99983,'eggs',53,'spam')
>>> outstr
'I have                   4.0 kg of eggs and 53 bins of spam'
>>>outstr = 'I have %-21.1f kg of %s and %0.3d bins of %s' %(3.99983,'eggs',53,'spam')
>>> outstr
'I have 4.0                   kg of eggs and 053 bins of spam'
```

- The general idea is to make a string including `'%'`, a conversion flag (optional), a width and resolution (optional), and a conversion type (required).

  For example:

  `%<flag><width>.<resolution><type>`

  `%-12.3f` Is a left-justified, floating point value with width of 12 and 3 decimal places.

- Following the format string must be a list of values as a tuple identified by `%`

```
'%4d is the %s\n' %(42,'answer')
```

Writing Strings the Old School Way (%)

Details about formatted output available at:

`http://docs.python.org/library/stdtypes.html`

- Conversion flag characters
  - `'#'` Invokes alternate behavior (see website for details)
  - `'0'` Pads numeric values with zeros
  - `'-'` Left-adjusts the output
  - `' '` Leave a space before signed positive values so they line up with negative ones
- Most common conversion types.
  - `%d` or `%i` Signed integer
  - `%f` or `%F` Floating point
  - `%e` or `%E` Floating point exponential (lower or upper case)
  - `%g` or `%G` Combination of `%f` and `%e` depending on resolution
  - `%s` or `%r` String. Width is used, but not resolution

Writing Strings the Old School Way (%)

Try it out! `'%4d is the %s\n' %(42,'answer')`

`%<flag><width>.<resolution><type>`

- Conversion flag characters
  - `'#'` Invokes alternate behavior (see website for details)
  - `'0'` Pads numeric values with zeros
  - `'-'` Left-adjusts the output
  - `' '` Leave a space before signed positive values so they line up with negative ones
- Most common conversion types.
  - `%d` or `%i` Signed integer
  - `%f` or `%F` Floating point
  - `%e` or `%E` Floating point exponential (lower or upper case)
  - `%g` or `%G` Combination of `%f` and `%e` depending on resolution
  - `%s` or `%r` String. Width is used, but not resolution

Writing Strings the New School Way (`format`)

Details about new school string formatting at:

`http://docs.python.org/library/string.html#formatstrings`

- The general syntax is similar, but conversion information is supplied differently. For example:

```
>>>outstr = 'I have %{0:21.1f} kg of {1:s} and {2:0=3d} bins of {3:s}'.
format(3.99983,'eggs',53,'spam')
>>> outstr
'I have                   4.0 kg of eggs and 053 bins of spam'
```

- In this case, make a string including {. . .}, statements with conversion information.
  The general pattern is {`[index]:[format]`}
  - The `[index]` argument refers to the item index being mapped in
  - The `[format]` argument is similar to those in the old school way, but with some additional flexibility

USGS science for a changing world

A Slight Aside on User Input

- There are two main ways to get user input into a script from the command line
  1. Ask the user for it
  2. Get it from the script call

Ask the user

- Asking the user for input

```
>>> st = raw_input("What is your favorite color?  ")
What is your favorite color?  blue, no green!
>>> st
'blue, no green!'
```

- The input will always be a string which you can parse and convert as you wish.

Parse the call string

- Arguments in the call string can also be passed

```
>>> import sys
$ python testscript.py arg1 arg2
>>>scriptname = sys.argv[0]
>>>arg1 = sys.argv[1]
>>>arg2 = sys.argv[2]
...
```

- The list returned by `sys.argv` is all strings
  - 0th argument is the stript name
  - space-delimited arguments follow from there

Now that we can write strings, we can write them to files

But first, We need to read stuff back in *from* files

Interacting with Text Files

- The first thing is to open a file and make a file object

```
ifp = open('somefile.txt','r')
ofp = open('someotherfile.txt','w')
```

  - This object can be used to read or write from.
    I use `ifp` for "input file pointer" and
    `ofp` for "output file pointer"
    The arguments `'r'` and `'w'` indicate "read" and "write" respectively.

- To read the file can use `readline()` or `readlines()`
  - The difference is that `readlines()` reads the entire file into memory rather than `readline()` which reads one line at a time. Most of the time, `readlines()` is better
  - With `readlines()` once the data are read in, the result is a list with each element representing a line in the text file

Readlines Example

Here's a file called `example_file.txt`

```
This is a file.
It is a very nice file, no?
It has several lines.
Some of them are numbers.
This is NOT a poem.
3.14 pi 5
But code --> now THAT's poetry!
```

Now let's read it in:

```
>>>import os
>>>infilepath = os.path.join('data','example_file.txt')
>>>whole_file = open(infilepath,'r').readlines()
>>> whole_file
['This is a file.\n', 'It is a very nice file, no?\n', 'It has several lines.\n',
'Some of them are numbers.\n', 'This is NOT a poem.\n', '3.14 pi 5\n',
"But code --> now THAT's poetry!"]
```

What if it's a windows file?

```
>>>infilepath = os.path.join('data','example_file_win.txt')
>>>whole_file = open(infilepath,'r').readlines()
>>> whole_file
['This is a file.\r\n', 'It is a very nice file, no?\r\n', 'It has several lines.\r\n',
'Some of them are numbers.\r\n', 'This is NOT a poem.\r\n', '3.14 pi 5\r\n',
"But code --> now THAT's poetry!"]
```

Parsing input strings

- Using `strip` and `split`
  - `strip()` removes newline and tab characters from the end

```
>>>line = 'USGS        430406089232901 2010-12-03      15.04   P\t\r\n'
>>>line.strip()
'USGS\t430406089232901\t2010-12-03\t15.04\tP'
```

  - `split()` breaks up a string on whitespace
  - Can take any character as an argument (usually ',' or ' ')

```
>>>line.strip().split()
['USGS', '430406089232901', '2010-12-03', '15.04', 'P']
>>>line.strip().split('0')
['USGS\t43', '4', '6', '892329', '1\t2', '1', '-12-', '3\t15.', '4\tP']
```

  - Stacking `strip` and `split` is a common violation of the general rule not to stack up function calls

Parsing input strings (continued)

- Using `pop`

```
>>>a=line.strip().split()
>>>a
['USGS', '430406089232901', '2010-12-03', '15.04', 'P']
>>>a.pop()
'P'
>>>a
['USGS', '430406089232901', '2010-12-03', '15.04']
>>>a.pop(1)
'430406089232901'
>>>a
['USGS', '2010-12-03', '15.04']
```

  - `pop()` *both* returns an element from a list *and* removes it from the remaining list

- Regular expressions are very flexible but another topic

```
>>>import re
>>>allints = re.findall("[0-9]",line)
>>>allints
['4', '3', '0', '4', '0', '6', '0', '8', '9', '2', '3', '2', '9', '0', '1', '2',
'0', '1', '0', '1', '2', '0', '3', '1', '5', '0', '4']
```

USGS science for a changing world

An Example Text File from NWIS

```
# ---------------------------------- WARNING ---------------------------------------
# Provisional data are subject to revision. Go to
# http://waterdata.usgs.gov/nwis/help/?provisional for more information.
#
# File-format description:  http://waterdata.usgs.gov/nwis/?tab_delimited_format_info
# Automated-retrieval info: http://waterdata.usgs.gov/nwis/?automated_retrieval_info
#
# Contact:   gs-w_support_nwisweb@usgs.gov
# retrieved: 2012-07-16 17:24:35 EDT (vaas01)
#
# Data for the following 2 site(s) are contained in this file
#    USGS 430406089232901 DN-07/09E/23-1297
#    USGS 430427089284901 DN-07/09E/19-0064
# ----------------------------------------------------------------------------------
#
# Data provided for site 430406089232901
#    DD parameter statistic   Description
#    01   72019     00001     Depth to water level, feet below land surface (Maximum)
#
# Data-value qualification codes included in this output:
#     P  Provisional data subject to revision.
#
agency_cd site_no datetime 01_72019_00001 01_72019_00001_cd
5s 15s 20d 14n 10s
USGS 430406089232901 2010-12-03 15.04 P
USGS 430406089232901 2010-12-04 14.92 P
...
```

Reading NWIS Output File

```
def NWIS_reader(infile):
    '''
    NWIS_reader(infile)
    A function to read in an NWIS file generated using USGS webservices.
    Mike Fienen - 7/16/2012
    <mnfienen *at* usgs *dot* gov>

    INPUT:
    infile --> the name of an input file in USGS RDB (tab-delimited) format

    OUTPUT:
    indat --> a dictionary with keys corresponding to site numbers and each
            element being a dictionary with keys date and depth to water.
    '''
    # tell the user what's happening
    print 'Reading Data from file: %s' %(infile)
    #
    # set up a couple initial variables
    #
    # format for reading the date --> formats noted at
    #        http://docs.python.org/library/datetime.html (bottom of the page)
    indatefmt = "%Y-%m-%d"
```

Reading NWIS Output File (Continued)

```
# open the text file and read all lines into a variable "tmpdat"
tmpdat = open(infile,'r').readlines()

# make empty lists to temporarily hold the data
Site_ID = []    # site ID
dates = []      # date of measurement (daily values)
DTW = []        # depth to water below land surface (feet)
prov_code = [] # provisional code: [P] is provisional, [A] is accepted
# loop over the input data, keep only proper data rows. Parse and assign to lists
for lnum, line in enumerate(tmpdat):
    # first read the lookup information from the header of the file
    if ("data for the following" in line.lower()):
        nWells = int(re.findall("[0-9]+",line)[0])
        statnums = []
        countynums = []
        for cwell in np.arange(nWells):
            nextline = lnum+1+cwell
            tmp = tmpdat[nextline].strip().split()
            statnums.append(tmp[2])
            countynums.append(tmp[3])
        station_lookup = dict(zip(statnums,countynums))

    if (('usgs' in line.lower()) and ('#' not in line)):
        tmp = line.strip().split() # strip newline off the end and split on whitespace
        Site_ID.append(tmp[1])
        dates.append(datetime.strptime(tmp[2],indatefmt)) #convert date to a time tuple
        DTW.append(tmp[3])
        prov_code.append(tmp[4].lower()) # --> note conversion to lower case!
```

Try Running the Code

Quick aside on `os` module...
Windows uses "\" for separating path components, but everyone else uses "/"

So, you can make a Windows path as:

```
>>>infile =
'..\\data\\NWIS_data.dat'
```

That works, but only on Windows.
Better style is:

```
>>>infile =
os.path.join('..','data','NWIS_data.dat')
>>>infile # on a Mac
'../data/NWIS_data.dat'
>>>infile # on Windows
'..\\data\\NWIS_data.dat'
```

That is platform independent

Now, let's try an example in the EXERCISES/FILE_I_O directory

```
>>> import NWIS_read_parse as NWR, os
>>> infile = os.path.join('..','data','dane_county_GW_wells.dat')
>>>indat,county_lookup = NWR.NWIS_reader(infile)
Reading Data from file: ../data/dane_county_GW_wells.dat
Reading ../data/dane_county_GW_wells.dat complete!
>>>indat.keys()
>>>county_lookup.keys()
```

USGS science for a changing world

np.genfromtxt: flexible way to read columns

Example file: STATE_FIPS.csv

```
State Abbreviation,FIPS Code,State Name
AK,02,ALASKA
AL,01,ALABAMA
AR,05,ARKANSAS
AS,60,AMERICAN SAMOA
AZ,04,ARIZONA
CA,06,CALIFORNIA
...
```

```
import numpy as np
infilename = 'STATE_FIPS.csv'
indat = np.genfromtxt(infilename,delimiter=',',dtype=None,names=True)
```

`delimiter=','` delimiter can be *anything*

`dtype=None` Numpy interprets column data types. If unknown, makes it a string

`names=True` Each column gets a data type and a name

```
In [10]: indat
Out[7]:
array([('AK', 2, 'ALASKA'), ('AL', 1, 'ALABAMA'), ('AR', 5, 'ARKANSAS'), ...
dtype=[('State_Abbreviation', '|S2'), ('FIPS_Code', '<i4'), ('State_Name', '|S20')])
```

N.B.→underscore replaces space in names

USGS science for a changing world

Writing Back out to a File

- First need a file object in the same way as reading

```
ofp = open('some_outfile.txt','w')
```

- Next, create a string of output
- Write the string using

```
ofp.write(<string>)
```

- Remember to put a newline character `'\n'` at the end of each line

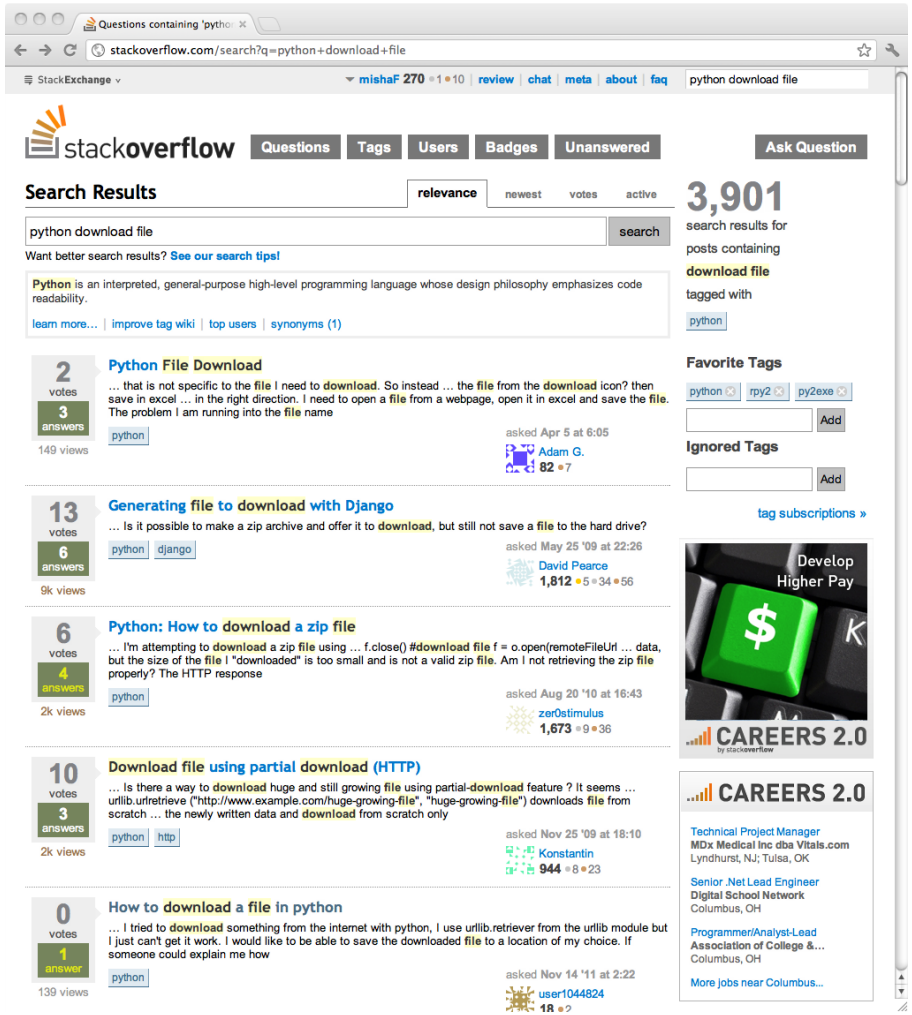
Pulling a data file from the Web

- An example using REST (Representational State Transfer a.k.a. a RESTful query) of USGS water data.

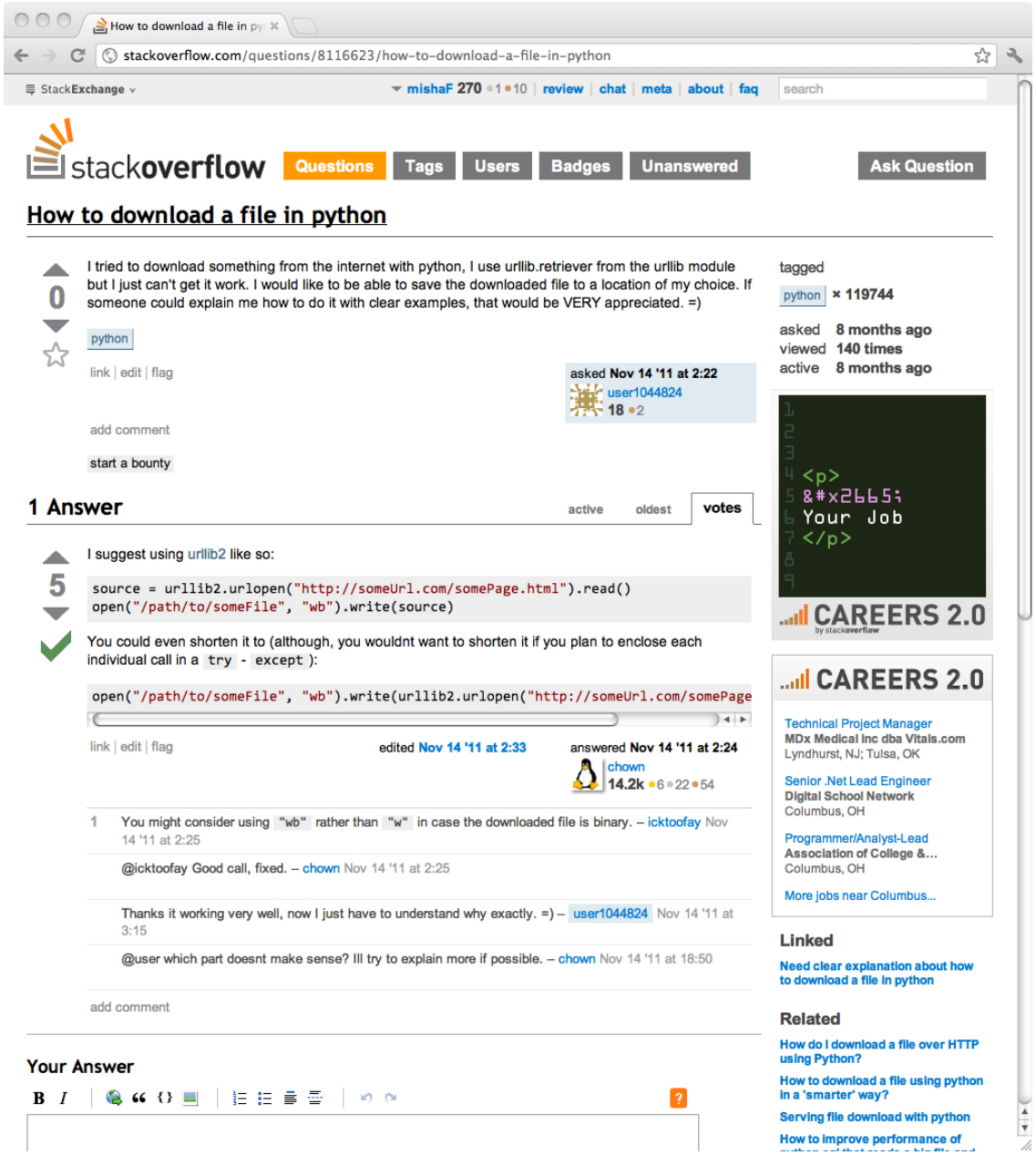
```
import urllib
fullURL = 'www.place.gov/some_path_to_a_data_file.txt'
datastream = urllib.urlopen(fullURL).read()
outfilename = 'local_filename.txt'
open(outfilename,'wb').write(datastream)
```

- `urllib` enables simple interaction with a URL
- BeautifulSoup allows for much more sophisticated complete web-scraping applications (not built in)
- Writing the local version of the file as binary is most robust:
  - Retains a copy of exactly what was downloaded
  - Writes the copy without respect to formatting issues
- One could work only in memory and not make a local copy

Using Stackoverflow



Using Stackoverflow



USGS science for a changing world

Some Useful Resources

- Building queries for RESTful[1] queries of USGS water data
  `http://waterservices.usgs.gov/`
- USGS Water data type pm code lookup
  `http://nwis.waterdata.usgs.gov/nwis/pmcodes/`
- General I/O information in Python documentation
  `http://docs.python.org/tutorial/inputoutput.html`

[1] REST=Representational State Transfer

Some More Useful Resources

- Getting data through CIDA/ACWI from the National Groundwater monitoring Network (NGWMN) Portal
- Main page
  `http://cida.usgs.gov/gw_data_portal/`
- List of wells where data are available
  `http://cida.usgs.gov/ngwmn/wells`
  Hover over a link to see code information
- Data are returned in WaterML2 Format
  `http://www.waterml2.org/`
- Similar RESTful Query
  `http://cida.usgs.gov/ngwmn/data/<agencyCd>/<siteNo>/<data-type>`