DATA 301
Introduction to Data Analytics
Python Data Analytics

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Python File Input/Output

Many data processing tasks require reading and writing to files.

Open a file for reading:

I/O Type

```
infile = open("input.txt", "r")
```

Open a file for writing:

```
outfile = open("output.txt", "w")
```

Open a file for read/write:

```
myfile = open("data.txt", "r+")
```

Reading from a Text File (as one String)

```
infile = open("input.txt", "r")

val = infile.read()      ← Read all file as one string
print(val)

infile.close()           ← Close file
```

Reading from a Text File (line by line)

```
infile = open("input.txt", "r")
for line in infile:
  print(line.strip('\n'))
infile.close()


# Alternate syntax - will auto-close file
with open("input.txt", "r") as infile:
   for line in infile:
      print(line.strip('\n'))
```

Writing to a Text File

```
outfile = open("output.txt", "w")

for n in range(1,11):
    outfile.write(str(n) + "\n")

outfile.close()
```

Other File Methods

```
infile = open("input.txt", "r")

# Check if a file is closed
print(infile.closed)# False

# Read all lines in the file into a list
lines = infile.readlines()
infile.close()
print(infile.closed)# True
```

Use Split to Process a CSV File

```
with open("data.csv", "r") as infile:
  for line in infile:
    line = line.strip(" \n")
    fields = line.split(",")
    for i in range(0,len(fields)):
      fields[i] = fields[i].strip()
    print(fields)
```

Using csv Module to Process a CSV File

```
import csv

with open("data.csv", "r") as infile:
  csvfile = csv.reader(infile)
  for row in csvfile:
    if int(row[0]) > 1:
      print(row)
```

List all Files in a Directory

```
import os
print(os.listdir("."))
```

Python File I/O Question

Question: How many of the following statements are **TRUE**?

1) A Python file is automatically closed for you.
2) If you use the `with` syntax, Python will close the file for you.
3) To read from a file, use `w` when opening a file.
4) The `read()` method will read the entire file into a string.
5) You can use a `for` loop to iterate through all lines in a file.

A) 0 **B)** 1 **C)** 2 **D)** 3 **E)** 4

Try it: Python Files

Question 1: Write a Python program that writes to the file `test.txt` the numbers from 20 to 10 in descending order.

Question 2: Write a Python program that reads your newly created `test.txt` file line by line and only prints out the value if it is even.

Question 3: Print out the contents of the CSV census file from:
https://people.ok.ubc.ca/rlawrenc/teaching/301/notes/code/data/province_population.csv

- Try to print out only the provinces with population > 1 million people and only the 2015 data. You will need to use float() and remove commas in data.

Internet Terminology Basics

An ***Internet Protocol*** (***IP***) ***address*** is an identifier for a computer on the Internet.

- IP version 4 (IPv4) address is 4 numbers in the range of 0 to 255. The numbers are separated by dots. Example: 142.255.0.1
- IP version 6 (IPv6) address has 16 numbers from 0 to 255 represented in hexadecimal. Example: 2002:CE57:25A2:0000:0000:0000:CE57:25A2

A ***domain name*** is a text name for computer(s) that are easier to remember. A ***domain*** is a related group of networked computers.

- Domain names are organized ***hierarchically***. The most general part of the hierarchy is at the end of the name.
- Example: `people.ok.ubc.ca`
  - `ca` – Canadian domain, `ubc` – University of British Columbia, `ok` – Okanagan campus, `people` – name of computer/server on campus

Internet Terminology Basics (2)

A ***uniform resource locator*** (***URL***) is an address of an item on the Internet. A URL has three parts:

- Protocol: `http://` - Hypertext Transfer Protocol
  - Tells the computer how to handle the file
- Server computer's domain name or IP address
- Item's path and name:
  - Tells the server which item (file, page, resource) is requested and where to find it.

Example:

`http://people.ok.ubc.ca/rlawrenc/teaching/301/index.html`

http protocol server domain name location of file/resource on server

Accessing (GET) Web Sites via URL with Python

```
import urllib.request
loc="http://people.ok.ubc.ca/rlawrenc/teaching/301"
site = urllib.request.urlopen(loc)
contents = site.read()
print(contents)
site.close()
```

Google Search with Python

```
import urllib
url = "http://www.google.com/search?hl=en&q=data+analysis"
headers={'User-Agent':'Mozilla/5.0 (Windows NT 6.1)'}
request = urllib.request.Request(url,None,headers)
response = urllib.request.urlopen(request)
data = response.read()
data = data.decode()    # Convert from Unicode to ASCII
print(data)
request.close()
```

Sending Data (PUT) to URL with Python

```
import urllib.parse
import urllib.request

url = 'http://cosc304.ok.ubc.ca/rlawrenc/tomcat/provinceState.jsp'
headers={'User-Agent':'Mozilla/5.0 (Windows NT 6.1)'}
# Build and encode data
values = {'country' : 'US'}
data = urllib.parse.urlencode(values)
data = data.encode('ascii')
req = urllib.request.Request(url, data, headers)
with urllib.request.urlopen(req) as response:
   page = response.read()
   print(page)
```

Python Web/URL Question

Question: How many of the following statements are **TRUE**?

1) An IPv4 address has 4 numbers between 0 and 256 inclusive.
2) A domain name is hierarchical with most specific part at the end.
3) Typically, a URL will reference more than one resource/item.
4) Python uses the file module for accessing URLs.

A) 0 **B)** 1 **C)** 2 **D)** 3 **E)** 4

Try it: Python URLs

Question 1: Write a Python program that connects to any web page and prints its contents.

Question 2: Write a Python program that connects to:
https://people.ok.ubc.ca/rlawrenc/teaching/301/notes/code/data/province_population.csv
and outputs the CSV data.

- Modify your program to print each province and its 2015 population in descending sorted order.

Handling Errors and Exceptions

An ***exception*** is an error situation that must be handled or the program will fail.

- ***Exception handling*** is how your program deals with these errors.

Examples:

- Attempting to divide by zero
- An array index that is out of bounds
- A specified file that could not be found
- A requested I/O operation that could not be completed normally
- Attempting to follow a null or invalid reference
- Attempting to execute an operation that violates some kind of security measure

The `try-except` Statement

The ***`try-except` statement*** will handle an exception that may occur in a block of statements:

Execution flow:

- The statements in the `try` block are executed.
- If no exception occurs:
  - If there is an `else` clause, it is executed.
  - Continue on with next statement after `try`.
- If an exception occurs:
  - Execute the code after the `except`.
- If the optional `finally` block is present, it is always executed regardless if there is an exception or not.
- Keyword `pass` is used if any block has no statements.

Python Exceptions Example

```
try:
   num = int(input("Enter a number:"))      } try block exit if error
   print("You entered:",num)
except ValueError:
     print("Error: Invalid number")         } only execute if exception
else:
     print("Thank you for the number")      } only execute if no exception
finally:
     print("Always do finally block")       } always execute
```

Question: Exceptions

Question: What is the output of the following code if enter 10?

```
try:
   num = int(input("Enter num:"))
   print(num)
except ValueError:
    print("Invalid")
else:
    print("Thanks")
finally:
    print("Finally")
```

A) `10`

B) `10`

C) `Invalid`

D) `10`
`Thanks`

E) `10`
`Thanks`
`Finally`

Question: Exceptions (2)

Question: What is the output of the following code if enter `hat`?

```
try:
   num = int(input("Enter num:"))
   print(num)
except ValueError:
    print("Invalid")
else:
    print("Thanks")
print("Finally")
```

A) `hat`

B) `Invalid`

C) `Invalid`
`Finally`

D) `hat`
`Thanks`
`Finally`

E) `Finally`

Try it: Python Exceptions

Question: Write a Python program that reads two numbers and converts them to integers, prints both numbers, and then divides the first number by the second number and prints the result.

- If get an exception `ValueError` when converting to an integer, print `Invalid`.
- If get a `ZeroDivisionError`, print `Cannot divide by 0!`

Python Modules

A Python ***module*** or ***library*** is code written by others for a specific purpose. Whenever coding, make sure to look for modules that are already written for you to make your development faster!

Modules are imported using the import command:

```
import modulename
```

Useful modules for data analytics:

- Biopython (bioinformatics), NumPy (scientific computing/linear algebra), scikit-learn (machine learning), pandas (data structures), BeautifulSoup (HTML/Web)

Biopython

Biopython (http://biopython.org) is a Python library for biological and bioinformatics computation.

Features:

- parsers for bioinformatics file formats (BLAST, Clustalw, FASTA, Genbank)
- access to online services (NCBI - National Center for Biotechnology Information)
- sequence class
- clustering/classification (k Nearest Neighbors, Naïve Bayes, Support Vector Machines)
- Integration with BioSQL (sequence database schema)

Biopython Installation

Install in Anaconda by:

```
conda install biopython
```

Check if successfully installed and current version by:

```
import Bio
print(Bio.__version__)
```

Biopython Example - Using Sequences

```
# Create a sequence as a string
from Bio.Seq import Seq
my_seq = Seq("AGTACACTGGT")
print(my_seq)

# Read a FASTA file and print sequence info
from Bio import SeqIO
for seq_record in SeqIO.parse("sequence.fasta", "fasta"):
    print(seq_record.id)
    print(repr(seq_record.seq))
    print(len(seq_record))
    print(seq_record.seq.complement())
```

Biopython Transcription Example

```
# Transcription
from Bio.Seq import Seq
from Bio.Alphabet import IUPAC

coding_dna = Seq("TGCATTGGGTGCTGA",IUPAC.unambiguous_dna)
template_dna = coding_dna.reverse_complement()
messenger_rna = coding_dna.transcribe()

print("Coding:       ",coding_dna)
print("Template:     ",template_dna)
print("Messenger RNA:",messenger_rna)
print("Translation:  ",messenger_rna.translate())
```

Biopython - Entrez Database Search

Entrez is a federated database enabling retrieval of data from many health sciences databases hosted by the NCBI.

```
# Retrieve data from nucleotide database as FASTA
from Bio import Entrez
from Bio import SeqIO
Entrez.email = "test@test.com"
# Providing GI for single entry lookup
handle = Entrez.efetch(db="nucleotide", rettype="fasta",
retmode="text", id="3288717")
record = SeqIO.read(handle, "fasta")
handle.close()
print(record)
```

Biopython - BLAST

BLAST (Basic Local Alignment Search Tool) compares an input sequence with database and returns similar sequences.
http://blast.ncbi.nlm.nih.gov/

```
# Retrieve data from nucleotide database as FASTA
from Bio.Blast import NCBIWWW
from Bio.Blast import NCBIXML

sequence = "ACTATTCCAAACAGCTCATAACCAGAAA"
handle = NCBIWWW.qblast("blastn", "nt", sequence)

result = handle.read()
print(result)     # Output is in XML format
```

Biopython BLAST - Parsing Results

```
from Bio.Blast import NCBIWWW
from Bio.Blast import NCBIXML
sequence = "ACTATTCCAAACAGCTCATAACCAGAAA"
handle = NCBIWWW.qblast("blastn", "nt", sequence)
records = NCBIXML.parse(handle)
record = next(records)
for alignment in record.alignments:
    for hsp in alignment.hsps:
        print('\nsequence:', alignment.title)
        print('length:', alignment.length)
        print('e value:', hsp.expect)
        print(hsp.query[0:75] + '...')
        print(hsp.match[0:75] + '...')
        print(hsp.sbjct[0:75] + '...')
```

Try it: Biopython

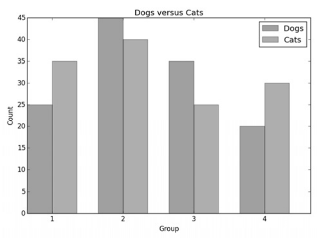
Question: Write a program that has a DNA sequence that you create, performs a BLAST, and then outputs the top 3 hits.

Charts

There are numerous graphing and chart libraries for Python:

- matplotlib (http://matplotlib.org/) - foundational 2D plotting library
- ggplot (http://ggplot.yhathq.com/) - based on R's ggplot2
- pygal - dynamic chart library
- Bokeh (http://bokeh.pydata.org/) - goal is to produce charts similar to D3.js for browsers
- Seaborn (http://stanford.edu/~mwaskom/software/seaborn/) - based on matplotlib and designed for statistical graphics

matplotlib - Bar Chart Example



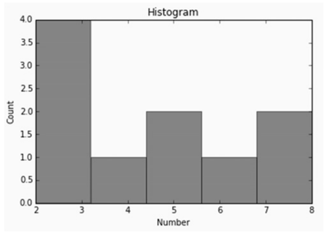
```
%matplotlib inline
import matplotlib.pyplot as plt
import numpy as np

data1 = [25,45,35,20]
data2 = [35,40,25,30]
index = np.arange(len(data1))
bar_width = 0.35
opacity = 0.4
error_config = {'ecolor': '0.3'}
rects1 = plt.bar(index, data1, bar_width, alpha=opacity,
                 color='b', yerr=None, error_kw=error_config,
                 label='Dogs')
```

matplotlib - Bar Chart Example (2)

```
rects2 = plt.bar(index + bar_width, data2, bar_width,
                 alpha=opacity, color='r', yerr=None,
                 error_kw=error_config, label='Cats')

plt.xlabel('Group')
plt.ylabel('Count')
plt.title('Dogs versus Cats')
plt.xticks(index + bar_width, ('1', '2', '3', '4'))
plt.legend()
plt.tight_layout()
plt.show()
```

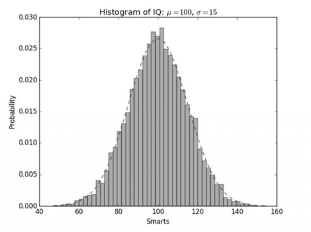
matplotlib - Histogram Example

```
%matplotlib inline

import numpy as np
import matplotlib.pyplot as plt

num_bins = 5
x = [5, 3, 8, 5, 2, 7, 2, 4, 6, 2]
n, bins, patches = plt.hist(x, num_bins,
          normed=False, facecolor='blue',
          alpha=0.5)

plt.xlabel('Number')
plt.ylabel('Count')
plt.title('Histogram')
plt.show()
```



matplotlib - Histogram Example #2

```
import numpy as np
import matplotlib.mlab as mlab
import matplotlib.pyplot as plt
mu = 100
sigma = 15
x = mu+sigma*np.random.randn(10000)
num_bins = 50
n, bins, patches = plt.hist(x, num_bins,
          normed=1, facecolor='green',
           alpha=0.5)
y = mlab.normpdf(bins, mu, sigma)
plt.plot(bins, y, 'r--')
plt.xlabel('Smarts')
plt.ylabel('Probability')
plt.title(r'Histogram of IQ: $\mu=100$, $\sigma=15$')
plt.subplots_adjust(left=0.15)
plt.show()
```



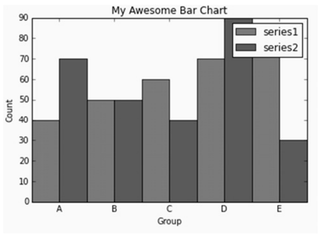
Note: Set `normed=0` to show counts rather than probabilities.

Try it: Charts

Question: Write a program to create a bar chart for this data:

- series1 = [40, 50, 60, 70, 80]
- series2 = [70, 50, 40, 90, 30]

Output:



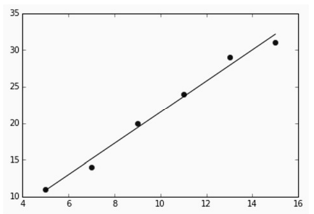
SciPy

SciPy is group of Python libraries for scientific computing:

- NumPy (http://www.numpy.org/) - N-dimensional arrays, integrating C/C++ and Fortran code, linear algebra, Fourier transform, and random numbers
- SciPy (http://www.scipy.org/) - numerical integration and optimization
- matplotlib (http://matplotlib.org/) - 2D plotting library
- IPython (http://ipython.org/) - interactive console (Jupyter)
- Sympy (http://www.sympy.org/) - symbolic mathematics (equations, calculus, statistics, combinatorics, cryptography)
- pandas (http://pandas.pydata.org/) - data structures, reading/writing data, data merging/joining/slicing/grouping, time series

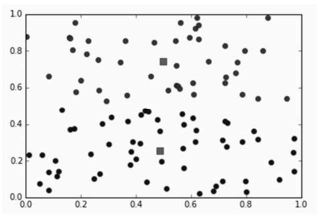
SciPy Linear Regression Example

```
from scipy import stats
import numpy as np
import matplotlib.pyplot as plt
x = np.array([5, 7, 9, 11, 13, 15])
y = np.array([11, 14, 20, 24, 29, 31])
slope, intercept, r_value, p_value,
  slope_std_error = stats.linregress(x, y)
predict_y = intercept + slope * x
print("Predicted y-values:",predict_y)
pred_error = y - predict_y
print("Prediction error:",pred_error)
degr_freedom = len(x) - 2
residual_std_error = np.sqrt(np.sum(pred_error**2) / degr_freedom)
print("Residual error:",residual_std_error)
plt.plot(x, y, 'o')
plt.plot(x, predict_y, 'k-')
plt.show()
```



SciPy k-Means Clustering Example

```
%matplotlib inline
import matplotlib.pyplot as plt
from scipy.cluster.vq import kmeans,vq
import random as rnd



# data generation
data = []
for i in range(0,100):
    data.append([rnd.random(), rnd.random()])

# Perform k-means clustering
numclusters = 2
centroids,_ = kmeans(data,numclusters) # Calculates centroids
idx,_ = vq(data,centroids)             # Puts each point in a cluster
```



SciPy k-Means Clustering Example (2)

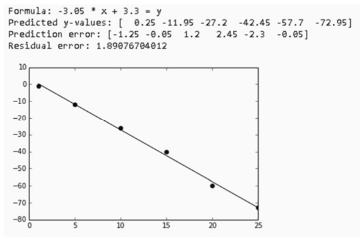
```
# Move data into individual lists based on clustering
clusters = []
for i in range(0, numclusters):
    clusters.append([[],[]])

for i in range(0,len(idx)):
    clusterIdx = idx[i]
    clusters[clusterIdx][0].append(data[i][0])
    clusters[clusterIdx][1].append(data[i][1])

# Plot data points and cluster centroids
plt.plot(clusters[0][0],clusters[0][1],'ob',
         clusters[1][0],clusters[1][1],'or')
plt.plot(centroids[:,0],centroids[:,1],'sg',markersize=8)
plt.show()
```

Try it: SciPy

Question: Write a program that uses SciPy to perform a linear regression on this data set:

- `x = [1, 5, 10, 15, 20, 25]`
- `y = [-1, -12, -26, -40, -60, -73]`

Output:



```
Formula: -3.05 * x + 3.3 = y
Predicted y-values: [  0.25 -11.95 -27.2  -42.45 -57.7  -72.95]
Prediction error: [-1.25 -0.05  1.2   2.45 -2.3  -0.05]
Residual error: 1.89076704012
```

scikit-learn Library

scikit-learn (http://scikit-learn.org/) is a machine learning library for Python.

Features: classification, regression, clustering, dimensionality reduction

BeautifulSoup Library

BeautifulSoup (http://www.crummy.com/software/BeautifulSoup/) is a library to make it easy to search, navigate, and extract data from HTML and XML documents.

Databases

Python can connect to databases to retrieve data. MySQL example:

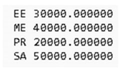
```
import mysql.connector
try:
    cnx = mysql.connector.connect(user='rlawrenc', password='test',
                  host='cosc304.ok.ubc.ca', database='WorksOn')
    cursor = cnx.cursor()
    query = ("SELECT eno, ename, salary FROM Emp WHERE title > %s "
             +"and salary < %s")
    cursor.execute(query, ('EE', 50000))
    for (eno, ename, salary) in cursor:
        print(eno, ename, salary)
   cursor.close()
except mysql.connector.Error as err:
    print(err)
finally:
    cnx.close()
```

Try it: Databases

Question: Write a program that queries the WorksOn database and returns the employees grouped by title where the employee name is after `'J'`. The output should display their title and the average salary for that title. Connection info:

- `cnx = mysql.connector.connect(user='rlawrenc', password='test', host='cosc304.ok.ubc.ca', database='WorksOn')`

Output:



```
EE 30000.000000
ME 40000.000000
PR 20000.000000
SA 50000.000000
```

Map-Reduce

Map-Reduce is a technique for processing large data sets in a functional manner.

- The technique was invented by Google and is implemented in a variety of systems including Python, NoSQL databases, and a Big Data system called Hadoop.
- In Hadoop, map takes as input key-value pairs and outputs key-value pairs. The shuffle step will move pairs to particular machines based on keys. The reduce step takes a list of key-value pairs (with same key) and reduces to one value.
- It is possible to code map/reduce functions in Python for use in Hadoop cluster.

Simpler version of Map-Reduce in Python without a cluster:

- Map function - takes as input a list and a function then applies function to each element of the list to produce a new list as output
- Filter function - only keeps list elements where filter function is `True`
- Reduce function - takes result of map/filter and produces single value from list

Python Map-Reduce Example

```
import functools     # For Reduce

data = [1, 2, 3, 4, 5, 6]

# Map function
def triple(x):
    return x*3

# Filter function
def myfilter(x):
    if x % 2 == 0:
        return True
    return False

# Reduce function
def sum(x, y):
    return x+y
```

Python Map-Reduce Example (2)

```
result = list(map(triple, data))
print("Result after map:",result)

result = list(filter(myfilter, result))
print("Result after filter:",result)

result = functools.reduce(sum, result)
print("Result after reduce:",result)
```

Try it: Map-Reduce

Question: Write a map-reduce program that during the map step will subtract 2 from each element. The reduce step should return the product of all the elements in the list.

Conclusion

Python has many libraries to help with data analysis tasks:

- reading and write to files
- `csv` module for processing CSV files
- Biopython for bioinformatics
- numerous chart libraries including `matplotlib` and `ggplot`
- SciPy - collection of libraries for scientific computing
- libraries for web access and parsing (BeautifulSoup)
- database access libraries and connectors

The ***`try-except` statement*** is used to handle exceptions so that the program may continue when an error condition occurs.

Objectives

- Open, read, write, and close text files
- Process CSV files including using the `csv` module
- Define: IPv4/IPv6 address, domain, domain name, URL
- Read URLs using `urllib.request`.
- Define: exception, exception handling
- Use `try-except` statement to handle exceptions and understand how each of `try`, `except`, `else`, `finally` blocks are used
- Import Python modules
- Use Biopython module to retrieve NCBI data and perform BLAST
- Build charts using `matplotlib`
- Perform linear regression and k-means clustering using SciPy
- Connect to and query the MySQL database using Python
- Write simple Map-Reduce programs