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INF1100 Lectures, Chapter 6: Files, Strings, and Dictionaries

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Reading data from a file

- A file is a sequence of characters (text)
- We can read text in the file into strings in a program
- This is a common way for a program to get input data
- Basic recipe:

```
infile = open('myfile.dat', 'r')
# read next line:
line = infile.readline()

# read lines one by one:
for line in infile:
    <process line>

# load all lines into a list of strings (lines):
lines = infile.readlines()
for line in lines:
    <process line>
```


Example: reading a file with numbers (part 1)

- The file `data1.txt` has a column of numbers:

```
21.8
18.1
19
23
26
17.8
```

- Goal: compute the average value of the numbers:

```
infile = open('data1.txt', 'r')
lines = infile.readlines()
infile.close()
mean = 0
for number in lines:
    mean = mean + number
mean = mean/len(lines)
```

- Running the program gives an error message:

```
TypeError: unsupported operand type(s) for +:
           'int' and 'str'
```

- Problem: `number` is a string!

Example: reading a file with numbers (part 2)

- We must convert strings to numbers before computing:

```
infile = open('data1.txt', 'r')
lines = infile.readlines()
infile.close()
mean = 0
for line in lines:
    number = float(line)
    mean = mean + number
mean = mean/len(lines)
print mean
```

- A quicker and shorter variant:

```
infile = open('data1.txt', 'r')
numbers = [float(line) for line in infile.readlines()]
infile.close()
mean = sum(numbers)/len(numbers)
print mean
```

While loop over lines in a file

Especially older Python programs employ this technique:

```
infile = open('data1.txt', 'r')
mean = 0
n = 0
while True:                # loop "forever"
    line = infile.readline()
    if not line:           # line='' at end of file
        break              # jump out of loop
    mean += float(line)
    n += 1
infile.close()
mean = mean/float(n)
print mean
```


Experiment with reading techniques

```
>>> infile = open('data1.txt', 'r')
>>> fstr = infile.read()       # read file into a string
>>> fstr
'21.8\n18.1\n19\n23\n26\n17.8\n'
>>> line = infile.readline()   # read after end of file...
>>> line
''
>>> bool(line)            # test if line:
False                     # empty object is False
>>> infile.close(); infile = open('data1.txt', 'r')
>>> lines = infile.readlines()
>>> lines
['21.8\n', '18.1\n', '19\n', '23\n', '26\n', '17.8\n']
>>> infile.close(); infile = open('data1.txt', 'r')
>>> for line in infile: print line,
...
21.8
18.1
19
23
26
17.8
```


Reading a mixture of text and numbers (part 1)

- The file `rainfall.dat` looks like this:

```
Average rainfall (in mm) in Rome: 1188 months between 1782 and 1970
Jan  81.2
Feb  63.2
Mar  70.3
Apr  55.7
May  53.0
...
```

- Goal: read the numbers and compute the mean
- Technique: for each line, split the line into words, convert the 2nd word to a number and add to sum

```
for line in infile:
    words = line.split()     # list of words on the line
    number = float(words[1])
```

- Note `line.split()`: very useful for grabbing individual words on a line, can split wrt any string, e.g., `line.split(';')`, `line.split(':')`

Reading a mixture of text and numbers (part 2)

The complete program:

```
def extract_data(filename):
    infile = open(filename, 'r')
    infile.readline() # skip the first line
    numbers = []
    for line in infile:
        words = line.split()
        number = float(words[1])
        numbers.append(number)
    infile.close()
    return numbers

values = extract_data('rainfall.dat')
from scitools.std import plot
month_indices = range(1, 13)
plot(month_indices, values[:-1], 'o2')
```

What is a file?

- A file is a sequence of characters
- For simple text files, each character is one byte (=8 bits, a bit is 0 or 1), which gives $2^8 = 256$ different characters
- (Text files in, e.g., Chinese and Japanese need several bytes for each character)
- Save the text "ABCD" to file in Emacs and OpenOffice/Word and examine the file
- In Emacs, the file size is 4 bytes

Dictionaries

- Lists and arrays are fine for collecting a bunch of objects in a single object
- List and arrays use an integer index, starting at 0, for reaching the elements
- For many applications the integer index is "unnatural" - a general text (or integer not restricted to start at 0) will ease programming
- Dictionaries meet this need
- Dictionary = list with text (or any constant object) as index
- Other languages use names like hash, HashMap and associative array for what is known as dictionary in Python

Example on a dictionary

- Suppose we need to store the temperatures in Oslo, London and Paris
- List solution:

```
temps = [13, 15.4, 17.5]
# temps[0]: Oslo
# temps[1]: London
# temps[2]: Paris
```

- We need to remember the mapping between the index and the city name – with a dictionary we can index the list with the city name directly (e.g., `temps["Oslo"]`):

```
temps = {'Oslo': 13, 'London': 15.4, 'Paris': 17.5}
# or
temps = dict(Oslo=13, London=15.4, Paris=17.5)
# application:
print 'The temperature in London is', temps['London']
```


Dictionary operations (part 1)

- Add a new element to a dict (dict = dictionary):

```
>>> temps['Madrid'] = 26.0
>>> print temps
{'Oslo': 13, 'London': 15.4, 'Paris': 17.5,
 'Madrid': 26.0}
```

- Loop (iterate) over a dict:

```
>>> for city in temps:
...     print 'The temperature in %s is %g' % \
...           (city, temps[city])
...
The temperature in Paris is 17.5
The temperature in Oslo is 13
The temperature in London is 15.4
The temperature in Madrid is 26
```

- The index in a dictionary is called *key*
  (a dictionary holds key–value pairs)

```
for key in dictionary:
    value = dictionary[key]
    print value
```

Dictionary operations (part 2)

- Does the dict have a particular key?

```
>>> if 'Berlin' in temps:
...     print 'Berlin:', temps['Berlin']
... else:
...     print 'No temperature data for Berlin'
...
No temperature data for Berlin
>>> 'Oslo' in temps     # standard boolean expression
True
```

- The keys and values can be reached as lists:

```
>>> temps.keys()
['Paris', 'Oslo', 'London', 'Madrid']
>>> temps.values()
[17.5, 13, 15.4, 26.0]
```

- Note: the sequence of keys is arbitrary! Never rely on it – if you need a specific order of the keys, use a sort:

```
for key in sorted(temps):
    value = temps[key]
    print value
```


Dictionary operations (part 3)

- More operations:

```
>>> del temps['Oslo']   # remove Oslo key w/value
>>> temps
{'Paris': 17.5, 'London': 15.4, 'Madrid': 26.0}
>>> len(temps)          # no of key-value pairs in dict.
3
```

- Two variables can refer to the same dictionary:

```
>>> t1 = temps
>>> t1['Stockholm'] = 10.0    # change t1
>>> temps                     # temps is also changed
{'Stockholm': 10.0, 'Paris': 17.5, 'London': 15.4,
  'Madrid': 26.0}
>>> t2 = temps.copy()         # take a copy
>>> t2['Paris'] = 16
>>> t1['Paris']
17.5
```


Examples: polynomials represented by dictionaries

- The polynomial

$$p(x) = -1 + x^2 + 3x^7$$

  can be represented by a dict with power as key and coefficient as value:

```
p = {0: -1, 2: 1, 7: 3}
```

- Evaluate polynomials represented as dictionaries: $\sum_{i \in I} c_i x^i$

```
def poly1(data, x):
    sum = 0.0
    for power in data:
        sum += data[power]*x**power
    return sum
```

- Shorter:

```
def poly1(data, x):
    return sum([data[p]*x**p for p in data])
```


Lists as dictionaries

- A list can also represent a polynomial
- The list index must correspond to the power
- $-1 + x^2 + 3x^7$ becomes

```
p = [-1, 0, 1, 0, 0, 0, 0, 3]
```

- Must store all zero coefficients, think about $1 + x^{100}$...
- Evaluating the polynomial at a given x value: $\sum_{i=0}^{N} c_i x^i$

```
def poly2(data, x):
    sum = 0
    for power in range(len(data)):
        sum += data[power]*x**power
    return sum
```

What is best for polynomials: lists or dictionaries?

- Dictionaries need only store the nonzero terms
- Dictionaries can easily handle negative powers, e.g., $\frac{1}{2}x^{-3} + 2x^4$

```
p = {-3: 0.5, 4: 2}
```

- Lists need more book-keeping with negative powers:

```
p = [0.5, 0, 0, 0, 0, 0, 0, 4]
# p[i] corresponds to power i-3
```

- Dictionaries are much more suited for this task

Example: read file data into a dictionary

- Here is a data file:

```
Oslo:          21.8
London:        18.1
Berlin:        19
Paris:         23
Rome:          26
Helsinki:      17.8
```

- City names = keys, temperatures = values

```
infile = open('deg2.dat', 'r')
temps = {}                  # start with empty dict
for line in infile.readlines():
    city, temp = line.split()
    city = city[:-1]        # remove last char (:)
    temps[city]  = float(temp)
```


Reading file data into nested dictionaries

- Data file `table.dat` with measurements of four properties:

```
        A       B       C       D
1     11.7    0.035    2017    99.1
2      9.2    0.037    2019   101.2
3     12.2     no       no    105.2
4     10.1    0.031     no    102.1
5      9.1    0.033    2009   103.3
6      8.7    0.036    2015   101.9
```

- Create a dict `data[p][i]` (dict of dict) to hold measurement no. `i` of property `p` (`"A"`, `"B"`, etc.)
- Examine the first line: split it into words and initialize a dictionary with the property names as keys and empty dictionaries (`{}`) as values
- For each of the remaining lines: split line into words
- For each word after the first: if word is not "no", convert to float and store
- See the book for implementation details!

Comparing stock prices (part 1)

- Problem: we want to compare the stock prices of Microsoft, Sun, and Google over a long period
- finance.yahoo.com offers such data in files with tabular form

```
Date,Open,High,Low,Close,Volume,Adj Close
2008-06-02,28.24,29.57,27.11,28.35,79237800,28.35
2008-05-01,28.50,30.53,27.95,28.32,69931800,28.32
2008-04-01,28.83,32.10,27.93,28.52,69066000,28.42
2008-03-03,27.24,29.59,26.87,28.38,74958500,28.28
2008-02-01,31.06,33.25,27.02,27.20,122053500,27.10
...
```

- Columns are separated by comma
- First column is the date, the final is the price of interest
- We can compare Microsoft and Sun from e.g. 1988 and add in Google from e.g. 2005
- For comparison we should normalize prices: Microsoft and Sun start at 1, Google at the max Sun/Microsoft price in 2005

Comparing stock prices (part 2)

Algorithm for file reading:

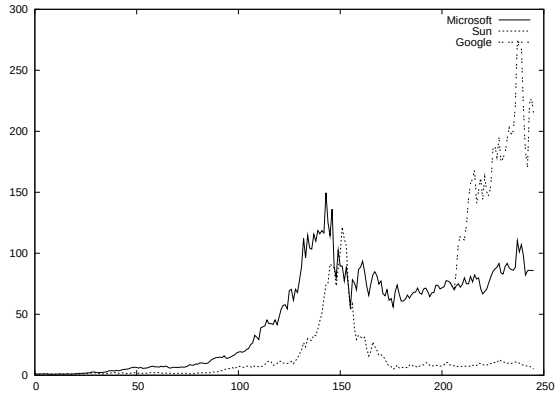
- Skip first line, read line by line, split line wrt. colon, store first "word" in a list of dates, final "word" in a list of prices; collect lists in dictionaries with company names as keys; make a function so it is easy to repeat for the three data files

Algorithm for file plotting:

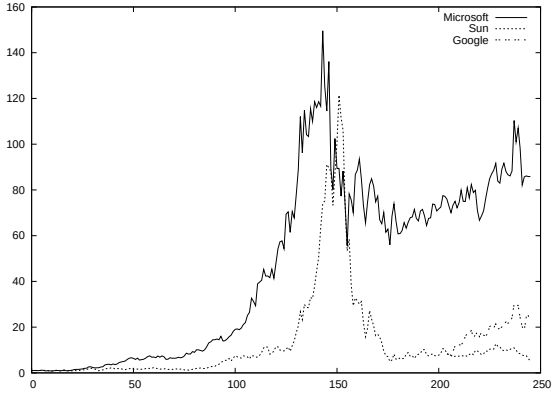
- Convert year-month-day time specifications in strings into coordinates along the x axis (use month indices for simplicity), Sun/Microsoft run 0,1,2,... while Google start at the Sun/Microsoft index corresponding to Jan 2005

See the book for all details. If you understand this example, you know and understand a lot!

Plot of stock prices 1988-2008



tarted with Sun in 1988 and switched to Google in 2005? (simple



String manipulation

- Text in Python is represented as strings
- Programming with strings is therefore the key to interpret text in files and construct new text
- First we show some common string operations and then we apply them to real examples
- Our sample string used for illustration is

```
>>> s = 'Berlin: 18.4 C at 4 pm'
```

- Strings behave much like lists/tuples - they are a sequence of characters:

```
>>> s[0]
'B'
>>> s[1]
'e'
```

Extracting substrings

- Substrings are just as slices of lists and arrays:

```
>>> s
'Berlin: 18.4 C at 4 pm'
>>> s[8:]     # from index 8 to the end of the string
'18.4 C at 4 pm'
>>> s[8:12]   # index 8, 9, 10 and 11 (not 12!)
'18.4'
>>> s[8:-1]
'18.4 C at 4 p'
>>> s[8:-8]
'18.4 C'
```

- Find start of substring:

```
>>> s.find('Berlin')  # where does 'Berlin' start?
0                     # at index 0
>>> s.find('pm')
20
>>> s.find('Oslo')    # not found
-1
```


Checking if a substring is contained in a string

```
>>> 'Berlin' in s:
True
>>> 'Oslo' in s:
False

>>> if 'C' in s:
...     print 'C found'
... else:
...     print 'no C'
...
C found
```


Substituting a substring by another string

- `s.replace(s1, s2)`: replace `s1` by `s2`

```
>>> s.replace(' ', '__')
'Berlin:__18.4__C__at__4__pm'
>>> s.replace('Berlin', 'Bonn')
'Bonn: 18.4 C at 4 pm'
```

- Example: replacing the text before the first colon by `'Bonn'`

```
\>>> s
'Berlin: 18.4 C at 4 pm'
>>> s.replace(s[:s.find(':')], 'Bonn')
'Bonn: 18.4 C at 4 pm'
```

- 1) `s.find(':')` returns 6, 2) `s[:6]` is `'Berlin'`, 3) this is replaced by `'Bonn'`

Splitting a string into a list of substrings

- Split a string into a list of substrings where the seperator is `sep`: `s.split(sep)`
- No separator implies split wrt whitespace

```
>>> s
'Berlin: 18.4 C at 4 pm'
>>> s.split(':')
['Berlin', ' 18.4 C at 4 pm']
>>> s.split()
['Berlin:', '18.4', 'C', 'at', '4', 'pm']
```

- Try to understand this one:

```
>>> s.split(':')[1].split()[0]
'18.4'
>>> deg = float(_)  # convert last result to float
>>> deg
18.4
```

Splitting a string into lines

- Very often, a string contains lots of text and we want to split the text into separate lines
- Lines may be separated by different control characters on different platforms. On Unix/Linux/Mac, backslash n is used:

```
>>> t = '1st line\n2nd line\n3rd line'
>>> print t
1st line
2nd line
3rd line
>>> t.split('\n')
['1st line', '2nd line', '3rd line']
>>> t.splitlines()  # cross platform - better!
['1st line', '2nd line', '3rd line']
```


Strings are constant (immutable) objects

- You cannot change a string in-place (as you can with lists and arrays) - all changes of a strings results in a new string

```
>>> s[18] = 5
...
TypeError: 'str' object does not support item assignment

>>> # build a new string by adding pieces of s:
>>> s[:18] + '5' + s[19:]
'Berlin: 18.4 C at 5 pm'
```


Stripping off leading/trailing whitespace

```
>>> s = '   text with leading/trailing space   \n'
>>> s.strip()
'text with leading/trailing space'
>>> s.lstrip()   # left strip
'text with leading/trailing space   \n'
>>> s.rstrip()   # right strip
'   text with leading/trailing space'
```


Some convenient string functions

```
>>> '214'.isdigit()
True
>>> '  214 '.isdigit()
False
>>> '2.14'.isdigit()
False

>>> s.lower()
'berlin: 18.4 c at 4 pm'
>>> s.upper()
'BERLIN: 18.4 C AT 4 PM'

>>> s.startswith('Berlin')
True
>>> s.endswith('am')
False

>>> '    '.isspace()   # blanks
True
>>> '  \n'.isspace()   # newline
True
>>> '  \t '.isspace()  # TAB
True
>>> ''.isspace()       # empty string
False
```

Joining a list of substrings to a new string

- We can put strings together with a delimiter in between:

```
>>> strings = ['Newton', 'Secant', 'Bisection']
>>> ', '.join(strings)
'Newton, Secant, Bisection'
```

- These are inverse operations:

```
t = delimiter.join(stringlist)
stringlist = t.split(delimiter)
```

- Split off the first two words on a line:

```
>>> line = 'This is a line of words separated by space'
>>> words = line.split()
>>> line2 = ' '.join(words[2:])
>>> line2
'a line of words separated by space'
```


Example: read pairs of numbers (x,y) from a file

- Sample file:

```
(1.3,0)    (-1,2)    (3,-1.5)
(0,1)      (1,0)     (1,1)
(0,-0.01)  (10.5,-1) (2.5,-2.5)
```

- Method: read line by line, for each line: split line into words, for each word: split off the parethesis and the split the rest wrt comma into two numbers

The code for reading pairs

```
lines = open('read_pairs.dat', 'r').readlines()

pairs = []   # list of (n1, n2) pairs of numbers
for line in lines:
    words = line.split()
    for word in words:
        word = word[1:-1]  # strip off parenthesis
        n1, n2 = word.split(',')
        n1 = float(n1);  n2 = float(n2)
        pair = (n1, n2)
        pairs.append(pair)  # add 2-tuple to last row
```


Output of a pretty print of the pairs list

```
[(1.3, 0.0),
 (-1.0, 2.0),
 (3.0, -1.5),
 (0.0, 1.0),
 (1.0, 0.0),
 (1.0, 1.0),
 (0.0, -0.01),
 (10.5, -1.0),
 (2.5, -2.5)]
```

Alternative solution: Python syntax in file format

- What if we write, in the file, the pairs (x,y) with comma in between the pairs?
- Adding a leading and trailing square bracket gives a Python syntax for a list of tuples (!)
- `eval` on that list could reproduce the list...
- The file format:

```
(1.3, 0),    (-1, 2),    (3, -1.5)
...
```

- We want to add a comma at the end of every line and square brackets around the whole file text, and then do an eval:

```
list = eval("[(1.3,0),    (-1, 2),    (3, -1.5),
...
]")
```


The code for reading pairs with eval

```
infile = open('read_pairs_wcomma.dat', 'r')
listtext = '['
for line in infile:
    # add line, without newline (line[:-1]),
    # with a trailing comma:
    listtext += line[:-1] + ', '
infile.close()
listtext = listtext + ']'
pairs = eval(listtext)
```


What are web pages?

- Web pages are nothing but text files
- Commands in the text files tell the browser that this is a headline, this is boldface text, here is an image, etc.
- The commands are written in the HTML language

```
<html>
<body bgcolor="orange">
<h1>A Very Simple Web Page</h1> <!-- headline -->
Ordinary text is written as ordinary text, but when we
need headlines, lists,
<ul>
<li><em>emphasized words</em>, or
<li> <b>boldfaced words</b>,
</ul>
we need to embed the text inside HTML tags. We can also
insert GIF or PNG images, taken from other Internet sites,
if desired.
<hr> <!-- horizontal line -->
<img src="http://www.simula.no/simula_logo.gif">
</body>
</html>
```


The web page generated by HTML code from the previous slide

Getting data from the Internet

- A program can download a web page, as an HTML file, and extract data by interpreting the text in the file (using string operations)
- Example: climate data from the UK

```
http://www.metoffice.gov.uk/climate/uk/stationdata/
```

- Download the file:

```
import urllib
url = \
'http://www.metoffice.gov.uk/climate/uk/stationdata/oxforddata.txt'
urllib.urlretrieve(url, filename='Oxford.txt')
```

- View the file `weather.html` to see how the text looks like

The structure of the Yahoo! weather forecast file

```
Oxford
Location: 4509E 2072N, 63 metres amsl
Estimated data is marked with a * after the value.
Missing data (more than 2 days missing in month) is marked by  ---.
Sunshine data taken from an automatic ...
   yyyy  mm   tmax    tmin      af    rain     sun
              degC    degC    days      mm   hours
   1853   1    8.4     2.7       4    62.8     ---
   1853   2    3.2    -1.8      19    29.3     ---
   1853   3    7.7    -0.6      20    25.9     ---
   1853   4   12.6     4.5       0    60.1     ---
   1853   5   16.8     6.1       0    59.5     ---

...

   2010   5   17.6     7.3       0    28.6   207.4
   2010   6   23.0    11.1       0    34.5   230.5
   2010   7   23.3*   14.1*      0*   24.4*  184.4*  Provisional
   2010  10   14.6     7.4       2    43.5   128.8   Provisional
```


We want to extract the weather conditions and the temperature

- Read the file line by line
- If a line contains `Current conditions`, grab the text between the <h3> tags on the next line
- If a line contains `forecast-temperature`, grab the temperature between the <h3> tags on the next line

```
lines = infile.readlines()
for i in range(len(lines)):
    line = lines[i]  # short form
    if 'Current conditions' in line:
        weather = lines[i+1][4:-6]
    if 'forecast-temperature' in line:
        temperature = float(lines[i+1][4:].split('&')[0])
        break  # everything is found, jump out of loop
```


File writing

- File writing is simple: collect the text you want to write in one or more strings and do, for each string, a

```
outfile.write(string)
```

- `outfile.write` does not add a newline, like `print`, so you may have to do that explicitly:

```
outfile.write(string + '\n')
```

- That's it! Compose the strings and write!

Example: writing a nested list (table) to file (part 1)

- Given a table like

```
data = \
[[ 0.75,        0.29619813, -0.29619813, -0.75      ],
 [ 0.29619813,  0.11697778, -0.11697778, -0.29619813],
 [-0.29619813, -0.11697778,  0.11697778,  0.29619813],
 [-0.75,       -0.29619813,  0.29619813,  0.75      ]]
```

- Write this nested list to a file

Example: writing a nested list to file (part 2)

```
outfile = open('tmp_table.dat', 'w')
for row in data:
    for column in row:
        outfile.write('%14.8f' % column)
    outfile.write('
')   # ensure linebreak
outfile.close()
```


Summary of file reading and writing

- Reading a file:

```
infile = open(filename, 'r')
for line in infile:
    # process line

lines = infile.readlines()
for line in lines:
    # process line

for i in range(len(lines)):
    # process lines[i] and perhaps next line lines[i+1]

fstr = infile.read()
# process the while file as a string fstr

infile.close()
```

- Writing a file:

```
outfile = open(filename, 'w')   # new file or overwrite
outfile = open(filename, 'a')   # append to existing file
outfile.write("""Some string
....
""")
```


Dictionary functionality

`a = {}`	initialize an empty
`a = {'point':  [2,7], 'value':  3}`	initialize a dictiona
`a = dict(point=[2,7], value=3)`	initialize a dictiona
`a['hide'] = True`	add new key-value
`a['point']`	get value correspo
`'value' in a`	`True` if `value` is
`del a['point']`	delete a key-value
`a.keys()`	list of keys
`a.values()`	list of values
`len(a)`	number of key-valu
`for key in a:`	loop over keys in u
`for key in sorted(a.keys()):`	loop over keys in a

Summary of some string operations

```
s = 'Berlin: 18.4 C at 4 pm'
s[8:17]          # extract substring
s.find(':')      # index where first ':' is found
s.split(':')     # split into substrings
s.split()        # split wrt whitespace
'Berlin' in s    # test if substring is in s
s.replace('18.4', '20')
s.lower()        # lower case letters only
s.upper()        # upper case letters only
s.split()[4].isdigit()
s.strip()        # remove leading/trailing blanks
', '.join(list_of_words)
```