Carleton University
Department of Systems and Computer Engineering
SYSC 1005 - Introduction to Software Development - Fall 2018

Lab 9 - Using Tuples and Sets to Structure Data

Demo/Grading

After you finish all the exercises, a TA will review your solutions, ask you to demonstrate some of them, and assign a grade. For those who don't finish early, a TA will grade the work you've completed, starting about 30 minutes before the end of the lab period. **Any unfinished exercises should be treated as "homework"; complete these on your own time, before your next lab.**

Part 1 - Comparing Lists and Tuples (Review); Storing Tuples in Sets

Exercise 1

Step 1: Launch Wing 101.

Suppose we want to represent points on a two-dimensional Cartesian plane. We could store the (x, y) coordinates of each point in a list. Type this statement in the Python shell, which binds `point1` to a list that represents the point (1.0, 2.0):

```
>>> point1 = [1.0, 2.0]
```

What is displayed when Python evaluates `point1`? Try this:

```
>>> point1
```

Step 2: The problem with the approach used in Step 1 is that Python lists are *mutable*. For example, we could call the `append` method to insert a `float` at the end of the list. Try this:

```
>>> point1.append(3.0)
>>> point1
```

If the list is supposed to represent a two-dimensional point, this doesn't make sense.

We could then call the `pop` method on this list to remove numbers. Try this:

```
>>> point1.pop(0)  # Remove the number at index 0 in the list
>>> point1

>>> point1.pop()   # Remove the last number in the list
>>> point1
```

The list now has only one value, so it doesn't represent a point.

Step 3: To avoid the problems explored in the previous step, we should represent points using an *immutable* container. Recall that a *tuple* is a container that is similar to a list, except that it can't be modified after is initialized. In the next experiment, we'll see how to represent a point in the 2-D Cartesian coordinate system by a tuple containing two values of type `float`.

Type these statements in the shell (note that the numbers are enclosed in parentheses, not square brackets):

```
>>> point1 = (1.0, 2.0)
>>> point1
>>> type(point1)
```

What is displayed when variable `point1` is evaluated? What is the type of the object bound to `point1`?

Step 4: As with lists, an object stored in a tuple can be retrieved by using the `[]` operator to specify its position in the tuple. Type these statements to retrieve the *x* and *y* coordinates of the point represented by `point1`. What values are displayed when variables `x` and `y` are evaluated?

```
>>> x = point1[0]
>>> y = point1[1]
>>> x
>>> y
```

We can unpack all the objects in a tuple, binding them to individual variables, by using a statement of the form:

```
    var_1, var_2, var_3, ..., var_n = t
```

where `t` is variable bound to a tuple containing *n* objects. This is equivalent to:

```
    var_1 = t[0]
    var_2 = t[1]
        ...
    var_n = t[n-1]
```

Try this experiment. What values are displayed when variables `x` and `y` are evaluated?

```
>>> point2 = (4.0, 6.0)
>>> x, y = point2
>>> x
>>> y
```

Step 5: We can easily demonstrate that tuples are immutable. You can't replace objects in a tuple, or insert new objects in a tuple or remove objects from a tuple. Type these statements in the shell. What is displayed when each statement is executed?

```
>>> point2[0] = 2.0     # Can we change the point to (2.0, 6.0)?
>>> point2.append(4.0)  # Can we add a third coordinate?
>>> point2.pop(0)       # Can we remove the first coordinate?
```

Exercise 2

In the Wing 101 editor, open a new file. Save this file as points.py.

In points.py, define a function that is passed two tuples, each representing a point on a two-dimensional plane. The function returns the distance between the two points. The function header is:

```
def distance(pt1, pt2):
   """ (2-tuple of float, 2-tuple of float) -> float

   Return the distance of the line between 2-D points
   pt1 and pt2.

   >>> point1 = (1.0, 2.0)
   >>> point2 = (4.0, 6.0)
   >>> distance(point1, point2)
   5.0
   """
```

Use the shell to test your function.

Exercise 3

Try this experiment, which creates a set containing the points (1.0, 2.0), (4.0, 6.0) and (10.0, -2.0). What is displayed when `points` is evaluated?

```
>>> points = {(1.0, 2.0), (4.0, 6.0), (10.0, -2.0)}
>>> points
```

We can also initialize the set this way. Try this experiment:

```
>>> point1 = (1.0, 2.0)
>>> point2 = (4.0, 6.0)
>>> point3 = (10.0, -2.0)
>>> points = {point1, point2, point3}
>>> points
```

We could instead start with an empty set, and call the `add` method to initialize it, one point at a time. Try this experiment. What is displayed when `points` is evaluated?

```
>>> points = set()
>>> points.add(point1)
>>> points.add(point2)
>>> points.add(point3)
>>> points
```

What happens if we try to insert a point that is already in the set? Try this experiment:

```
>>> points.add(point2)
>>> points
```

We can use a `for` loop to iterate over all the points in the set. What is displayed when this loop is executed?

```
>>> for point in points:
...     print(point)
...
```

Part 2 - Curve Fitting Using the Method of Least Squares

Every engineering student has tackled the problem of fitting a line through a set of points obtained during a lab experiment.

Linear regression is a technique for fitting a curve through a set of points by applying a goodness-of-fit criterion. The most common form of linear regression is *least-squares fitting*. The mathematical derivation of this technique is beyond the scope of this course, but if you're interested, you can read this page: http://mathworld.wolfram.com/LeastSquaresFitting.html

Suppose we have a set of n points, $\{ (x_0, y_0), (x_1, y_1), \ldots (x_{n-1}, y_{n-1}) \}$. The equation of a straight line through these points has the form $y = mx + b$, where m is the slope of the line and b is the y-intercept.

Using the method of least squares, the slope m and y-intercept b of the line with the best fit are calculated this way:

$$m = (sumx \times sumy - n \times sumxy) \div (sumx \times sumx - n \times sumxx)$$

$$b = (sumx \times sumxy - sumxx \times sumy\ ) \div (sumx \times sumx - n \times sumxx)$$

where:

$sumx$ is $x_0 + x_1 + x_2 + \ldots + x_{n-1}$; i.e., the sum of all the x values *sumy* is $y_0 + y_1 + y_2 + \ldots + y_{n-1}$; i.e., the sum of all the y values

sumxx is $x_0^2 + x_1^2 + x_2^2 + \ldots + x_{n-1}^2$; i.e., the sum of the all the squares of the x values

sumxy is $x_0 \times y_0 + x_1 \times y_1 + x_2 \times y_2 + \ldots + x_{n-1} \times y_{n-1}$; i.e., the sum of all the products of the (x, y) pairs

Exercise 4

To ensure that you understand these formulas, use the method of least squares to calculate the slope and y-intercept of the line through this set of points: {(1.0, 5.0), (2.0, 8.0), (3.5, 12.5)}. Don't write a program to do this; use a calculator. If your calculations are correct, the equation of the line will be:

$y = 3.0x + 2.0.$

Exercise 5

Download linear_regression.py from cuLearn and open the file in Wing 101. This file contains a function named `get_points`, which returns a set of tuples. Each tuple represents one (x, y) point. In the shell, type these statements to verify that the set returned by this function contains three tuples:

```
>>> samples = get_points()
>>> len(samples)  # How many elements are in the set?
>>> samples
```

Exercise 6

In linear_regression.py, define a function named `fit_line_to_points` which is passed a set of tuples, with each tuple representing one (x, y) point. This function should use the method of least squares to calculate the slope and y-intercept of the best-fit straight line through the points. The slope and intercept must be returned in a tuple.

The function header is:

```
def fit_line_to_points(points):
```

In addition to coding the function's body, remember to write a documentation string that provides the type contract, a short description of what the function does, and an example showing how the function can be tested from the Python shell.

Use the shell to call `fit_line_to_points`, passing it the set returned by `get_points`. Verify that the slope and y-intercept returned by the function are 3.0 and 2.0.

Exercise 7

The block after the statement, `if __name__ == "__main__":` contains a single statement, `pass`. Replace `pass` with a short script that:

- calls `fit_line_to_points`, passing it the set of points returned by `get_points`;
- prints "The best-fit line is y = *m*x + *b*", where *m* and *b* are the values returned by your function.

Test your script.

Part 3 - Working with Data Stored in a File

Suppose we want to fit lines through different sets of points. You could modify the script you wrote in Exercise 8 to read the (*x*, *y*) coordinates of each point from the keyboard, but this would be tedious and error-prone when you want to fit a line through many points. Instead, we'll store the points in a text file that can be prepared with any text editor, and modify the script to read the points from the file.

Exercise 8 - Experiments with Text Files

Step 1: You've been provided with a file named data.txt that contains the (*x*, *y*) coordinates of three points, one per line:

1.0 5.0

2.0 8.0

3.5 12.5

Download this file from cuLearn to the same folder where linear_regression.py is stored.

To read data from a file, we must first open it, using Python's built-in `open` function. Type this:

```
>>> infile = open('data.txt', 'r')
```

`open` takes two arguments, The first argument is a string containing the name of the file to open. The second argument is a string that specifies the mode; `'r'` means open the file for reading.

`open` returns an object that stores information about the opened file. Here, we've bound that object to variable `infile`.

Next, we'll use the `readline` method to read the file, one line at a time. Type these statements. What is displayed each time variable `s` is evaluated?

```
>>> s = infile.readline()
>>> s
>>> s = infile.readline()
>>> s
```

```
>>> s = infile.readline()
>>> s
>>> s = infile.readline()
>>> s
>>> infile.close()
```

Notes:

- The `readline` method returns each line as a string (an object of type `str`).
- There is a `\n` at the end of each string. This is the *newline character*, which terminates every line of text in the file.
- The `readline` method returns an empty string (`''`) if it is called after all the lines have been read from the file.
- After you've finished reading a file, you should always close it by calling the `close` method.

Step 2: We can use a `for` loop to read lines from a file. Define the following function in linear_regression.py:

```
def read_and_print_lines():
    infile = open('data.txt', 'r')
    for line in infile:
        print(line)
    infile.close()
```

On each iteration of the `for` loop, Python automatically calls `readline` and binds the line read from the file to variable `line`.

Call `read_and_print_lines` from the shell, and observe what is printed.

Exercise 9 - Converting Strings to Real Numbers

Step 1: Recall that the string representation of a real number can be converted to a `float` by calling Python's built-in `float` function. Try this:

```
>>> s = '2.0'
>>> x = float(s)
>>> x
```

Step 2: The `float` function doesn't work with strings containing multiple numbers. Try this:

```
>>> float('1.0   5.0')
```

We need to break up each line read from the file into two strings, each containing one number, then individually convert each string to a `float`. This is easy to do, using the `split` method.

Try this:

```
>>> s = '1.0   5.0'
>>> numbers = s.split()
>>> numbers
```

Notice that `split` chops the string into two strings, each containing one of the numbers, and returns a list containing both strings.

Step 3: How would you convert the two strings in list `numbers` to values of type `float`? Design some experiments that show how to do this, and execute them in the shell.

Exercise 10 - Reading Points from a Text File

Apply what you learned in Exercises 8 and 9 by defining a function named `read_points` in linear_regression.py. This function takes a single argument, a string containing the name of a text file. The function header is:

```
def read_points(filename):
```

Each line in the text file will contain two real numbers. The function will return a set of tuples, with each tuple containing one (x, y) point (i.e., a pair of `float`s).

Remember to write a documentation string!

Interactively test this function. If you call `read_points` with 'data.txt' as the argument, the set returned by the function should be identical to the set returned by `get_points`.

Exercise 11 - Modifying the Curve-Fitting Script to Read Points from a File

Modify your main script (not function `read_points`) so that it prompts the user to enter the name of a text file. The script should then read the points from the file, then calculate and display the formula for the best-fit line through the points.

Test your script.

Wrap-up

1. Remember to have a TA review your solutions to the exercises, assign a grade (Satisfactory, Marginal or Unsatisfactory) and have you initial the grading/sign-out sheet.

2. Remember to backup your linear_regression.py file before you leave the lab; for example, copy it to a flash drive and/or a cloud-based file storage service.