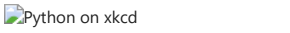
MY470 Computer Programming

Data Types in Python

Week 2 Lecture

Overview

- About Python
- Scalars: `int` , `float` , `bool` , `None`
  - Operators: arithmetic, boolean, comparison, assignment, membership
- Non-scalars: `list` , `tuple` , `str` , `set` , `dict`
  - Methods
  - Ordered vs. unordered non-scalars
  - Mutable vs. immutable non-scalars



Source: http://xkcd.com/353/

Why Python?

- Open-source – free and well-documented
- Simple and concise syntax
- Many useful libraries
- Cross-platform
- Widely used in industry and science

Python vs. Java: Syntax

- Python

In [4]:
```
print('Hello world!')
```

```
Hello world!
```

- Java

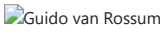
```
public class HelloWorld
{
    public static void main (String[] args)
    {
        System.out.println("Hello world!");
    }
}
```

Python vs. C, Matlab, R, and Julia: Speed

Task	Python	C	Matlab	R	Julia
Loops	61.97	0.55	6.80	744.93	0.34
Matrix multiplication	0.95	-	0.90	11.46	1.09
Open files and plot data	1399	-	1678	2220	1317
Metropolis-Hastings algorithm	0.08	4.30	0.99	28.63	0.73

Source: https://modelingguru.nasa.gov/docs/DOC-2625

A Brief History of Python



- Started in December 1989 by Guido van Rossum, BDFL (Benevolent Dictator for Life)
- Python 2.0 released in 2000
- Python 3.0, which is backward-incompatible, released in 2008
- End of Life date for Python 2.7 was January 1st, 2020

From Last Week: Objects, Data Types, and Expressions

- Computer programs manipulate objects
- Objects have types
  - Scalar — indivisible
  - Non-scalar — with internal structure
- Expressions combine objects and operators

Scalar Data Types

- Integer
- Float
- Boolean
- NoneType
- (String is non-scalar in Python)

In [5]:
```
print(type(2))
print(type(1.125))
print(type(True))
print(type(None))
print(type('a'))
```

```
<class 'int'>
<class 'float'>
<class 'bool'>
<class 'NoneType'>
<class 'str'>
```

Converting between Scalar Data Types

- Use the name of a type to convert values to that type

In [6]:
```
a = float(123)
b = int('32')
print(a, b)
```

```
123.0 32
```

Operators

- Arithmetic
- Boolean
- Comparison
- Assignment

Arithmetic Operators

- `+` addition
- `-` subtraction
- `*` multiplication
- `/` division
- `%` modulus
- `//` floor division
- `**` exponent

In [7]:
```
# + and * have different meanings depending on the types of objects with which they are used
print(2 + 2)
print('a' + 'bc')
print(3 * 2)
print(3 * 'a' + 'h!')
```

```
4
abc
6
aaah!
```

Boolean Operators

- `and`
- `or`
- `not`

In [8]:
```
print(True and False)
print(True or False)
print(not False)
```

```
False
True
True
```

Comparison Operators

- `==` equals
- `!=` does not equal
- `>` is greater than
- `<=` is less than or equal, etc.

Assignment Operators

- `=` assign right operand to left operand
- `+=` add right operand to left operand and assign to left operand
- `-=` subtract right operand from left operand and assign to left operand, etc.

In [2]:
```
a = 2
```

```
a += 3 # Equivalent to a = a + 3
print(a)
```

```
5
```

Comparison vs. Assignment Operators

In [9]:
```
a = 2 # This is assignment
print(a == 1) # This is test for equality. It returns bool.
```

```
False
5
```

Non-Scalar Data Types

- List – a mutable ordered sequence of values
- Tuple – an immutable ordered sequence of values
- String – an immutable ordered sequence of characters
- Set – a mutable unordered collection of unique values
- Dictionary – a set of key/value pairs

In [7]:
```
list_var = [1, 2, 2, 'a', 'a'] # list
tuple_var = (1, 2, 'a', 'b') # tuple
set_var = {1, 2, 2, 'a', 'b'} # set
dict_var = {1: 'a', 2: 'b', 3: 'c'} # dictionary
print(list_var, set_var)
```

```
[1, 2, 2, 'a', 'a'] {'b', 1, 2, 'a'}
```

Converting between Non-Scalar Data Types

- Use the name of a type to convert values to that type

In [12]:
```
tup = tuple([1, 2, 3])
dic = dict( [(1, 'a'), (2, 'b'), (3, 'c')] )
print(tup, dic)
```

```
(1, 2, 3) {1: 'a', 2: 'b', 3: 'c'}
```

Membership Operator

- `in` left element is in right non-scalar

In [5]:
```
print('x' not in 'abcdefg')
```

```
True
```

Length of Non-Scalar Objects

- The `len()` function returns the length of the element

In [13]:
```
print( len( [0, 1, 2] ) )
print( len('ab') )
print( len( (1, 2, 3, 4, 'a') ) )
print( len( {1: 'a', 2: 'b'} ) )
```

```
3
2
5
2
```

Non-Scalar Data Types: Exercise

In [1]:
```
# Use len() to count the number of unique letters in the string below

s = 'jackie will budget for the most expensive zoology equipment'
```

Strings

- You can write string literals in different ways
  - Single quotes: `'allows embedded "double" quotes'`
  - Double quotes: `"allows embedded 'single' quotes"`
  - Triple quoted: `'''Three single quotes'''`, `"""Three double quotes"""`

In [14]:
```
'''Triple quoted strings may span multiple lines -
all associated whitespace will be included
in the string literal.'''
```

Out[14]:
```
'Triple quoted strings may span multiple lines - \nall associated whitespace will be included \nin the string literal.'
```

- Strings implement all of the common sequence operations we will shortly discuss, along with some additional methods: http://docs.python.org/3/library/stdtypes.html#string-methods

Objects Have Methods Associated with Them

`object.method()`

Use the period `.` to link the method to the object.

In [11]:
```
string1 = 'Hello'

string1 + '!'   # This is an operator. Operators combine objects in expressions.
len(string1)   # This is a function. Functions take objects as arguments.
string1.upper()   # This is a method. Methods are attached to objects.
```

Out[11]:
```
'HELLO'
```

String Methods: Formatting

- `S.upper()` – change to upper case
- `S.lower()` – change to lower case
- `S.capitalize()` – capitalize the first word
- `S.find(S1)` – return the index of the first instance of input

In [15]:
```
print('Make me scream!'.upper())
x = 'make this into a proper sentence'
print(x.capitalize() + '.')

print('Find the first "i" in this sentence.'.find('i'))
```

```
MAKE ME SCREAM!
Make this into a proper sentence.
1
```

String Methods: `strip` and `replace`

- `S.replace(S1, S2)` – find all instances of S1 and change to S2
- `S.strip(S1)` – remove whitespace characters from the beginning and end of a string (useful when reading in from a file)

In [16]:
```
x = ' This is a long sentence that we will use as an example.\n'
print(x.replace('s', 'S'))
print(x.strip())
print(x.replace(' ', ''))
```

```
 ThiS iS a long Sentence that we will uSe aS an example.

This is a long sentence that we will use as an example.
ThisisalongsentencethatwewilluseasanexampleA.
```

String Methods: `split` and `join`

- `S.split(S1)` – split the string into a list
- `S.join(L)` – combine the input sequence into a single string

In [17]:
```
x = 'this is a collection of words i would like to break it into tokens'
y = x.split()    # default is to split on ' '
print(y)
print(x.split('o'))

x_new = '-'.join(y)
print(x_new)
```

```
['this', 'is', 'a', 'collection', 'of', 'words', 'i', 'would', 'like', 'to', 'break', 'it', 'into', 'tokens']
['this is a c', 'llecti', 'n ', 'f w', 'rds i w', 'uld like t', ' break it int', ' t', 'kens']
this-is-a-collection-of-words-i-would-like-to-break-it-into-tokens
```

String Methods: Exercise

In [2]:
```
# Use string methods to create a properly formatted sentence
# from the words below:

ls = ['  ThiS', 'SenTence', 'NEEDS', 'bEttEr!', 'foRmatting']
```

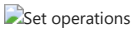
Unordered Types vs. Sequences

- Unordered types: `set`, `dict`
- Ordered (sequence) types: `str`, `list`, `tuple`

In [9]:
```
st = {1, 2, 2, 'a', 'b'} # sets are unordered
print(st)
```

```
{'b', 1, 2, 'a'}
```

Set Methods



- `S1.union(S2)`, `S1 | S2` — elements in S1 or S2, or both
- `S1.intersection(S2)`, `S1 & S2` — elements in both S1 and S2
- `S1.difference(S2)`, `S1 - S2` — elements in S1 but not in S2
- `S1.symmetric_difference(S2)`, `S1 ^ S2` — elements in S1 or S2 but not both

In [1]:
```
st1 = set('homophily')
st2 = set('heterophily')
print(st1 ^ st2)
```

```
{'m', 'r', 'e', 't'}
```

Dictionary Operations: Indexing

- Dictionaries are indexed by keys

In [20]:
```
mydic = {'Howard': 'aerospace engineer', 'Leonard': 'physicist', 'Sheldon': 'physicist',
         'Penny': 'waitress', 'Raj': 'astrophysicist'}
print(mydic['Raj'])
```

```
astrophysicist
```

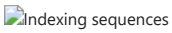
Sequence Operations: Indexing

- Lists, tuples, and strings are indexed by numbers

In [21]:
```
'ABCDEFG'[2]
```

Out[21]:
```
'C'
```

Indexing in Python starts from 0!



Source: https://devrant.com/rants/1798534/array-start-from-zero-d

Sequence Operations: Indexing

- Use `elem[index]` to extract individual sub-elements

In [42]:
```
print( 'abc'[0] )
print( ('a', 'b', 'c')[-1]) # use negative numbers to index from the end
print( ['a', 'b', 'c'][3])
```

```
a
c
---------------------------------------------------------------------------
IndexError                                Traceback (most recent call last)
<ipython-input-42-3b1b01b1ae7f> in <module>()
      1 print( 'abc'[0] )
      2 print( ('a', 'b', 'c')[-1]) # use negative numbers to index from the end
----> 3 print( ['a', 'b', 'c'][3])

IndexError: list index out of range
```

Sequence Operations: Slicing

- Use `elem[start:end]` to get sub-sequence starting from index `start` and ending at index `end-1`

In [1]:
```
ls = [10, 20, 30, 40, 50]
print( ls[1:4] )
print( ls[:3] )
print( ls[1:] )

ls[:] == ls[0:len(ls)]
```

```
[20, 30, 40]
[10, 20, 30]
[20, 30, 40, 50]
```

Out[1]:
```
True
```

Sequence Operations: Extended Slices

- Use `elem[start:end:step]` to get sub-sequence starting from index `start`, in steps of `step`, ending at index `end-1`

In [1]:
```
ls = [10, 20, 30, 40, 50]
print( ls[::2] ) # get elements with even indeces
print( ls[::-1] ) # get elements in reverse order
```

```
[10, 30, 50]
[50, 40, 30, 20, 10]
```

Indexing and Slicing: Exercise

In [3]:
```
# Use indexing and slicing to create a new string that contains
# the 2nd, 4th, 5th, 6th, and last characters from the string below

s = 'abcdefghijklmnopqrstuvwxyz'
```

More Sequence Operations

In [24]:
```
tup1 = 3 * (1,) # Notice that tuple of length 1 needs comma!
tup2 = tup1 + (2, 2) # Concatenate the two elements
print(tup1, tup2)

print( max(tup2) ) # or min()
print( sum(tup2) )
print( tup2.count(1) )
print( tup2.index(2) )
```

```
(1, 1, 1) (1, 1, 1, 2, 2)
2
7
3
3
```

- Why use tuples?
  - ⚡ They use less memory than lists
  - They can be used as dictionary keys; lists can't

Mutability

- Immutable types: `str`, `tuple`, and all scalars
- Mutable types: `list`, `set`, `dict`

Objects of mutable types can be modified once they are created.

In [25]:
```
dic = {1:'a', 2:'b'}
dic[3] = 'c'
print(dic)

ls = [5, 4, 1, 3, 2]
ls.sort()
print(ls)
```

```
{1: 'a', 2: 'b', 3: 'c'}
[1, 2, 3, 4, 5]
```

Mutability Can Be Quite Convenient

There are several useful list methods, see http://docs.python.org/3/library/stdtypes.html#mutable-sequence-types:

- `L.append(e)`
- `L.insert(i, e)`
- `L.remove(e)`
- `L.extend(L1)`
- `L.pop(i)`
- `L.sort()`
- `L.reverse()`

In [13]:
```
ls1 = [1, 2, 3]
ls1.append(4)
print(ls1)
ls1.extend([5, 6, 7, 8, 9, 10])
print(ls1)
```

```
[1, 2, 3, 4]
[1, 2, 3, 4, 5, 6, 7, 8, 9, 10]
```

Mutability Can Also Be Dangerous

In [14]:
```
ls1 = [1, 2, 3]
ls2 = [4, 5, 6, 7]

ls1.append(ls2)
print(ls1)

ls2.extend([8, 9, 10])
print(ls1)
```

```
[1, 2, 3, [4, 5, 6, 7]]
[1, 2, 3, [4, 5, 6, 7, 8, 9, 10]]
```

Aliasing vs. Cloning

In [16]:
```
ls1 = [1, 2, 3]
ls2 = ls1[:]  # Using [:] is one way to clone

ls1.reverse()
print(ls2)
```

```
[1, 2, 3]
```

List Methods: `append` vs. `extend`

In [29]:
```
mylist = [1, 2, 3, 4]
mylist.append(5)
print(mylist)

mylist.extend([8, 7, 6])
print(mylist)
```

```
[1, 2, 3, 4, 5]
[1, 2, 3, 4, 5, 8, 7, 6]
```

List Methods: `remove` vs. `pop`

In [13]:
```
mylist = [1, 2, 3, 4]
```

```
mylist.remove(1)
print(mylist)

popped = mylist.pop(1)
print(popped, mylist)
```

```
[2, 3, 4]
3 [2, 4]
```

List Methods: `L.sort()` vs. `sorted(L)`

In [31]:
```
mylist = [4, 5, 2, 1, 3]
mylist.sort()  # Sorts in-place. It is more efficient but overwrites the input.
print(mylist)

mylist = [10, 9, 6, 8, 7]
sorted(mylist)
print(mylist)

newlist = sorted(mylist)  # Creates a new list that is sorted, not changing the original.
print(mylist, newlist)
```

```
[1, 2, 3, 4, 5]
[10, 9, 6, 8, 7]
[10, 9, 6, 8, 7] [6, 7, 8, 9, 10]
```

Aliasing and Cloning: Exercise

What will the following program print?

```
ls1 = [11, 3, 8, 6, 6, 1]
ls2 = ls1
ls2[2] = 0
print(ls1)
```

- (A) [11, 3, 8, 6, 6, 1]
- (B) [11, 0, 8, 6, 6, 1]
- (C) [11, 3, 0, 6, 6, 1]
- (D) 0

Data Types in Python

Type	Scalar	Mutability	Order
`int`	scalar	immutable	
`float`	scalar	immutable	
`bool`	scalar	immutable	
`None`	scalar	immutable	
`str`	non-scalar	immutable	ordered
`tuple`	non-scalar	immutable	ordered
`list`	non-scalar	mutable	ordered
`set`	non-scalar	mutable	unordered
`dict`	non-scalar	mutable	unordered

- Objects have types
- Objects have methods

- **Lab**: Lists, lists, lists (and some strings)
- **Next week**: Control flow in Python