Fundamentals of Machine Learning
Python for Data Science – Part 1

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The Python Interpreter

- Python is an interpreted language (as opposed to compiled languages such as C++).
- Commands can be executed interactively, or a series of commands can be saved in a plain text file known as source code or a script.
- For Python, source code is normally stored in a file with the .py suffix (e.g., hello.py).
- We will use Python 3 for this class.

How to run Python code (1)

We can use one of the following ways

- Start Python at the command line by typing
  $ python
- Edit source.py and run
  $ python source.py
- Make the python file executable and run it directly
  - Make the Python source code executable
    $ chmod +x source.py
  - Put the path to the Python interpreter at the very first line of the Python source code, e.g.
    #!/usr/local/bin/python
  - Run the Python source code directly
    $ ./source.py

How to run Python code (2)

- Use an IDE (Integrated Development Environment) such as Pycharm.
- Use Jupyter notebooks
- Use online notebooks such as
  - `https://colab.research.google.com/`
  - `https://www.kaggle.com/`

Sample Python source code

```
def calc_mean(f_list):
    l_len = len(f_list)
    # Calculate the mean
    l_sum = 0
    for e in f_list:
        l_sum += e
    l_mean = float(l_sum) / l_len
    return l_mean

my_list = [4, 5, 20]
calc_mean(my_list)
```

Identifiers, Objects, and the Assignment Statement

- Python is an object-oriented language and all data types are based on classes.
- Consider the assignment (Example from [1] Goldwasser, Goodrich, and Tamassia)

```
temperature = 98.6
```

- This associates the identifier *temperature* with a floating-point object with value 98.6.
- Identifiers in Python are case-sensitive, so *temperature* and *Temperature* are distinct names.
- Identifiers can be composed of almost any combination of letters, numerals, and underscore characters.
- An identifier, however, cannot begin with a numeral (E.g., '4runner' is not a valid identifier.

```
temperature = 98.6
```

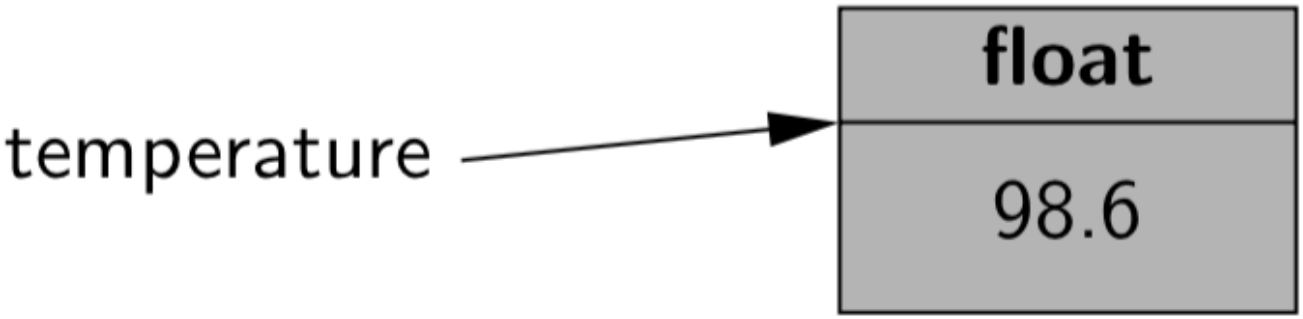


Figure: The identifier *temperature* is associated with a floating-point object with value 98.6 (Figure from [1])

Identifiers, Objects, and the Assignment Statement

- An identifier cannot be one of the reserved words (Table from [1] Goldwasser, Goodrich, and Tamassia)

Reserved Words								
False	as	continue	else	from	in	not	return	yield
None	assert	def	except	global	is	or	try	
True	break	del	finally	if	lambda	pass	while	
and	class	elif	for	import	nonlocal	raise	with	

Table 1.1: A listing of the reserved words in Python. These names cannot be used as identifiers.

- Unlike statically typed languages such as C++, Python is a dynamically typed language.
- We do not need to associate an identifier with a particular data type during declaration.
- We can associate an identifier with any type of object, and later reassign it to another object of the same (or different) type.
- Although an identifier has no declared type, the object to which it refers has a definite type.

```
original = temperature
```

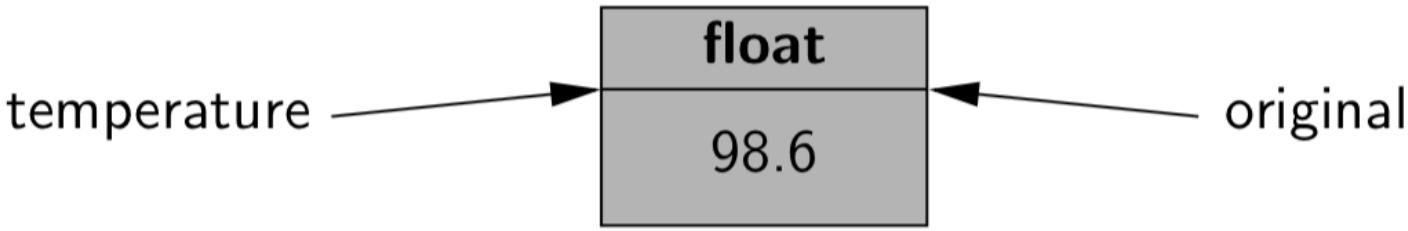


Figure: We can assign a second identifier, *original*, to the floating-point object. Now both *temperature* and *original* are **alias**es of the floating-point object (Figure from [1])

- Any alias of an object can be used to access the object.
- If an object supports operations to change its state, changes made using an alias (without using an assignment statement) will still be effective as seen from another alias
- If we assign a new value to an alias using an assignment statement, the alias will point to a new object

```
temperature = temperature + 5.0
```

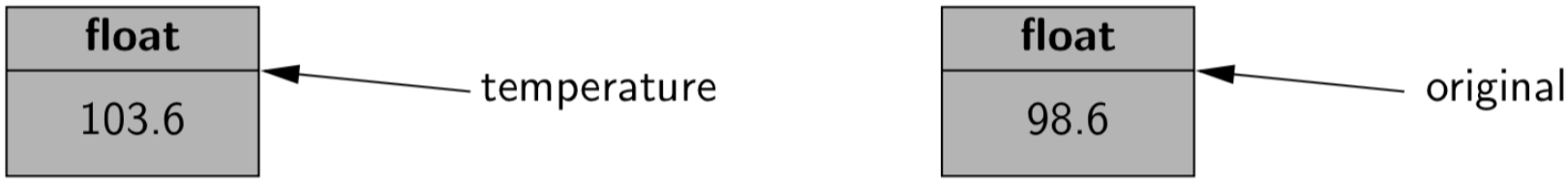


Figure: If we assign a new value to an alias using an assignment statement, the alias will point to a new object (Figure from [1])

```
[ ]  group = ['An', 'Binh', 'Cuong', 'Dai']

[ ]  group_2 = group

[ ]  group_2

     ['An', 'Binh', 'Cuong', 'Dai']

[ ]  group_2.append('En')

[ ]  group_2

     ['An', 'Binh', 'Cuong', 'Dai', 'En']

[ ]  group

     ['An', 'Binh', 'Cuong', 'Dai', 'En']
```

Figure: If an object supports operations to change its state, changes made using an alias (without using an assignment statement) will still be effective as seen from another alias

```
[ ]  group_2

     ['An', 'Binh', 'Cuong', 'Dai', 'En']

[ ]  group

     ['An', 'Binh', 'Cuong', 'Dai', 'En']

     group_2 = ["Fiona"]

[15] group

     ['An', 'Binh', 'Cuong', 'Dai', 'En']
```

Figure: Here we assign a new value to *group_2* using an assignment statement, *group_2* will point to a new object, while *group* stays the same.

Instantiation

- Instantiation is the process of creating a new object (instance) of a class
- For example s1 = Student('An', 'UEL', 'MLEF1') creates a student of UEL's MLEF1 course named An
- Some built-in classes of Python also support the **literal** form of instantiation.
- E.g. The command `temperature=98.6` creates a new object of the **float** class
- The term 98.6 is a literal form
- In the canonical form, it may look something like `temperature = float(98.6)`

Calling Methods

- In Python, we can call independent (non-class) functions that are invoked with a syntax such as calculate_mean(my_list), in which case my_list is a parameter passed into the function.
- We can also define methods (member functions) for Python's classes, which can be invoked on an instance of the class using the dot (".") operator.
- Methods that return information about the state of an object are called **accessors**
- Methods that change the state of an object are called **mutators** or **update methods**

A Python class

```
class MyList():
    def __init__(self, in_list):
        # Data members (attributes)
        self._list = in_list

     # Member functions (methods)
    def calculate_mean(self):
         # Here we use the independent function
         # calculate_mean() provided earlier
        return calc_mean(self._list)

scores = MyList([4, 5, 10])
scores.calculate_mean()
```

Python's Built-In Classes

- The table below [1] provides a summary of commonly used, built-in classes in Python
- There are mutable and immutable classes.
- A class is immutable if each object of that class has a fixed value upon instantiation that cannot be changed later on.

Class	Description	Immutable?
bool	Boolean value	✓
int	integer (arbitrary magnitude)	✓
float	floating-point number	✓
list	mutable sequence of objects	
tuple	immutable sequence of objects	✓
str	character string	✓
set	unordered set of distinct objects	
frozenset	immutable form of set class	✓
dict	associative mapping (aka dictionary)	

Table 1.2: Commonly used built-in classes for Python

Expressions

- An **expression** consists of variables, values and **operators**.
- E.g., $a + b$ is an expression where a and b are variables and $'+'$ is an operator
- In **compound expressions** such as $a + b * c$, Python defines a specific order of precedence for evaluating operators.

Logical Operators

Python supports the following keyword operators for Boolean values:

not	unary negation
and	conditional and
or	conditional or

Equality Operators

Python supports the following operators to test two notions of equality:

is	same identity
is not	different identity
==	equivalent
!=	not equivalent

Comparison Operators

Data types may define a natural order via the following operators:

<	less than
<=	less than or equal to
>	greater than
>=	greater than or equal to

Arithmetic Operators

Python supports the following arithmetic operators:

+	addition
−	subtraction
*	multiplication
/	true division
//	integer division
%	the modulo operator

Bitwise Operators

Python provides the following bitwise operators for integers:

~	bitwise complement (prefix unary operator)
&	bitwise and
|	bitwise or
^	bitwise exclusive-or
<<	shift bits left, filling in with zeros
>>	shift bits right, filling in with sign bit

Sequence Operators

Python Data types	Description
`list`	**mutable** sequence of objects
`tuple`	**immutable** sequence of objects
`str`	character **string**

Sequence Operators

All sequences define comparison operations based on lexicographic order, performing an element by element comparison until the first difference is found. For example, $[5, 6, 9] < [5, 7]$ because of the entries at index 1. Therefore, the following operations are supported by sequence types:

- $s == t$ equivalent (element by element)
- $s! = t$ not equivalent
- $s < t$ lexicographically less than
- $s <= t$ lexicographically less than or equal to
- $s > t$ lexicographically greater than
- $s >= t$ lexicographically greater than or equal to

Sequence Operators

Sequence Operators	Description
`s[i]`	Element at index i
`s[start:stop]`	Slice including indices [start, stop)
`s[start:stop:step]`	Slice including indices start, start + step, start + 2*step,... up to but not equaling or stop
`s + t`	Concatenation of sequences
`k * s`	Shorthand for s + s + s + … (k times)
`val in s`	Containment check
`val not in s`	Non-containment check

Operators for Sets and Dictionaries

key in *s*	containment check
key not in *s*	non-containment check
$s == t$	s is equivalent to t
$s != t$	s is not equivalent to t
$s <= t$	s is a subset of t
$s < t$	s is a proper subset of t
$s >= t$	s is a superset of t
$s > t$	s is a proper superset of t
$s \mid t$	the union of s and t
$s \& t$	the intersection of s and t
$s - t$	the set elements in s but not in t
$s \hat{} t$	the set of elements in precisely s or t

Dictionaries

d[key]	value associated with given key
d[key] = value	set (or reset) the value associated with given key
del d[key]	remove key and its associated value from dictionary
key **in** d	containment check
key **not in** d	non-containment check
d1 == d2	d1 is equivalent to d2
d1 != d2	d1 is not equivalent to d2

Extended Assignment Operators

```
alpha = [1, 2, 3]
beta = alpha                # an alias for alpha
beta += [4, 5]              # extends the original list with two more elements
beta = beta + [6, 7]        # reassigns beta to a new list [1, 2, 3, 4, 5, 6, 7]
print(alpha)                # will be [1, 2, 3, 4, 5]
```

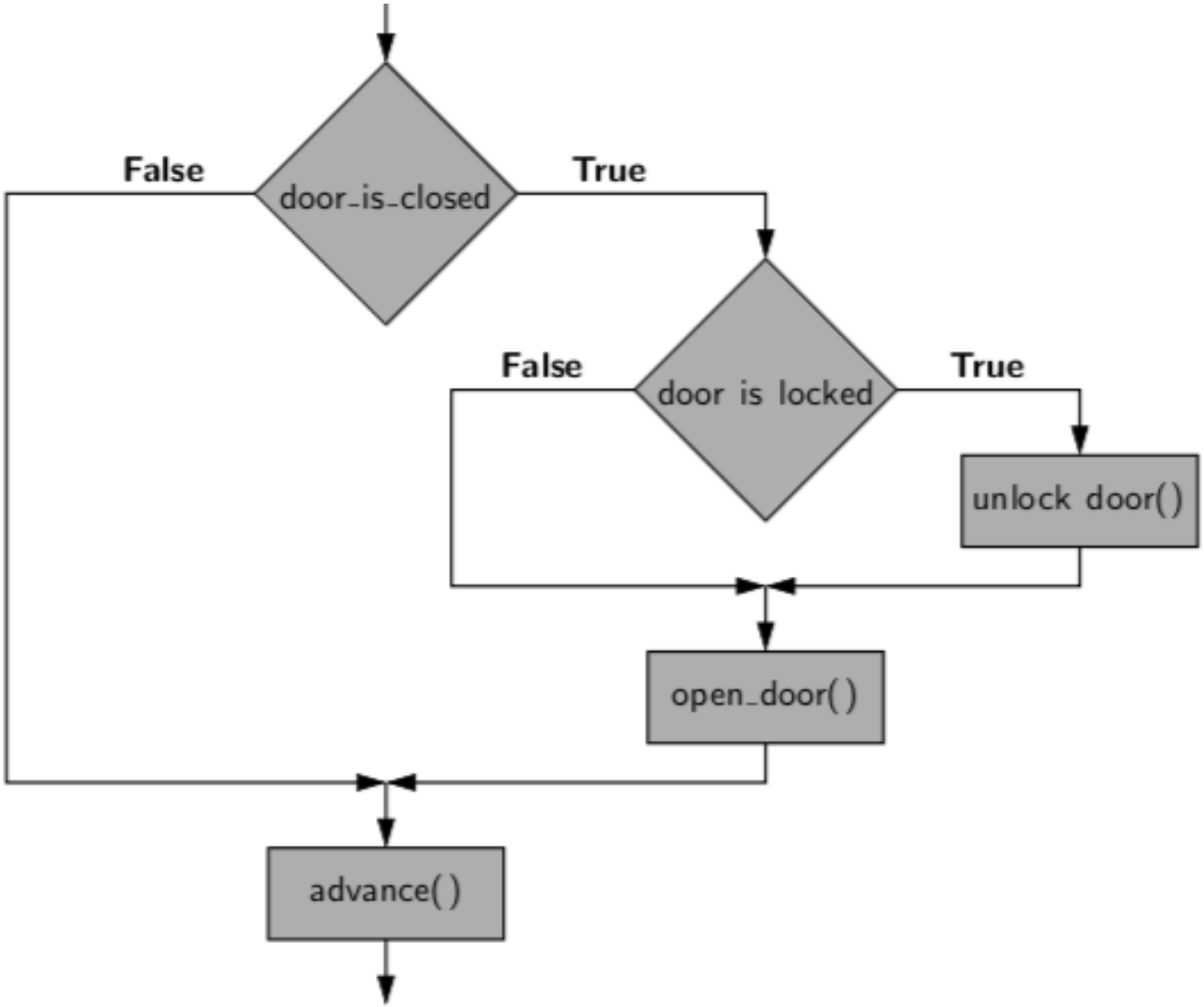
Compound Expressions and Operator Precedence

Operator Precedence		
	Type	**Symbols**
1	member access	expr.member
2	function/method calls container subscripts/slices	expr(...) expr[...]
3	exponentiation	**
4	unary operators	+expr, −expr, ~expr
5	multiplication, division	*, /, //, %
6	addition, subtraction	+, −
7	bitwise shifting	<<, >>
8	bitwise-and	&
9	bitwise-xor	^
10	bitwise-or	|
11	comparisons containment	**is**, **is not**, ==, !=, <, <=, >, >= **in**, **not in**
12	logical-not	**not** expr
13	logical-and	**and**
14	logical-or	**or**
15	conditional	val1 **if** cond **else** val2
16	assignments	=, +=, −=, *=, etc.

Conditionals

```
if first_condition:
    first_body
elif second_condition:
    second body
elif third_condition:
    third_body
else:
    fourth_body
```

An example flowchart



While loops

```
while condition:
    body
```

For example, below is a loop that increments an index until we find an entry with value ‘X‘ or reaching the end of the sequence.

```
j = 0
while j < len(data) and data[j] != 'X':
    j += 1
```

For loops

```
for element in iterable:
    body # body may refer to element as an identifier
```

```
# Calculate squares of integers
numbers = [1, 2, 3, 4, 5]
squares = []
for num in numbers:
    squares.append(num**2)
```

Index-Based For Loops

```
for i in range(len(ml_class)):
    print("Student number %d: %s" % (i, ml_class[i]))
```

Break and Continue Statements

```
found = False
for item in data:
    if item == target:
        found = True
        break
```

Break Statements

Listing 1: Break statement

```
found = False
for student_name in mlef1_class_list:
    if student_name == "Nguyen Van A":
        found = true
        break
```

Continue Statements

Listing 2: Continue statement

```
count = 0
for student_name in mlef1_class_list:
    if student_name == "Nguyen Van A":
        continue
    count += 1
```

Functions

```
def count(data, target):
    n = 0
    for item in data:
        if item == target: # found a match
            n +=1
    return n
```

Functions

- Information passing
- Mutable parameters
- Default parameter values
- Keyword parameters

Functions

Listing 3: Function example in Python

```
def count_students_by_name(
    dsa_class_list,
    name_of_interest
    ):
    count = 0
    for student_name in dsa_class_list:
        if student_name == name_of_interest:
            count += 1
    return count
```

High-level Languages

- Represent a giant leap towards easier programming
- Syntax similar to the English language
- Divided into 2 groups
  - Procedural languages
  - Object-oriented languages

Procedural Languages

- Specify the sequence of steps that implements a particular Algorithms
- Revolves around keeping code as concise as possible
- Focus on a very specific end result to be achieved
- Examples:
  - C
  - Fortran
  - Pascal

Object-Oriented Languages

- Focus not on structure, but on modeling data
- Programmers code using blueprints of data models called classes

Object-Oriented Programming

- A design program philosophy
- Key idea: the real world can be accurately described as a collection of objects that interact
- Everything is grouped as objects $\rightarrow$ enhance reusability

OOP Basic Terminology

- Object
- Method
- Attribute
- Class

Classes and Objects

- A class is a prototype, idea, and **blueprint** for creating objects
- An object is an **instance** of a class
- A class has a constructor for creating objects
- A class is composed of 3 things
  - Name
  - Attributes
  - Methods

Formal Definition of Objects

- A computational entity that:
  - Encapsulates some state
  - Is able to perform actions/methods on its state
  - Communicates with other objects

Classes and Objects Examples

Listing 4: Class example Python

```
class Human:
    def __init__(self, name):
        self.name = name

    def getName(self):
        return self.name

viet = Human("Viet Nguyen")
```

OOP Basic Concepts

- Encapsulation
- Inheritance
- Polymorphism
- Abstraction

Encapsulation

- Inclusion of properties and methods within a class/object
- Enable reusability

Encapsulation

- Inclusion of properties and methods within a class/object
- Enable reusability

Polymorphism

- Literally means many forms
- Objects of different classes in a class hierarchy can be accessed through the same interface
- Each class can provide its own implementation of this interface
- When we invoke a method, objects of different classes can have different behaviors.

Inheritance

- Allow class hierarchy
- Enable reusability

Abstraction

- Allows programmers to represent complex real world in the simplest manner
- When we design abstract classes, we define the framework for later extensions

Advantages of OOP

- Code reuse and recycling
- Improved productivity
- Improved maintainability
- Faster development
- Higher quality, lower cost of software development

Disadvantages of OOP

- Steep learning curve
- Could lead to larger programs
- Could produce slower programs

References

[1] M. H. Goldwasser, M. T. Goodrich, and R. Tamassia – Data Structures and Algorithms in Python, John Wiley & Sons, 2013
[2] J. Unpingco, Python for Probability, Statistics, and Machine Learning (1st. ed.). Springer Publishing Company, Incorporated, 2016
[3] VEF Academy, Machine Learning, 2020
[4] VEF Academy, Data Analytics, 2020