DM561 / DM562

Linear Algebra with Applications

Intoduction to Python - Part 1

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[*Based on the booklet "Python Essentials"*]

Outline

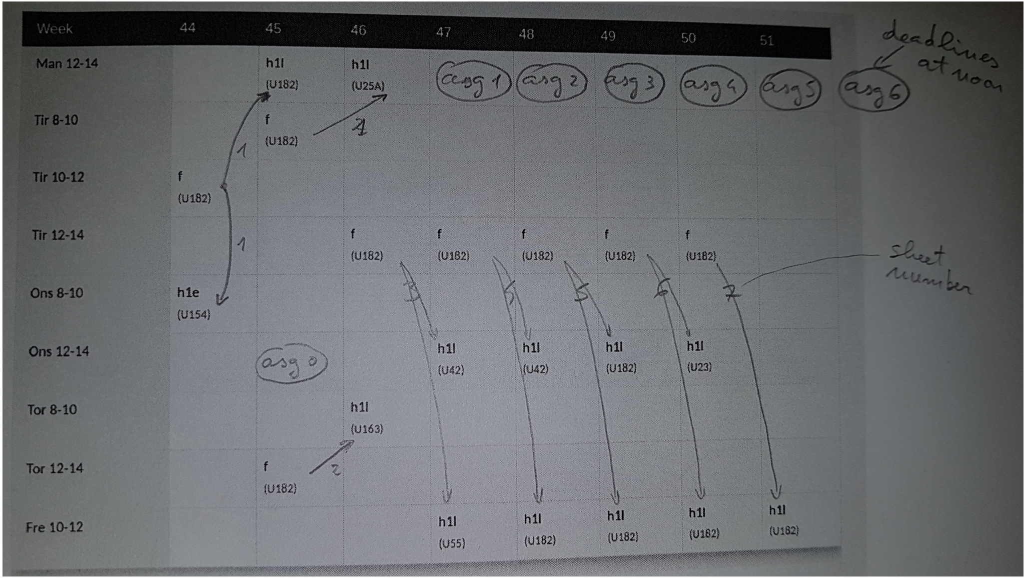
Outline

Contents

Introductory Classes

Week	Date	Teacher	Topics and Slides	Suggested reading
44	Oct 29	Marco	Intro to Python - Part 1	App A, B and ch 1-3 of [HJ1]; [DB]
45	Nov 5	Marco	Intro to Python - Part 2	ch 4-6 of [HJ1]
45	Nov 7	Marco	Intro to Python - Part 3	
46	Nov 12	Marco	Least Squares Data Fitting	
47	Nov 19	Daniel	Graph Isomorphism and Molecules	
48	Nov 26	Daniel	From Random Polygon to Ellipse	
49	Dec 3	Marco	Page Rank	
50	Dec 10	Daniel	Eigenfaces	

Plan: Draft



Week	44	45	46	47	48	49	50	51	
Man 12-14		h1l (U182)	h1l (U25A)	asg 1	asg 2	asg 3	asg 4	asg 5	asg 6
Tir 8-10		f (U182)							
Tir 10-12	f (U182)								
Tir 12-14			f (U182)	f (U182)	f (U182)	f (U182)	f (U182)		
Ons 8-10	h1e (U154)								
Ons 12-14		asg 0		h1l (U42)	h1l (U42)	h1l (U182)	h1l (U23)		
Tor 8-10			h1l (U163)						
Tor 12-14		f (U182)							
Fre 10-12				h1l (U55)	h1l (U182)	h1l (U182)	h1l (U182)	h1l (U182)	

Student Assessment

DM561

- Theoretical assignment
  (with Wojciech, 26/10 - 18/11)
- Weekly Python assignments
  (with us)

7 grade scale

DM562

- Programming Assignment
  (with Luìs, 28/10 - 15/11)
- Weekly Python assignments
  (with us)

Pass/Fail

Weekly Assignments

Weekly Python assignments from now on $\rightsquigarrow$ labs

All scored from 0 to 100 (some with extra points)

DM561

- You must achieve an average score > 50 in the labs to be guaranteed to pass
- Final grade: is based on an overall impression. Indicatively, the grade of the labs can only improve by at most one grade the grade of the theoretical part.

DM562

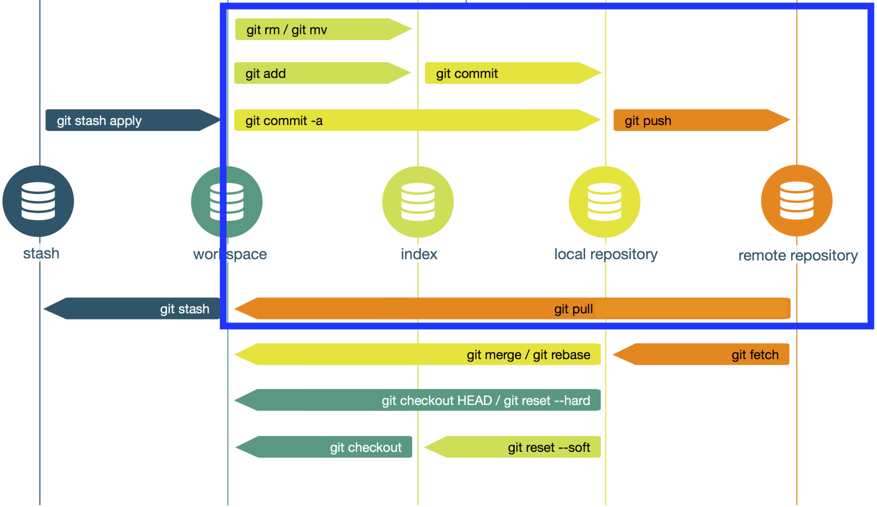
- You must achieve an average score > 50 in the labs to be guaranteed to pass
- Final decision: you must pass both the programming assignment and the labs

Labs: Practicalities

- Submissions via git
  - Read the Appendix A and B
  - Check that your repository exists in `https://git.imada.sdu.dk`
- Specifications file with examples
- Automatic grading up to the deadline (everytime at noon)
  Only the last grading on the day of the deadline counts

git data transport commands

patrickzahnd.ch



Outline

Running Python — Scripts

A Python script

```python
# python_intro.py
"""This is the file header.
The header contains basic information about the file.
"""


if __name__ == "__main__":
    print("Hello, world!\n")    # indent with four spaces (not TAB)
```

- insert in a file with a text editor, for example, Atom, emacs, vim.
- execute from command prompt on Terminal on Linux or Mac and Command Prompt on Windows

Running Python — Interactively

Python:

```
$ python                            # Start the Python interpreter.
>>> print("This is plain Python.")  # Execute some code.
This is plain Python.
```

IPython:

```
>>> exit()                          # Exit the Python interpreter.
$ ipython                           # Start IPython.

In [1]: print("This is IPython!")   # Execute some code.
This is IPython!

In [2]: %run python_intro.py         # Run a particular Python script.
Hello, world!
```

IPython

- Object introspection: quickly reveals all methods and attributes associated with an object.
- `help()` provides interactive help.

```
# A list is a basic Python data structure. To see the methods associated with
# a list, type the object name (list), followed by a period, and press tab.
In [1]: list.   # Press 'tab'.
              append()  count()   insert()  remove()
              clear()   extend()  mro()     reverse()
              copy()    index()   pop()     sort()

# To learn more about a specific method, use a '?' and hit 'Enter'.
In [1]: list.append?
Docstring: L.append(object) -> None -- append object to end
Type:      method_descriptor

In [2]: help()                          # Start IPython's interactive help utility.
help> list                              # Get documentation on the list class.
Help on class list in module __builtin__:
...
<<help> quit                              # End the interactive help session.
```

Resources

- Use IPython side-by-side with a text editor to test syntax and small code snippets quickly.
- Spyder3
- Consult the internet with questions; stackoverflow.com
- The official Python tutorial:
  `http://docs.python.org/3.6/tutorial/introduction.html`
- PEP8 - Python style guide: `http://www.python.org/dev/peps/pep-0008/`

Outline

Arithmetics

- +, -, *, and / operators.
- ** exponentiation; % modular division.
- underscore character _ is a variable with the value of the previous command's output

```
>>> 12 * 3
36
>>> _ / 4
9.0
```

- Data comparisons like < and > act as expected.
- == operator checks for numerical equality and the <= and >= operators correspond to $\leq$ and $\geq$
- Operators `and`, `or`, and `not` (no need for parenthesis)

```
>>> 3 > 2.99
True
>>> 1.0 <= 1 or 2 > 3
True
>>> 7 == 7 and not 4 < 4
True
```

Variables

Dynamically typed language: does not require to specify data type

```
>>> x = 12                                   # Initialize x with the integer 12.
>>> y = 2 * 6                                # Initialize y with the integer 2*6 = 12.
>>> x == y                                   # Compare the two variable values.
True

>>> x, y = 2, 4                              # Give both x and y new values in one line.
>>> x == y
False
```

Functions: Syntax

```
>>> def add(x, y):
...     return x + y                    # Indent with four spaces.
```

- mixing tabs and spaces confuses the interpreter and causes problems.
- most text editors set the indentation type to spaces (soft tabs)

Functions are defined with parameters and called with arguments,

```
>>> def area(width, height):            # Define the function.
...     return width * height
...
>>> area(2, 5)                          # Call the function.
10
```

```
>>> def arithmetic(a, b):
...     return a - b, a * b             # Separate return values with commas.
...
>>> x, y = arithmetic(5, 2)             # Unpack the returns into two variables.
>>> print(x, y)
3 10
```

Functions: `lambda`

The keyword `lambda` is a shortcut for creating one-line functions.

```python
# Define the polynomials the usual way using 'def'.
>>> def g(x, y, z):
...     return x + y**2 - z**3

# Equivalently, define the polynomials quickly using 'lambda'.
>>> g = lambda x, y, z: x + y**2 - z**3
```

Functions: Docstrings

```
>>> def add(x, y):
...     """Return the sum of the two inputs."""
...     return x + y

>>> def area(width, height):
...     """Return the area of the rectangle with the specified width
...     and height.
...     """
...     return width * height
...
>>> def arithmetic(a, b):
...     """Return the difference and the product of the two inputs."""
...     return a - b, a * b
```

Functions: Returned Values

```
>>> def oops(i):
...     """Increment i (but forget to return anything)."""
...     print(i + 1)
...
>>> def increment(i):
...     """Increment i."""
...     return i + 1
...
>>> x = oops(1999)                # x contains 'None' since oops()
2000                              # doesn't have a return statement.
>>> y = increment(1999)           # However, y contains a value.
>>> print(x, y)
None 2000
```

Functions: Arguments

Arguments are passed to functions based on position or name
Positional arguments must be defined before named arguments.

```
# Correctly define pad() with the named argument after positional arguments.
>>> def pad(a, b, c=0):
...     """Print the arguments, plus a zero if c is not specified."""
...     print(a, b, c)
# Call pad() with 3 positional arguments.
>>> pad(2, 4, 6)
2 4 6
# Call pad() with 3 named arguments. Note the change in order.
>>> pad(b=3, c=5, a=7)
7 3 5
# Call pad() with 2 named arguments, excluding c.
>>> pad(b=1, a=2)
2 1 0
# Call pad() with 1 positional argument and 2 named arguments.
>>> pad(1, c=2, b=3)
1 3 2
```

Functions: Generalized Input

- `*args` is a list of the positional arguments
- `**kwargs` is a dictionary mapping the keywords to their argument.

```
>>> def report(*args, **kwargs):
...     for i, arg in enumerate(args):
...         print("Argument " + str(i) + ":", arg)
...     for key in kwargs:
...         print("Keyword", key, "-->", kwargs[key])
...
>>> report("TK", 421, exceptional=False, missing=True)
Argument 0: TK
Argument 1: 421
Keyword missing --> True
Keyword exceptional --> False
```

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Numerical types

Python has four numerical data types: `int`, `long`, `float`, and `complex`.

```
>>> type(3)                           # Numbers without periods are integers.
int

>>> type(3.0)                         # Floats have periods (3. is also a float).
float
```

Division:

```
>>> 15 / 4                            # Float division performs as expected. (but not
     in Py 2.7!)
3.75
>>> 15 // 4                           # Integer division rounds the result down.
3
>>> 15. // 4
3.0
```

Strings

Strings are created with " or '

To concatenate two or more strings, use the + operator between string variables or literals.

```
>>> str1 = "Hello"  # either single or double quotes.
>>> str2 = 'world'
>>> my_string = str1 + " " + str2 + '!'    # concatenation
>>> my_string
'Hello world!'
```

Slicing

- Strings are arrays of characters. Indexing begins at 0!
- Slicing syntax is `[start:stop:step]`. Defaults: `[0:len():1]`.

```
>>> my_string = "Hello world!"
>>> my_string[4]                # Indexing begins at 0.
'o'
>>> my_string[-1]               # Negative indices count backward from the end.
'!'
# Slice from the 0th to the 5th character (not including the 5th character).
>>> my_string[:5]
'Hello'
# Slice from the 6th character to the end.
>>> my_string[6:]
'world!'
# Slice from the 3rd to the 8th character (not including the 8th character).
>>> my_string[3:8]
'lo wo'
# Get every other character in the string.
>>> my_string[::2]
'Hlowrd'
```

Built-in Types

The built-in data structures:

- tuple, list, set, dict
- `collections` module
- Various built in operations

These are always available:

- all versions of Python
- all operating systems
- all distributions of Python
- you do not need to install any package

Fast development:

- exploring ideas
- building prototypes
- solving one-off problems

If you need performance need to optimize or change language

Tuple

- aka, record, structure, a row in a database: ordered collection of elements
- packing and unpacking values.

```
# Basic usage
record = (val1, val2, val3)
a, b, c = record
val = record[n]
```

```
>>> row = ("Mike", "John", "Mads")
>>> row[1]
"John"
>>> both = arithmetic(5,2)  # or get them both as a tuple.
>>> print(both)
(3, 10)
```

Mutable vs Immutable Objects

Immutable Objects: built-in types like `int`, `float`, `bool`, `string`, `tuple`. Objects of these types can't be changed after they are created.

```
message = "Welcome to DM561"
message[0] = 'p'
print(message)

# Error :
#
# Traceback (most recent call last):
#   File "/home/
    ff856d3c5411909530c4d328eeca165b.
    py", line 3, in
#     message[0] = 'p'
# TypeError: 'str' object does not
    support item assignment
```

```
> tuple1 = (0, 1, 2, 3)
> tuple1[0] = 4
> print(tuple1)

# Error :
#
# Traceback (most recent call last):
#   File "
    e0eaddff843a8695575daec34506f126.
    py", line 3, in
#     tuple1[0]=4
# TypeError: 'tuple' object does not
    support item assignment
```

Mutable Objects: are the following built-in types `list`, `dict`, `set` and custom classes

List

- Mutable sequence, array
- Enforcing order

```
# Basic usage
items = [ val1, val2, ..., ↩
    val3 ]
x = items[n]
items[n] = x
del items[n]
items.append(value)
items.sort()
items.insert(n, value)
items.remove(value)
items.pop()
```

```
>>> my_list = ["Hello", 93.8, "world", 10]
>>> my_list[0]
'Hello'
>>> my_list[-2]
'world'
>>> my_list[:2]
['Hello', 93.8]
```

List

```
>>> my_list = [1, 2]                # Create a simple list of two integers.
>>> my_list.append(4)               # Append the integer 4 to the end.
>>> my_list.insert(2, 3)            # Insert 3 at location 2.
>>> my_list
[1, 2, 3, 4]
>>> my_list.remove(3)               # Remove 3 from the list.
>>> my_list.pop()                   # Remove (and return) the last entry.
4
>>> my_list
[1, 2]
```

Slicing is also very useful for replacing values in a list.

```
>>> my_list = [10, 20, 30, 40, 50]
>>> my_list[0] = -1
>>> my_list[3:] = [8, 9]
>>> print(my_list)
[-1, 20, 30, 8, 9]
```

List

The `in` operator quickly checks if a given value is in a list (or another iterable, including strings).

```
>>> my_list = [1, 2, 3, 4, 5]
>>> 2 in my_list
True
>>> 6 in my_list
False
>>> 'a' in "xylophone"              # 'in' also works on strings.
False
```

Set

- unordered sequence
- uniqueness, membership test

```
# Basic usage
s = {val1, val2, ..., valn}
s.add(val)
s.discard(val)
s.remove(val) # throws ↩
    exception if the element↩
     is not present in the ↩
    set
val in s
s.union({val})
s.intersection({val})
s.difference({val})
s.symmetric_difference({val↩
    })
```

```
# Initialize some sets. Repeats are not added.
>>> gym_members = {"John", "John", "Jane", "Bob"}
>>> print(gym_members)
{'John', 'Bob', 'Jane'}

>>> gym_members.add("Josh")
>>> gym_members.discard("John")
>>> print(gym_members)
{'Josh', 'Bob', 'Jane'}

>>> gym_members.intersection({"Josh", "Ian", "Jared"↩
    })
{'Josh'}
>>> gym_members.difference({"Bob", "Sarah"})
{'Josh', 'Jane'}
```

Dict

- mapping, associative (key,value) array (implemented as a hash table)
- unordered
- lookup table, indices, key values need to be immutable

```python
# Basic usage
d = { key1: val1, key2: val2,
      key3: val3 }
val = d[key]
d[key] = val
del d[key]
key in d
d.keys()
d.values()
d.pop(key)
```

```python
>>> my_dictionary = {"business": 4121, "math": 2061,
      "visual arts": 7321}
>>> print(my_dictionary["math"])
2061

>>> my_dictionary["science"] = 6284
>>> my_dictionary.pop("business")
4121
>>> print(my_dictionary)
{'math': 2061, 'visual arts': 7321, 'science': 6284}

>>> my_dictionary.keys()
dict_keys(['math', 'visual arts', 'science'])
>>> my_dictionary.values()
dict_values([2061, 7321, 6284])
```

Further Collections

```
>>> from collections import namedtuple
>>> Person = namedtuple('Person', ['first','last','address'])
>>> row = Person('Marco','Chiarandini','Campusvej')
>>> row.first
'Marco'
```

```
>>> from collections import Counter # histograms
>>> c = Counter('xyzzzy')
>>> c
Counter({'z': 2, 'x': 1, 'y': 1})
```

```
>>> from collections import defaultdict  # multidict, one-many relationships
>>> d = defaultdict(list)
>>> d['spam'].append(42)
>>> d['blah'].append(13)
>>> d['spam'].append(10)
>>> d
{'blah': [42], 'spam': [13, 10]}
```

Further Collections

```
>>> from collections import OrderedDict  # remembers the order entries were added
>>> # regular unsorted dictionary
>>> d = {'banana': 3, 'apple': 4, 'pear': 1, 'orange': 2}

>>> # dictionary sorted by key
>>> OrderedDict(sorted(d.items(), key=lambda t: t[0]))
OrderedDict([('apple', 4), ('banana', 3), ('orange', 2), ('pear', 1)])

>>> # dictionary sorted by value
>>> OrderedDict(sorted(d.items(), key=lambda t: t[1]))
OrderedDict([('pear', 1), ('orange', 2), ('banana', 3), ('apple', 4)])

>>> # dictionary sorted by length of the key string
>>> OrderedDict(sorted(d.items(), key=lambda t: len(t[0])))
OrderedDict([('pear', 1), ('apple', 4), ('orange', 2), ('banana', 3)])
```

Type Casting

```
# Cast numerical values as different kinds of numerical values.
>>> x = int(3.0)
>>> y = float(3)

# Cast a list as a set and vice versa.
>>> set([1, 2, 3, 4, 4])
{1, 2, 3, 4}
>>> list({'a', 'a', 'b', 'b', 'c'})
['a', 'c', 'b']

# Cast other objects as strings.
>>> str(['a', str(1), 'b', float(2)])
"['a', '1', 'b', 2.0]"
```

Outline

The If Statement

```
>>> food = "bagel"
>>> if food == "apple":               # As with functions, the colon denotes
...     print("72 calories")          # the start of each code block.
... elif food == "banana" or food == "carrot":
...     print("105 calories")
... else:
...     print("calorie count unavailable")
...
calorie count unavailable
```

The While Loop

```
>>> i = 0
>>> while True: # i < 10
...     print(i, end=' ')
...     i += 1
...     if i >= 10:
...         break                        # Exit the loop.
...
0 1 2 3 4 5 6 7 8 9

>>> i = 0
>>> while i < 10:
...      i += 1
...      if i % 3 == 0:
...          continue                    # Skip multiples of 3.
...      print(i, end=' ')
1 2 4 5 7 8 10
```

The For Loop

- A `for` loop iterates over the items in any iterable.
- Iterables include (but are not limited to) strings, lists, sets, and dictionaries.

```
>>> colors = ["red", "green", "blue", "yellow"]
>>> for entry in colors:
...     print(entry + "!")
...
red!
green!
blue!
yellow!
```

- The `break` and `continue` statements also work in for loops
- but a `continue` in a for loop will automatically increment the index or item

Built-in Functions

1. `range(start, stop, step)`: Produces a sequence of integers, following slicing syntax.
2. `zip()`: Joins multiple sequences so they can be iterated over simultaneously.
3. `enumerate()`: Yields both a count and a value from the sequence. Typically used to get both the index of an item and the actual item simultaneously.
4. `reversed()`: Reverses the order of the iteration.
5. `sorted()`: Returns a new list of sorted items that can then be used for iteration.

```
# Iterate through the list in sorted (alphabetical) order.
>>> for item in sorted(colors):
...     print(item, end=' ')
...
blue purple red white yellow
```

They (except for `sorted()`) are generators and return an iterator.
To put the items of the sequence in a collection, use `list()`, `set()`, or `tuple()`.

List Comprehension

```
>>> loop_output = []
>>> for i in range(5):
...     loop_output.append(i**2)
...
>>> list_output = [i**2 for i in range(5)]
```

```
[ expression for x in iterable if conditions ] # list
{ expression for x in iterable if conditions } # set
{ key: val for key, val in iterable if conditions } # dict
```

```
>>> colors = ["red", "blue", "yellow"]
>>> {"bright " + c for c in colors}
{'bright blue', 'bright red', 'bright yellow'}

>>> {c[0]:c for c in colors}
{'y': 'yellow', 'r': 'red', 'b': 'blue'}
```

Generators

```
( expression for x in iterable if condition )
```

```
>>> nums = [1, 2, 3, 4, 5, 6]
>>> squares = (i*i for i in nums)
>>> squares
<generator object <genexpr> at 0x110468200>
>>> for n in squares:
    print(n)
1
4
9
16
25
36
```

Decorators — Function Wrappers

```
>>> def typewriter(func):
...     """Decorator for printing the type of output a function returns"""
...     def wrapper(*args, **kwargs):
...         output = func(*args, **kwargs)      # Call the decorated function.
...         print("output type:", type(output)) # Process before finishing.
...         return output                       # Return the function output.
...     return wrapper
```

```
>>> @typewriter
... def combine(a, b, c):
...     return a*b // c
```

```
>>> combine = typewriter(combine)
```

Now calling `combine()` actually calls `wrapper()`, which then calls the original `combine()`.

```
>>> combine(3, 4, 6)
output type: <class 'int'>
2
>>> combine(3.0, 4, 6)
output type: <class 'float'>
2.0
```

Decorators — Function Wrappers

```
>>> def repeat(times):
...     """Decorator for calling a function several times."""
...     def decorator(func):
...         def wrapper(*args, **kwargs):
...             for _ in range(times):
...                 output = func(*args, **kwargs)
...             return output
...         return wrapper
...     return decorator
...
>>> @repeat(3)
... def hello_world():
...     print("Hello, world!")
...
>>> hello_world()
Hello, world!
Hello, world!
Hello, world!
```

Outline

Built-in Functions

Common built-in functions for numerical calculations:

Function	Returns
`input()`	Gets input from console
`abs()`	The absolute value of a real number, or the magnitude of a complex number.
`min()`	The smallest element of a single iterable, or the smallest of several arguments. Strings are compared based on lexicographical order: numerical characters first, then upper-case letters, then lower-case letters.
`max()`	The largest element of a single iterable, or the largest of several arguments.
`len()`	The number of items of a sequence or collection.
`round()`	A float rounded to a given precision in decimal digits.
`sum()`	The sum of a sequence of numbers.

See `https://docs.python.org/3/library/functions.html` for more detailed documentation on all of Python's built-in functions.

Built-in Functions

Function	Description
`all()`	Return `True` if `bool(entry)` evaluates to `True` for every entry in the input iterable.
`any()`	Return `True` if `bool(entry)` evaluates to `True` for any entry in the input iterable.
`bool()`	Evaluate a single input object as `True` or `False`.
`eval()`	Execute a string as Python code and return the output.
`map()`	Apply a function to every item of the input iterable and return an iterable of the results.
`filter()`	Apply a filter to the elements of the input iterable and return an set.

Mutable vs Immutable Objects

- a mutable object can be changed after it is created, and an immutable object can't.
- Objects of built-in types like (int, float, bool, str, tuple, unicode) are immutable
- Objects of built-in types like (list, set, dict) are mutable

```
>>> x = "Holberton"
>>> y = "Holberton"
>>> id(x)
140135852055856
>>> id(y)
140135852055856
>>> print(x is y) '''comparing the types'''
True

>>> a = 50
>>> type(a)
<class: 'int'>
>>> b = "Holberton"
>>> type(b)
<class: 'string'>
```

Mutable vs Immutable Objects

```
>>> holy = {"moly": 1.99, "hand_grenade": 3, "grail": 1975.41}
>>> tax_prices = holy                    # Try to make a copy for processing.
>>> for item, price in tax_prices.items():
...     # Add a 7 percent tax, rounded to the nearest cent.
...     tax_prices[item] = round(1.07 * price, 2)
...
# Now the base prices have been updated to the total price.
>>> print(tax_prices)
{'moly': 2.13, 'hand_grenade': 3.21, 'grail': 2113.69}

# However, dictionaries are mutable, so 'holy' and 'tax_prices' actually
# refer to the same object. The original base prices have been lost.
>>> print(holy)
{'moly': 2.13, 'hand_grenade': 3.21, 'grail': 2113.69}
```

To avoid this problem, explicitly create a copy of the object by casting it as a new structure.

```
>>> tax_prices = dict(holy)
```

Pass by-value or by-reference

- A pointer refers to a variable by storing the address in memory where the corresponding object is stored.
- Python names are essentially pointers, and traditional pointer operations and cleanup are done automatically.
- Python automatically deletes objects in memory that have no names assigned to them (no pointers referring to them). This feature is called garbage collection.
- All objects that are arguments of functions are passed by reference

Modules

- A module is a Python file containing code that is meant to be used in some other setting
- All `import` statements should occur at the top of the file, below the header but before any other code.

1. `import <module>` makes the specified module available under the alias of its own name.

```
>>> import math                   # The name 'math' now gives
>>> math.sqrt(2)                  # access to the math module.
1.4142135623730951
```

2. `import <module> as <name>` creates an alias for an imported module. The alias is added to the current namespace, but the module name itself is not.

```
>>> import numpy as np            # The name 'np' gives access to the numpy
>>> np.sqrt(2)                    # module, but the name 'numpy' does not.
1.4142135623730951
>>> numpy.sqrt(2)
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
NameError: name 'numpy' is not defined
```

Modules

3. `from <module> import <object>` loads the specified object into the namespace without loading anything else in the module or the module name itself. This is used most often to access specific functions from a module. The `as` statement can also be tacked on to create an alias.

```
>>> from random import randint  # The name 'randint' gives access to the
>>> r = randint(0, 10000)       # randint() function, but the rest of
>>> random.seed(r)              # the random module is unavailable.
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
NameError: name 'random' is not defined
```

Running and Importing

```
# example1.py

data = list(range(4))
def display():
    print("Data:", data)

if __name__ == "__main__":
    display()
    print("This file was executed from the command line or an interpreter.")
else:
    print("This file was imported.")
```

```
$ python example1.py
Data: [0, 1, 2, 3]
This file was executed from the command line or an interpreter.
```

The Python Standard Library

Module	Description
`cmath`	Mathematical functions for complex numbers.
`csv`	Comma Separated Value (CSV) file parsing and writing.
`itertools`	Tools for iterating through sequences in useful ways.
`math`	Standard mathematical functions and constants.
`os`	Tools for interacting with the operating system.
`random`	Random variable generators.
`string`	Common string literals.
`sys`	Tools for interacting with the interpreter.
`time`	Time value generation and manipulation.
`timeit`	Measuring execution time of small code snippets.

Explore the documentation in IPython

Python Packages

- A package is simply a folder that contains a file called `__init__.py`.
- This file is always executed first whenever the package is used.
- A package must also have a file called `__main__.py` in order to be executable.
- Executing the package will run `__init__.py` and then `__main__.py`
- Importing the package will only run `__init__.py`

- Use `from <subpackage.module> import <object>` to load a module within a subpackage.
- Once a name has been loaded into a package's `__init__.py`, other files in the same package can load the same name with `from . import <object>`.

To execute a package, run Python from the shell with the flag `-m` (for "module-name") and exclude the extension `.py`.

```
$ python -m package_name
```

See https://docs.python.org/3/tutorial/modules.html#packages for examples and more details.

Outline

Classes

A class is a template for an object that binds together specified variables and routines.

```python
class Backpack:
    """A Backpack object class. Has a name and a list of contents.

    Attributes:
        name (str): the name of the backpack's owner.
        contents (list): the contents of the backpack.
    """
    def __init__(self, name):           # This function is the constructor.
        """Set the name and initialize an empty list of contents.

        Parameters:
            name (str): the name of the backpack's owner.
        """
        self.name = name                # Initialize some attributes.
        self.contents = []
```

Instantiation

```python
# Import the Backpack class and instantiate an object called 'my_backpack'.
>>> from object_oriented import Backpack
>>> my_backpack = Backpack("Fred")
>>> type(my_backpack)
<class 'object_oriented.Backpack'>

# Access the object's attributes with a period and the attribute name.
>>> print(my_backpack.name, my_backpack.contents)
Fred []

# The object's attributes can be modified after instantiation.
>>> my_backpack.name = "George"
>>> print(my_backpack.name, my_backpack.contents)
George []
```

Methods

```python
class Backpack:
    # ...
    def put(self, item):
        """Add an item to the backpack's list of contents."""
        self.contents.append(item)  # Use 'self.contents', not just 'contents'.

    def take(self, item):
        """Remove an item from the backpack's list of contents."""
        self.contents.remove(item)
```

```python
>>> my_backpack.put("notebook")         # my_backpack is passed implicitly to
>>> my_backpack.put("pencils")          # Backpack.put() as the first argument.
>>> my_backpack.contents
['notebook', 'pencils']

# Remove an item from the backpack.     # This is equivalent to
>>> my_backpack.take("pencils")         # Backpack.take(my_backpack, "pencils")
>>> my_backpack.contents
['notebook']
```

Inheritance

Superclass $\rightsquigarrow$ Subclass

```
class Knapsack(Backpack): # Inherit from the Backpack class in the class definition
    """Attributes:
        name (str): the name of the knapsack's owner.
        color (str): the color of the knapsack.
        max_size (int): the maximum number of items that can fit inside.
        contents (list): the contents of the backpack.
        closed (bool): whether or not the knapsack is tied shut.
    """
    def __init__(self, name, color, max_size=3):
        """Use the Backpack constructor to initialize the name, color,
        and max_size attributes. A knapsack only holds 3 item by default.
        """
        Backpack.__init__(self, name, color, max_size)
        self.closed = True
```

Inheritance

- all methods defined in the superclass class are available to instances of the subclass.
- methods from the superclass can be changed for the subclass by overridden
- New methods can be included normally.

```
>>> from object_oriented import Knapsack
>>> my_knapsack = Knapsack("Brady", "brown")

# A Knapsack is a Backpack, but a Backpack is not a Knapsack.
>>> print(issubclass(Knapsack, Backpack), issubclass(Backpack, Knapsack))
True False
>>> isinstance(my_knapsack, Knapsack) and isinstance(my_knapsack, Backpack)
True

# The Knapsack class has a weight() method, but the Backpack class does not.
>>> print(hasattr(my_knapsack, 'weight'), hasattr(my_backpack, 'weight'))
True False
```

Magic Methods

- special methods used to make an object behave like a built-in data type.
- begin and end with two underscores, like the constructor `__init__()`.
- all variables and routines of a class are public
- magic methods are hidden

```
In [1]: %run object_oriented.py
In [2]: b = Backpack("Oscar", "green")
In [3]: b.          # Press 'tab' to see standard methods and attributes.
          color    max_size take()
          contents name
          dump()   put()
In [3]: b.__        # Press 'tab' to see magic methods and hidden attributes.
          __getattribute__  __new__()            __class__
          __delattr__         __hash__             __reduce_ex__()
          __dict__            __init__()           __repr__
          __dir__()           __init_subclass__()  __setattr__
          __doc__             __sizeof__()         __reduce__()
          __str__             __format__()         __module__
          __subclasshook__()  __weakref__
```

Magic Methods

Method	Arithmetic Operator
`__add__()`	+
`__sub__()`	-
`__mul__()`	*
`__pow__()`	**
`__truediv__()`	/
`__floordiv__()`	//

Method	Comparison Operator
`__lt__()`	<
`__le__()`	<=
`__gt__()`	>
`__ge__()`	>=
`__eq__()`	==
`__ne__()`	=

Operator overloading:

```
class Backpack:
    def __add__(self, other):
        return len(self.contents) + len(other.contents)
```

```
class Backpack(object)
    def __lt__(self, other):
        return len(self.contents) < len(other.contents)
```

Static Attributes and Methods

Static attributes and methods are defined without `self` and can be accessed both with and without instantiation

```
class Backpack:
    # ...
    brand = "Adidas"                # Backpack.brand is a static attribute.
```

```
class Backpack:
    # ...
    @staticmethod
    def origin():                   # Do not use 'self' as a parameter.
        print("Manufactured by " + Backpack.brand + ", inc.")
```

More Magic Methods and Hashing

Method	Operation	Trigger Function
`__bool__()`	Truth value	`bool()`
`__len__()`	Object length or size	`len()`
`__repr__()`	Object representation	`repr()`
`__getitem__()`	Indexing and slicing	`self[index]`
`__setitem__()`	Assignment via indexing	`self[index] = x`
`__iter__()`	Iteration over the object	`iter()`
`__reversed__()`	Reverse iteration over the object	`reversed()`
`__contains__()`	Membership testing	`in`

A hash value is an integer that uniquely identifies an object.
If the `__hash__()` method is not defined, the default hash value is the object's memory address (accessible via the built-in function `id()`) divided by 16, rounded down to the nearest integer.

```
class Backpack:
    def __hash__(self):
        return hash(self.name) ^ hash(self.color) ^ hash(len(self.contents))
```

Summary

1. Course Organization

2. Python
    - Basics
    - Data Structures
    - Control Flow Tools
    - Standard Library
    - Object Oriented Programming