Introduction to DataScience
for Cloud Computing

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INTRODUCTION TO DATASCIENCE

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1 PREFACE

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1.1 DISCLAIMER

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Bookmanager has been developed based on our experience over the last 3 years with a more sophisticated approach. Bookmanager takes the lessons from this approach and distributes a tool that can easily be used by others.

The following shields provide some information about it. Feel free to click on them.

1.1.1 Acknowledgment

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```

1.1.2 Extensions

We are happy to discuss with you bugs, issues and ideas for enhancements. Please use the convenient github issues at

- https://github.com/cyberaide/bookmanager/issues

Please do not file with us issues that relate to an editors book. They will provide you with their own mechanism on how to correct their content.

2 INTRODUCTION

2.1 INTRODUCTION TO PYTHON

Learning Objectives

- Learn quickly Python under the assumption you know a programming language
- Work with modules
- Understand docopts and cmd
- Contuct some python examples to refresh your python knpwledge
- Learn about the `map` function in Python
- Learn how to start subprocesses and rederect their output
- Learn more advanced constructs such as multiprocessing and Queues
- Understand why we do not use `anaconda`
- Get familiar with `pyenv`

Portions of this lesson have been adapted from the official Python Tutorial copyright Python Software Foundation.

Python is an easy to learn programming language. It has efficient high-level data structures and a simple but effective approach to object-oriented programming. Python's simple syntax and dynamic typing, together with its interpreted nature, make it an ideal language for scripting and rapid application development in many areas on most platforms. The Python interpreter and the extensive standard library are freely available in source or binary form for all major platforms from the Python Web site, https://www.python.org/, and may be freely distributed. The same site also contains distributions of and pointers to many free third party Python modules, programs and tools, and additional documentation. The Python interpreter can be extended with new functions and data types implemented in C or C++ (or other languages callable from C). Python is also suitable as an extension language for customizable applications.

Python is an interpreted, dynamic, high-level programming language suitable for a wide range of applications.

The philosophy of python is summarized in The Zen of Python as follows:

- Explicit is better than implicit
- Simple is better than complex
- Complex is better than complicated
- Readability counts

The main features of Python are:

- Use of indentation whitespace to indicate blocks
- Object orient paradigm
- Dynamic typing
- Interpreted runtime
- Garbage collected memory management
- a large standard library
- a large repository of third-party libraries

Python is used by many companies and is applied for web development, scientific computing, embedded applications, artificial intelligence, software development, and information security, to name a few.

The material collected here introduces the reader to the basic concepts and features of the Python language and system. After you have worked through the material you will be able to:

- use Python
- use the interactive Python interface
- understand the basic syntax of Python
- write and run Python programs
- have an overview of the standard library
- install Python libraries using pyenv for multipython interpreter development.

E doe not attempt to be comprehensive and cover every single feature, or even every commonly used feature. Instead, it introduces many of Python's most

noteworthy features, and will give you a good idea of the language's flavor and style. After reading it, you will be able to read and write Python modules and programs, and you will be ready to learn more about the various Python library modules.

In order to conduct this lesson you need

- A computer with Python 2.7.16 or 3.7.4
- Familiarity with command line usage
- A text editor such as PyCharm, emacs, vi or others. You should identity which works best for you and set it up.

2.1.1 References

Some important additional information can be found on the following Web pages.

- Python
- Pip
- Virtualenv
- NumPy
- SciPy
- Matplotlib
- Pandas
- pyenv
- PyCharm

Python module of the week is a Web site that provides a number of short examples on how to use some elementary python modules. Not all modules are equally useful and you should decide if there are better alternatives. However for beginners this site provides a number of good examples

- Python 2: https://pymotw.com/2/
- Python 3: https://pymotw.com/3/

3 INSTALLATION

3.1 PYTHON 3.7.4 INSTALLATION

Learning Objectives

- Learn how to install python.
- Find additional information about Python.
- Make sure your Computer supports Python.

In this setion we explain how to install python 3.7.4 on a computer. Likely much of the code will work with earlier versions, but we do the development in Python on the newest version of python available at https://www.python.org/downloads .

3.1.1 Hardware

Python does not require any special hardware. We have installed Python not only on PC's and Laptops, but also on Raspberry PI's and Lego Mindstorms.

However, there are some things to consider. If you use many programs on your desktop and run them all at the same time you will find that in up-to-date operating systems you will find your self quickly out of memmory. This is especially true if you use editors such as PyCharm which we highly recommend. Furthermore, as you likely have lots of disk access, make sure to use a fast HDD or better an SSD.

A typical modern developer PC or Laptop has *16GB RAM* and an *SSD*. You can certainly do python on a $35 Rapbperry PI, but you probably will not be able to run PyCharm. There are many alternative editors with less Memory footprint avialable.

3.1.2 Prerequisits Ubuntu 19.04

Python 3.7 is installed in ubuntu 19.04. Therefore, it already fulfills the prerequisits. However we recommend that you update to the newest version of python and pip. However we recommend that you update the the newest version of python. Please visit: https://www.python.org/downloads

3.1.3 Prerequisits macOS

3.1.3.1 Installation from Apple App Store

You want a number of useful tool on your macOS. They are not installed by default, but are available via Xcode. First you need to install xcode from

- https://apps.apple.com/us/app/xcode/id497799835

Next you need to install macOS xcode command line tools:

```
$ xcode-select --install
```

3.1.3.2 Installation from python.org

The easiest instalation of Python for cloudmesh is to use the instaltion from https://www.python.org/downloads. Please, visit the page and follow the instructions. After this install you have python3 avalable from the commandline

3.1.3.3 Installation from Hoembrew

An alternative instalation is provided from Homebrew. To use this install method, you need to install Homebrew first. Start the process by installing the python 3 using `homebrew`. Install `homebrew` using the instruction in their web page:

```
$ /usr/bin/ruby -e "$(curl -fsSL https://raw.githubusercontent.com/Homebrew/install/master/install)"
```

Then you should be able to install Python 3.7.4 using:

```
$ brew install python
```

3.1.4 Prerequisits Ubuntu 18.04

We recommend you update your ubuntu version to 19.04 and follow the

instructions for that version instead, as it is significantly easier. If you however are not able to do so, the following instructions may be helpful.

We first need to make sure that the correct version of the Python3 is installed. The default version of Python on Ubuntu 18.04 is 3.6. You can get the version with:

```
$ python3 --version
```

If the version is not 3.7.4 or newer, you can update it as follows:

```
$ sudo apt-get update
$ sudo apt install software-properties-common
$ sudo add-apt-repository ppa:deadsnakes/ppa
$ sudo apt-get install python3.7 python3-dev python3.7-dev
```

You can then check the installed version using `python3.7 --version` which should be `3.7.4`.

Now we will create a new virtual environment:

```
$ python3.7 -m venv --without-pip ~/ENV3
```

The edit the `~/.bashrc` file and add the following line at the end:

```
alias ENV3="source ~/ENV3/bin/activate"
ENV3
```

now activate the virtual environment using:

```
$ source ~/.bashrc
```

now you can install the pip for the virtual environment without conflicting with the native pip:

```
$ curl "https://bootstrap.pypa.io/get-pip.py" -o "get-pip.py"
$ python get-pip.py
$ rm get-pip.py
```

3.1.5 Prerequisite Windows 10

Python 3.7 can be installed on Windows 10 using: https://www.python.org/downloads

For 3.7.4 can go to the download page and download one of the different files for Windows.

Let us assume you choe the Web based installer, than you click on the file in the edge browser (make sure the account you use has administrative priviledges). Follow the instructions that the installer gives. Important is that you select at one point “[x] Add to Path”. There will be an empty checkmark about this that you will click on.

Once it is installed. chose a terminal and execute

```
python --version
```

However, if you have installed conda for some reason you need to read up on how to install 3.7.4 python in conda or identify how to run conda and python.org at the same time. We see often others giving the wrong installation instructions.

An alternative is to use python from within the Linux Subsystem. But that has some limitations and you will need to explore how to exxess the file system in the subssytem to have a smooth integration between your Windows host so you can for example use PyCharm.

3.1.5.1 Linux Subsystem Install

To activate the Linux Subsystem, please follow the instructions at

- https://docs.microsoft.com/en-us/windows/wsl/install-win10

A suitable distribution would be

- https://www.microsoft.com/en-us/p/ubuntu-1804-lts/9n9tngvndl3q?activetab=pivot:overviewtab

However as it uses an older version of python you will ahve to update it.

3.1.6 Prerequisit venv

This step is highly recommend if you have not yet already installed a `venv` for python to make sure you are not interfering with your system python. Not using a venv could have catastrophic consequences and a destruction of your operating system tools if they realy on Python. The use of venv is simple. For our purposes we assume that you use the directory:

```
~/ENV3
```

Follow these steps first:

First cd to your home directory. Then execute

```
$ python3 -m venv  ~/ENV3
$ source ~/ENV3/bin/activate
```

You can add at the end of your .bashrc (ubuntu) or .bash_profile (macOS) file the line

```
$ source ~/ENV3/bin/activate
```

so the environment is always loaded. Now you are ready to install cloudmesh.

Check if you have the right version of python installed with

```
$ python --version
```

To make sure you have an up to date version of pip issue the command

```
$ pip install pip -U
```

3.1.7 Install Python 3.7 via Anaconda

3.1.7.1 Download `conda` installer

Miniconda is recommended here. Download an installer for Windows, macOS, and Linux from this page: https://docs.conda.io/en/latest/miniconda.html

3.1.7.2 Install `conda`

Follow instructions to install `conda` for your operating systems:

- Windows. https://conda.io/projects/conda/en/latest/user-guide/install/windows.html
- macOS. https://conda.io/projects/conda/en/latest/user-guide/install/macos.html
- Linux. https://conda.io/projects/conda/en/latest/user-guide/install/linux.html

3.1.7.3 Install Python 3.7.4 via `conda`

```
$ cd ~
$ conda create -n ENV3 python=3.7.4
$ conda activate ENV3
$ conda install -c anaconda pip
$ conda deactivate ENV3
```

It is very important to make sure you have a newer version of pip installed. After you installed and created the ENV3 you need to activate it. This can be done with

```
$ conda activate ENV3
```

If you like to activate it when you start a new terminal, please add this line to your `.bashrc` or `.bash_profile`

If you use zsh please add it to `.zprofile` instead.

3.2 Multi-Version Python Installation

Learning Objectives

- Understand why we need to worry about python 3.7 and 2.7
- Use pyenv to support both versions
- Understand the limitations of anaconda/conda for developers

---

We are living in an interesting junction point in the development of Python. In January 2019, it is encouraged that Python developers swoth from python version 2.7 to python version 3.7.

However there may be the requirement when you still need to develop code not only in python 3.7 but also in python 2.7. To facilitate this multi-python version development, the best tool we know about capable of doing so is *pyenv*. We will explain you in this section how to install both versions with the help of pyenv.

Python is easy to install and very good instructions for most platforms can be found on the python.org Web page. We see two different versions:

- Python 2.7.16
- Python 3.7.4

To manage python modules, it is useful to have pip package installation tool on your system.

We assume that you have a computer with python installed. The version of python however may not be the newest version. Please check with

```
$ python --version
```

which version of python you run. If it is not the newest version, we use *pyenv* to install a newer version so you do not effect the default version of python from your system.

3.2.1 Disabling wrong python installs

While working with students we have seen at times that they take other classes either at universities or online that teach them how to program in python. Unfortunately, they seem to often ignore to teach you how to properly install Python. I just recently had a students that had installed python 7 different times on his macOS machine, while another student had 3 different installations, all of which conflicted with each other as they were not set up properly and the students did not even realize that they were using Python incorrectly on their computer due to setup issues and conflicting libraries.

We recommend that you inspect if you have a files such as `~/.bashrc` or `~/.bashrc_profile` in your home directory and identify if it activates various versions of python on your computer. If so you could try to deactivate them while out-commenting the various versions with the # character at the beginning of the line, start a new terminal and see if the terminal shell still works. Than you can follow our instructions here while using an install on pyenv.

3.2.2 Managing 2.7 and 3.7 Python Versions without Pyenv

If you need to have more than one python version installed and do not want or can use pyenv, we recommend you download and install python 2.7.16 and 3.7.4 from python.org (https://www.python.org/downloads/)

YOu can than use either `python2` or `python3` to invoke the python interpreter.

3.2.3 Managing Multiple Python Versions with Pyenv

Python has several versions that are used by the community. This includes Python 2 and Python 3, but all different management of the python libraries. As each OS may have their own version of python installed. It is recommended that you **not** modify that version. Instead you may want to create a localized python installation that you as a user can modify. To do that we recommend *pyenv*. Pyenv allows users to switch between multiple versions of Python (https://github.com/yyuu/pyenv). To summarize:

- users to change the global Python version on a per-user basis;
- users to enable support for per-project Python versions;
- easy version changes without complex environment variable management;
- to search installed commands across different python versions;
- integrate with tox (https://tox.readthedocs.io/).

To install pyenv on your system you can use the command

```
$ curl https://pyenv.run | bash
```

Now you can install different python versions on your system such as python 2.7 and 3.7 with a few commands:

```
$ pyenv install 3.7.4
$ pyenv install 2.7.16
$ pyenv virtualenv 3.7.4 ENV3
$ pyenv virtualenv 2.7.16 ENV2
```

To automatically access them from your shell we integrate them into bash by editing the bash configuration files. Make sure that on Linux you add to the `~/.bashrc` file and on macOS to the file `~/.bash_profile` or `.zprofile`.

```
export PYENV_ROOT="$HOME/.pyenv"
export PATH="$PYENV_ROOT/bin:$PATH"

export PYENV_VIRTUALENV_DISABLE_PROMPT=1
eval "$(pyenv init -)"
eval "$(pyenv virtualenv-init -)"

__pyenv_version_ps1() {
  local ret=$?;
  output=$(pyenv version-name)
  if [[ ! -z $output ]]; then
    echo -n "($output)"
  fi
  return $ret;
}
```

```
PS1="\$(__pyenv_version_ps1) ${PS1}"

alias ENV2="pyenv activate ENV2"
alias ENV3="pyenv activate ENV3"


ENV3
```

We recommend that you do this towards the end of your file. Than look up our convenience methods to set an ALIAS and install Python 3.7.4 via pyenv

Next we recommend to update pip

```
$ ENV2
$ pip install pip -U
$ ENV3
$ pip install pip -U
```

3.2.3.1 Installation pyenv via Homebrew

On macOS you can install pyenv also via Homebrew. Before installing anything on your computer make sure you have enough space. Use in the terminal the command:

```
$ df -h
```

which gives your an overview of your file system. If you do not have enough space, please make sure you free up unused files from your drive.

In many occasions it is beneficial to use readline as it provides nice editing features for the terminal and xz for completion. First, make sure you have xcode installed:

```
$ xcode-select --install
```

On Mojave you will get an error that zlib is not installed. THis is due to that the header files are not properly installed. To do this you can say

```
$ sudo installer -pkg /Library/Developer/CommandLineTools/Packages/macOS_SDK_headers_for_macOS_10.14.pkg -target /
```

Next install homebrew, pyenv, pyenv-virtualenv and pyenv-virtualwrapper. Additionally install readline and some compression tools:

```
$ /usr/bin/ruby -e "$(curl -fsSL https://raw.githubusercontent.com/Homebrew/install/master/install)"
$ brew update
$ brew install readline xz
```

To install pyenv with homebrew execute in the terminal:

```
brew install pyenv pyenv-virtualenv pyenv-virtualenvwrapper
```

3.2.3.2 Install pyenv on Ubuntu 18.04

The following steps will install pyenv in a new ubuntu 18.04 distribution.

Start up a terminal and execute in the terminal the following commands. We recommend that you do it one command at a time so you can observe if the command succeeds:

```
$ sudo apt-get update
$ sudo apt-get install git python-pip make build-essential libssl-dev
$ sudo apt-get install zlib1g-dev libbz2-dev libreadline-dev libsqlite3-dev
$ sudo pip install virtualenvwrapper

$ git clone https://github.com/yyuu/pyenv.git ~/.pyenv
$ git clone https://github.com/pyenv/pyenv-virtualenv.git ~/.pyenv/plugins/pyenv-virtualenv
$ git clone https://github.com/yyuu/pyenv-virtualenvwrapper.git ~/.pyenv/plugins/pyenv-virtualenvwrapper

$ echo 'export PYENV_ROOT="$HOME/.pyenv"' >> ~/.bashrc
$ echo 'export PATH="$PYENV_ROOT/bin:$PATH"' >> ~/.bashrc
```

You can also install pyenv using curl command in following way:

```
$ curl -L https://raw.githubusercontent.com/yyuu/pyenv-installer/master/bin/pyenv-installer | bash
```

Then install its dependencies:

```
$ sudo apt-get update && sudo apt-get upgrade
$ sudo apt-get install -y make build-essential libssl-dev
$ sudo apt-get install -y zlib1g-dev libbz2-dev libreadline-dev libsqlite3-dev
$ sudo apt-get install -y wget curl llvm libncurses5-dev git
```

Now that you have installed pyenv it is not yet activated in your current terminal. The easiest thing to do is to start a new terminal and typ in:

```
$ which pyenv
```

If you see a response pyenv is installed and you can proceed with the next steps.

Please remember whenever you modify `.bashrc` or `.bash_profile` or `.zprofile` you need to start a new terminal.

3.2.3.3 Using pyenv

3.2.3.3.1 Using pyenv to Install Different Python Versions

Pyenv provides a large list of different python versions. To see the entire list please use the command:

```
$ pyenv install -l
```

However, for us we only need to worry about python 2.7.16 and python 3.7.4. You can now install different versions of python into your local environment with the following commands:

```
$ pyenv update
$ pyenv install 2.7.16
$ pyenv install 3.7.4
```

You can set the global python default version with:

```
$ pyenv global 3.7.4
```

Type the following to determine which version you activated:

```
$ pyenv version
```

Type the following to determine which versions you have available:

```
$ pyenv versions
```

Associate a specific environment name with a certain python version, use the following commands:

```
$ pyenv virtualenv 2.7.16 ENV2
$ pyenv virtualenv 3.7.4 ENV3
```

In the example, ENV2 would represent python 2.7.16 while ENV3 would represent python 3.7.4. Often it is easier to type the alias rather than the explicit version.

3.2.3.3.2 Switching Environments

After setting up the different environments, switching between them is now easy. Simply use the following commands:

```
(2.7.16) $ pyenv activate ENV2
(ENV2) $ pyenv activate ENV3
(ENV3) $ pyenv activate ENV2
(ENV2) $ pyenv deactivate ENV2
(2.7.16) $
```

To make it even easier, you can add the following lines to your `.bash_profile` or or

`.zprofile` file:

```
alias ENV2="pyenv activate ENV2"
alias ENV3="pyenv activate ENV3"
```

If you start a new terminal, you can switch between the different versions of python simply by typing:

```
$ ENV2
$ ENV3
```

3.2.3.4 Updating Python Version List

Pyenv maintains locally a list of available python versions. To see the list use the command

```
$ pyenv update
$ pyenv install -l
```

You will see the updated list.

3.2.3.4.1 Updating to a new version of Python with pyenv

Naturally python itself evolves and new versions will become available via pyenv. To facilitate such a new version you need to first install it into pyenv. Let us assume you had an old version of python installed onto the ENV3 environment. Than you need to execute the following steps:

```
$ pyenv deactivate
$ pyenv uninstall ENV3
$ pyenv install 3.7.4
$ pyenv virtualenv 3.7.4 ENV3
$ ENV3
$ pip install pip -U
```

With the pi install command, we make sure we have the newest version of pip. In case you get an error, you may have to update xcode as follows and try again:

```
xcode-select --install
```

After you installed it you can activate it by typing `ENV3`. Naturally this requires that you added it to your bash environment as discussed in Section 1.1.1.8. 🅾

3.2.4 Anaconda and Miniconda and Conda

While in others on the internet or in your classes may have taught you to use anaconda, We will avoid it as it has several disadvantages for edevelopers. The reason for this is that it installs many packages that you are likely not to use. In fact installing anaconda on your VM will waste space and time and you should look into other installs.

We do not recommend that you use anaconda or miniconda as it may

interfere with your default python interpreters and setup.

Please note that beginners to python should always use anaconda or miniconda only after they have installed pyenv and use it. For this class neither anaconda nor miniconda is required. In fact we do not recommend it. We keep this section as we know that other classes at IU may use anaconda. We are not aware if these classes teach you the right way to install it, with *pyenv*.

3.2.4.1 Miniconda

> ⚠ *This section about miniconda is experimental and has not been tested. We are looking for contributors that help completing it. If you use anaconda or miniconda we recommend to manage it via pyenv.*

To install mini conda you can use the following commands:

```
$ mkdir ana
$ cd ana
$ pyenv install miniconda3-latest
$ pyenv local miniconda3-latest
$ pyenv activate miniconda3-latest
$ conda create -n ana anaconda
```

To activate use:

```
$ source activate ana
```

To deactivate use:

```
$ source deactivate
```

3.2.4.2 Anaconda

> ⚠ *This section about anaconda is experimental and has not been*

tested. We are looking for contributors that help completing it.

You can add anaconda to your pyenv with the following commands:

```
pyenv install anaconda3-4.3.1
```

To switch more easily we recommend that you use the following in your `.bash_profile` or `.zprofile` file:

```
alias ANA="pyenv activate anaconda3-4.3.1"
```

Once you have done this you can easily switch to anaconda with the command:

```
$ ANA
```

Terminology in anaconda could lead to confusion. Thus we like to point out that the version number of anaconda is unrelated to the python version. Furthermore, anaconda uses the term root not for the root user, but for the originating directory in which the anaconda program is installed.

In case you like to build your own conda packages at a later time we recommend that you install the conda-build package:

```
$ conda install conda-build
```

When executing:

```
$ pyenv versions
```

you will see after the install completed the anaconda versions installed:

```
pyenv versions
system
2.7.16
2.7.16/envs/ENV2
3.7.4
3.7.4/envs/ENV3
ENV2
ENV3
* anaconda3-4.3.1 (set by PYENV_VERSION environment variable)
```

Let us now create virtualenv for anaconda:

```
$ pyenv virtualenv anaconda3-4.3.1 ANA
```

To activate it you can now use:

```
$ pyenv ANA
```

However, anaconda may modify your `.bashrc` or `.bash_profile` or or `.zprofile` files and may result in incompatibilities with other python versions. For this reason we recommend not to use it. If you find ways to get it to work reliably with other versions, please let us know and we update this tutorial.

3.2.5 Exercises

E.Python.Install.1:

> *Install Python 3.7.4*

E.Python.Install.1:

> *Write installation instructions for an operating system of your choice and add to this documentation.*

E.Python.Install.2:

> *Replicate the steps to install pyenv, so you can type in ENV2 and ENV3 in your terminals to switch between python 2 and 3.*

E.Python.Install.3:

> *Why do you not want to use generally anaconda for cloud computing? When is it ok to use anaconda?*

4 FIRST STEPS

4.1 INTERACTIVE PYTHON

Python can be used interactively. You can enter the interactive mode by entering the interactive loop by executing the command:

```
$ python
```

You will see something like the following:

```
$ python
Python 3.7.1 (default, Nov 24 2018, 14:27:15)
[Clang 10.0.0 (clang-1000.11.45.5)] on darwin
Type "help", "copyright", "credits" or "license" for more information.
>>>
```

The `>>>` is the prompt used by the interpreter. This is similar to bash where commonly `$` is used.

Sometimes it is convenient to show the prompt when illustrating an example. This is to provide some context for what we are doing. If you are following along you will not need to type in the prompt.

This interactive python process does the following:

- *read* your input commands
- *evaluate* your command
- *print* the result of evaluation
- *loop* back to the beginning.

This is why you may see the interactive loop referred to as a **REPL**: **R**ead-**E**valuate-**P**rint-**L**oop.

4.1.1 REPL (Read Eval Print Loop)

There are many different types beyond what we have seen so far, such as **dictionaries**, **lists**, **sets**. One handy way of using the interactive python is to get the type of a value using type():

```
>>> type(42)
<type 'int'>
>>> type('hello')
<type 'str'>
>>> type(3.14)
<type 'float'>
```

You can also ask for help about something using help():

```
>>> help(int)
>>> help(list)
>>> help(str)
```

Using help() opens up a help message within a pager. To navigate you can use the spacebar to go down a page w to go up a page, the arrow keys to go up/down line-by-line, or q to exit.

4.1.2 Interpreter

Although the interactive mode provides a convenient tool to test things out you will see quickly that for our class we want to use the python interpreter from the commandline. Let us assume the program is called `prg.py`. Once you have written it in that file you simply can call it with

```
$ python prg.py
```

It is important to name the program with meaningful names.

4.1.3 Python 3 Features in Python 2

In this course we want to be able to seamlessly switch between python 2 and python 3. Thus it is convenient from the start to use python 3 syntax when it is supported also in python 2. One of the most used functions is the print statement that has in python 3 parentheses. To enable it in python 2 you just need to import this function:

```
from __future__ import print_function, division
```

The first of these imports allows us to use the print function to output text to the screen, instead of the print statement, which Python 2 uses. This is simply a design decision that better reflects Python's underlying philosophy.

Other functions such as the division also behave differently. Thus we use

```
from __future__ import division
```

This import makes sure that the division operator behaves in a way a newcomer to the language might find more intuitive. In Python 2, division / is *floor division* when the arguments are integers, meaning that the following

```
(5 / 2 == 2) is True
```

In Python 3, division / is a floating point division, thus

```
(5 / 2 == 2.5) is True
```

4.2 Editors

This section is meant to give an overview of the python editing tools needed for doing for this course. There are many other alternatives, however, we do recommend to use PyCharm.

4.2.1 Pycharm

PyCharm is an Integrated Development Environment (IDE) used for programming in Python. It provides code analysis, a graphical debugger, an integrated unit tester, integration with git.

 Python 8:56 Pycharm

4.2.2 Python in 45 minutes

An additional community video about the Python programming language that we found on the internet. Naturally there are many alternatives to this video, but the video is probably a good start. It also uses PyCharm which we recommend.

 Python 43:16 PyCharm

How much you want to understand of python is actually a bit up to you. While its good to know classes and inheritance, you may be able for this class to get away without using it. However, we do recommend that you learn it.

PyCharm Installation: Method 1: PyCharm Installation on ubuntu using umake

```
sudo add-apt-repository ppa:ubuntu-desktop/ubuntu-make
sudo apt-get update
sudo apt-get install ubuntu-make
```

Once umake command is run, use the next command to install Pycharm community edition:

```
umake ide pycharm
```

If you want to remove PyCharm installed using umake command, use this:

```
umake -r ide pycharm
```

Method 2: PyCharm installation on ubuntu using PPA

```
sudo add-apt-repository ppa:mystic-mirage/pycharm
sudo apt-get update
sudo apt-get install pycharm-community
```

PyCharm also has a Professional (paid) version which can be installed using following command:

```
sudo apt-get install pycharm
```

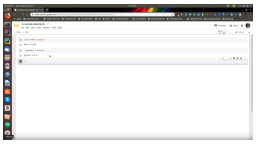
Once installed, go to your VM dashboard and search for PyCharm.

4.3 Google Colab

In this section we are going to introduce you, how to use Google Colab to run deep learning models.

4.3.1 Introduction to Google Colab

This video contains the introduction to Google Colab. In this section we will be learning how to start a Google Colab project.



4.3.2 Programming in Google Colab

In this video we will learn how to create a simple, Colab Notebook.

Required Installations

```
pip install numpy
```

4.3.3 Benchamrking in Google Colab with Cloudmesh

In this video we learn how to do a basic benchmark with Cloudmesh tools. Cloudmesh StopWatch will be used in this tutorial.

Required Installations

```
pip install numpy
pip install cloudmesh-installer
pip install cloudmesh-common
```

5 LANGUAGE

5.1 LANGUAGE

5.1.1 Statements and Strings

Let us explore the syntax of Python while starting with a print statement

```
print("Hello world from Python!")
```

This will print on the terminal

```
Hello world from Python!
```

The print function was given a **string** to process. A string is a sequence of characters. A **character** can be a alphabetic (A through Z, lower and upper case), numeric (any of the digits), white space (spaces, tabs, newlines, etc), syntactic directives (comma, colon, quotation, exclamation, etc), and so forth. A string is just a sequence of the character and typically indicated by surrounding the characters in double quotes.

Standard output is discussed in the Section Linux.

So, what happened when you pressed Enter? The interactive Python program read the line `print ("Hello world from Python!")`, split it into the print statement and the `"Hello world from Python!"` string, and then executed the line, showing you the output.

5.1.2 Comments

Comments in python are followed by a `#`:

```
# This is a comment
```

5.1.3 Variables

You can store data into a **variable** to access it later. For instance:

```
hello = 'Hello world from Python!'
print(hello)
```

This will print again

```
Hello world from Python!
```

5.1.4 Data Types

5.1.4.1 Booleans

A **boolean** is a value that can have the values `True` or `False`. You can combine booleans with **boolean operators** such as `and` and `or`

```
print(True and True) # True
print(True and False) # False
print(False and False) # False
print(True or True) # True
print(True or False) # True
print(False or False) # False
```

5.1.4.2 Numbers

The interactive interpreter can also be used as a calculator. For instance, say we wanted to compute a multiple of 21:

```
print(21 * 2) # 42
```

We saw here the print statement again. We passed in the result of the operation 21 * 2. An **integer** (or **int**) in Python is a numeric value without a fractional component (those are called **floating point** numbers, or **float** for short).

The mathematical operators compute the related mathematical operation to the provided numbers. Some operators are:

Operator	Function
*	multiplication
/	division
+	addition
-	subtraction
**	exponent

Exponentiation x^y is written as x**y is x to the yth power.

You can combine **float**s and **int**s:

```
print(3.14 * 42 / 11 + 4 - 2) # 13.9890909091
print(2**3) # 8
```

Note that **operator precedence** is important. Using parenthesis to indicate affect the order of operations gives a difference results, as expected:

```
print(3.14 * (42 / 11) + 4 - 2) # 11.42
print(1 + 2 * 3 - 4 / 5.0) # 6.2
print( (1 + 2) * (3 - 4) / 5.0 ) # -0.6
```

5.1.5 Module Management

A module allows you to logically organize your Python code. Grouping related code into a module makes the code easier to understand and use. A module is a Python object with arbitrarily named attributes that you can bind and reference. A module is a file consisting of Python code. A module can define functions, classes and variables. A module can also include runnable code.

5.1.5.1 Import Statement

When the interpreter encounters an import statement, it imports the module if the module is present in the search path. A search path is a list of directories that the interpreter searches before importing a module. The from…import Statement Python's from statement lets you import specific attributes from a module into the current namespace. It is preferred to use for each import its own line such as:

```
import numpy
import matplotlib
```

When the interpreter encounters an import statement, it imports the module if the module is present in the search path. A search path is a list of directories that the interpreter searches before importing a module.

5.1.5.2 The from … import Statement

Python's from statement lets you import specific attributes from a module into the current namespace. The from … import has the following syntax:

```
from datetime import datetime
```

5.1.6 Date Time in Python

The datetime module supplies classes for manipulating dates and times in both simple and complex ways. While date and time arithmetic is supported, the focus of the implementation is on efficient attribute extraction for output formatting and manipulation. For related functionality, see also the time and calendar modules.

The import Statement You can use any Python source file as a module by executing an import statement in some other Python source file.

```
from datetime import datetime
```

This module offers a generic date/time string parser which is able to parse most known formats to represent a date and/or time.

```
from dateutil.parser import parse
```

pandas is an open source Python library for data analysis that needs to be imported.

```
import pandas as pd
```

Create a string variable with the class start time

```
fall_start = '08-21-2018'
```

Convert the string to datetime format

```
datetime.strptime(fall_start, '%m-%d-%Y') \#
datetime.datetime(2017, 8, 21, 0, 0)
```

Creating a list of strings as dates

```
class_dates = [
    '8/25/2017',
    '9/1/2017',
    '9/8/2017',
    '9/15/2017',
    '9/22/2017',
    '9/29/2017']
```

Convert Class_dates strings into datetime format and save the list into variable a

```
a = [datetime.strptime(x, '%m/%d/%Y') for x in class_dates]
```

Use parse() to attempt to auto-convert common string formats. Parser must be a

string or character stream, not list.

```
parse(fall_start) # datetime.datetime(2017, 8, 21, 0, 0)
```

Use parse() on every element of the Class_dates string.

```
[parse(x) for x in class_dates]
# [datetime.datetime(2017, 8, 25, 0, 0),
#  datetime.datetime(2017, 9, 1, 0, 0),
#  datetime.datetime(2017, 9, 8, 0, 0),
#  datetime.datetime(2017, 9, 15, 0, 0),
#  datetime.datetime(2017, 9, 22, 0, 0),
#  datetime.datetime(2017, 9, 29, 0, 0)]
```

Use parse, but designate that the day is first.

```
parse (fall_start, dayfirst=True)
# datetime.datetime(2017, 8, 21, 0, 0)
```

Create a dataframe.A DataFrame is a tabular data structure comprised of rows and columns, akin to a spreadsheet, database table. DataFrame as a group of Series objects that share an index (the column names).

```
import pandas as pd
data = {
  'dates': [
    '8/25/2017 18:47:05.069722',
    '9/1/2017 18:47:05.119994',
    '9/8/2017 18:47:05.178768',
    '9/15/2017 18:47:05.230071',
    '9/22/2017 18:47:05.230071',
    '9/29/2017 18:47:05.280592'],
  'complete': [1, 0, 1, 1, 0, 1]}
df = pd.DataFrame(
  data,
  columns = ['dates','complete'])
print(df)
#                  dates  complete
#  0  8/25/2017 18:47:05.069722 1
#  1   9/1/2017 18:47:05.119994 0
#  2   9/8/2017 18:47:05.178768 1
#  3  9/15/2017 18:47:05.230071 1
#  4  9/22/2017 18:47:05.230071 0
#  5  9/29/2017 18:47:05.280592 1
```

Convert `df[`date`]` from string to datetime

```
import pandas as pd
pd.to_datetime(df['dates'])
# 0   2017-08-25 18:47:05.069722
# 1   2017-09-01 18:47:05.119994
# 2   2017-09-08 18:47:05.178768
# 3   2017-09-15 18:47:05.230071
# 4   2017-09-22 18:47:05.230071
# 5   2017-09-29 18:47:05.280592
# Name: dates, dtype: datetime64[ns]
```

5.1.7 Control Statements

5.1.7.1 Comparison

Computer programs do not only execute instructions. Occasionally, a choice needs to be made. Such as a choice is based on a condition. Python has several conditional operators:

Operator	Function
>	greater than
<	smaller than
==	equals
!=	is not

Conditions are always combined with variables. A program can make a choice using the if keyword. For example:

```
x = int(input("Guess x:"))
if x == 4:
   print('Correct!')
```

In this example, *You guessed correctly!* will only be printed if the variable x equals to four. Python can also execute multiple conditions using the elif and else keywords.

```
x = int(input("Guess x:"))
if x == 4:
    print('Correct!')
elif abs(4 - x) == 1:
    print('Wrong, but close!')
else:
    print('Wrong, way off!')
```

5.1.7.2 Iteration

To repeat code, the for keyword can be used. For example, to display the numbers from 1 to 10, we could write something like this:

```
for i in range(1, 11):
   print('Hello!')
```

The second argument to range, *11*, is not inclusive, meaning that the loop will only get to *10* before it finishes. Python itself starts counting from 0, so this code will also work:

```
for i in range(0, 10):
   print(i + 1)
```

In fact, the range function defaults to starting value of *0*, so it is equivalent to:

```
for i in range(10):
   print(i + 1)
```

We can also nest loops inside each other:

```
for i in range(0,10):
    for j in range(0,10):
        print(i,' ',j)
```

In this case we have two nested loops. The code will iterate over the entire coordinate range (0,0) to (9,9)

5.1.8 Datatypes

5.1.8.1 Lists

see: https://www.tutorialspoint.com/python/python_lists.htm

Lists in Python are ordered sequences of elements, where each element can be accessed using a 0-based index.

To define a list, you simply list its elements between square brackets '[ ]':

```
names = [
  'Albert',
  'Jane',
  'Liz',
  'John',
  'Abby']
# access the first element of the list
names[0]
# 'Albert'
# access the third element of the list
names[2]
# 'Liz'
```

You can also use a negative index if you want to start counting elements from the end of the list. Thus, the last element has index *-1*, the second before last element has index *-2* and so on:

```
# access the last element of the list
names[-1]
# 'Abby'
# access the second last element of the list
names[-2]
# 'John'
```

Python also allows you to take whole slices of the list by specifying a beginning and end of the slice separated by a colon

```
# the middle elements, excluding first and last
names[1:-1]
# ['Jane', 'Liz', 'John']
```

As you can see from the example, the starting index in the slice is inclusive and the ending one, exclusive.

Python provides a variety of methods for manipulating the members of a list.

You can add elements with append':

```
names.append('Liz')
names
# ['Albert', 'Jane', 'Liz',
#  'John', 'Abby', 'Liz']
```

As you can see, the elements in a list need not be unique.

Merge two lists with 'extend':

```
names.extend(['Lindsay', 'Connor'])
names
# ['Albert', 'Jane', 'Liz', 'John',
#  'Abby', 'Liz', 'Lindsay', 'Connor']
```

Find the index of the first occurrence of an element with 'index':

```
names.index('Liz') \# 2
```

Remove elements by value with 'remove':

```
names.remove('Abby')
names
# ['Albert', 'Jane', 'Liz', 'John',
#  'Liz', 'Lindsay', 'Connor']
```

Remove elements by index with 'pop':

```
names.pop(1)
# 'Jane'
names
# ['Albert', 'Liz', 'John',
#  'Liz', 'Lindsay', 'Connor']
```

Notice that pop returns the element being removed, while remove does not.

If you are familiar with stacks from other programming languages, you can use insert and 'pop':

```
names.insert(0, 'Lincoln')
names
# ['Lincoln', 'Albert', 'Liz',
#  'John', 'Liz', 'Lindsay', 'Connor']
names.pop()
```

```
# 'Connor'
names
# ['Lincoln', 'Albert', 'Liz',
#  'John', 'Liz', 'Lindsay']
```

The Python documentation contains a full list of list operations.

To go back to the range function you used earlier, it simply creates a list of numbers:

```
range(10)
# [0, 1, 2, 3, 4, 5, 6, 7, 8, 9]
range(2, 10, 2)
# [2, 4, 6, 8]
```

5.1.8.2 Sets

Python lists can contain duplicates as you saw previously:

```
names = ['Albert', 'Jane', 'Liz',
         'John', 'Abby', 'Liz']
```

When we do not want this to be the case, we can use a set:

```
unique_names = set(names)
unique_names
# set(['Lincoln', 'John', 'Albert', 'Liz', 'Lindsay'])
```

Keep in mind that the *set* is an unordered collection of objects, thus we can not access them by index:

```
unique_names[0]
# Traceback (most recent call last):
#   File "<stdin>", line 1, in <module>
#   TypeError: 'set' object does not support indexing
```

However, we can convert a set to a list easily:

```
unique_names = list(unique_names)
unique_names [`Lincoln', `John', `Albert', `Liz', `Lindsay']
unique_names[0]
# `Lincoln'
```

Notice that in this case, the order of elements in the new list matches the order in which the elements were displayed when we create the set. We had

```
set(['Lincoln', 'John', 'Albert', 'Liz', 'Lindsay'])
```

and now we have

```
['Lincoln', 'John', 'Albert', 'Liz', 'Lindsay'])
```

You should not assume this is the case in general. That is, do not make any assumptions about the order of elements in a set when it is converted to any type of sequential data structure.

You can change a set's contents using the add, remove and update methods which correspond to the append, remove and extend methods in a list. In addition to these, *set* objects support the operations you may be familiar with from mathematical sets: *union*, *intersection*, *difference*, as well as operations to check containment. You can read about this in the Python documentation for sets.

5.1.8.3 Removal and Testing for Membership in Sets

One important advantage of a `set` over a `list` is that **access to elements is fast**. If you are familiar with different data structures from a Computer Science class, the Python list is implemented by an array, while the set is implemented by a hash table.

We will demonstrate this with an example. Let us say we have a list and a set of the same number of elements (approximately 100 thousand):

```
import sys, random, timeit
nums_set = set([random.randint(0, sys.maxint) for _ in range(10**5)])
nums_list = list(nums_set)
len(nums_set)
# 100000
```

We will use the timeit Python module to time 100 operations that test for the existence of a member in either the list or set:

```
timeit.timeit('random.randint(0, sys.maxint) in nums',
              setup='import random; nums=%s' % str(nums_set), number=100)
# 0.0004038810729980469
timeit.timeit('random.randint(0, sys.maxint) in nums',
              setup='import random; nums=%s' % str(nums_list), number=100)
# 0.398054122924804
```

The exact duration of the operations on your system will be different, but the take away will be the same: searching for an element in a set is orders of magnitude faster than in a list. This is important to keep in mind when you work with large amounts of data.

5.1.8.4 Dictionaries

One of the very important data structures in python is a dictionary also referred to as *dict*.

A dictionary represents a key value store:

```
person = {
  'Name': 'Albert',
  'Age': 100,
  'Class': 'Scientist'
  }
print("person['Name']: ", person['Name'])
# person['Name']:  Albert
print("person['Age']: ", person['Age'])
# person['Age']:  100
```

A convenient for to print by named attributes is

```
print("{Name} {Age}'.format(**data))
```

This form of printing with the format statement and a reference to data increases readability of the print statements.

You can delete elements with the following commands:

```
del person['Name'] # remove entry with key 'Name'
# person
# {'Age': 100, 'Class': 'Scientist'}
person.clear()     # remove all entries in dict
# person
# {}
del person         # delete entire dictionary
# person
# Traceback (most recent call last):
#  File "<stdin>", line 1, in <module>
#  NameError: name 'person' is not defined
```

You can iterate over a dict:

```
person = {
  'Name': 'Albert',
  'Age': 100,
  'Class': 'Scientist'
  }
for item in person:
  print(item, person[item])

# Age 100
# Name Albert
# Class Scientist
```

5.1.8.5 Dictionary Keys and Values

You can retrieve both the keys and values of a dictionary using the keys() and values() methods of the dictionary, respectively:

```
person.keys() # ['Age', 'Name', 'Class']
person.values() # [100, 'Albert', 'Scientist']
```

Both methods return lists. Notice, however, that the order in which the elements appear in the returned lists (Age, Name, Class) is different from the order in which we listed the elements when we declared the dictionary initially (Name, Age, Class). It is important to keep this in mind:

> ⚠ *You cannot make any assumptions about the order in which the elements of a dictionary will be returned by the keys() and values() methods.*

However, you can assume that if you call `keys()` and `values()` in sequence, the order of elements will at least correspond in both methods. In the example Age corresponds to 100, Name to `Albert`, and Class to Scientist, and you will observe the same correspondence in general as long as *`keys()` and `values()` are called one right after the other*.

5.1.8.6 Counting with Dictionaries

One application of dictionaries that frequently comes up is counting the elements in a sequence. For example, say we have a sequence of coin flips:

```
import random
die_rolls = [
  random.choice(['heads', 'tails']) for _ in range(10)
]
# die_rolls
# ['heads', 'tails', 'heads',
#  'tails', 'heads', 'heads',
   'tails', 'heads', 'heads', 'heads']
```

The actual list die_rolls will likely be different when you execute this on your computer since the outcomes of the die rolls are random.

To compute the probabilities of heads and tails, we could count how many heads and tails we have in the list:

```
counts = {'heads': 0, 'tails': 0}
for outcome in coin_flips:
   assert outcome in counts
   counts[outcome] += 1
print('Probability of heads: %.2f' % (counts['heads'] / len(coin_flips)))
# Probability of heads: 0.70

print('Probability of tails: %.2f' % (counts['tails'] / sum(counts.values())))
# Probability of tails: 0.30
```

In addition to how we use the dictionary counts to count the elements of

coin_flips, notice a couple things about this example:

1. We used the assert outcome in counts statement. The assert statement in Python allows you to easily insert debugging statements in your code to help you discover errors more quickly. assert statements are executed whenever the internal Python `__debug__` variable is set to True, which is always the case unless you start Python with the -O option which allows you to run *optimized* Python.

2. When we computed the probability of tails, we used the built-in sum function, which allowed us to quickly find the total number of coin flips. sum is one of many built-in function you can read about here.

5.1.9 Functions

You can reuse code by putting it inside a function that you can call in other parts of your programs. Functions are also a good way of grouping code that logically belongs together in one coherent whole. A function has a unique name in the program. Once you call a function, it will execute its body which consists of one or more lines of code:

```
def check_triangle(a, b, c):
return \
    a < b + c and a > abs(b - c) and \
    b < a + c and b > abs(a - c) and \
    c < a + b and c > abs(a - b)

    print(check_triangle(4, 5, 6))
```

The def keyword tells Python we are defining a function. As part of the definition, we have the function name, check_triangle, and the parameters of the function – variables that will be populated when the function is called.

We call the function with arguments 4, 5 and 6, which are passed in order into the parameters a, b and c. A function can be called several times with varying parameters. There is no limit to the number of function calls.

It is also possible to store the output of a function in a variable, so it can be reused.

```
def check_triangle(a, b, c):
  return \
     a < b + c and a > abs(b - c) and \
     b < a + c and b > abs(a - c) and \
     c < a + b and c > abs(a - b)
```

```
    result = check_triangle(4, 5, 6)
    print(result)
```

5.1.10 Classes

A class is an encapsulation of data and the processes that work on them. The data is represented in member variables, and the processes are defined in the methods of the class (methods are functions inside the class). For example, let's see how to define a Triangle class:

```
class Triangle(object):

  def __init__(self, length, width,
                 height, angle1, angle2, angle3):
      if not self._sides_ok(length, width, height):
          print('The sides of the triangle are invalid.')
      elif not self._angles_ok(angle1, angle2, angle3):
          print('The angles of the triangle are invalid.')

      self._length = length
      self._width = width
      self._height = height

      self._angle1 = angle1
      self._angle2 = angle2
      self._angle3 = angle3

  def _sides_ok(self, a, b, c):
      return \
          a < b + c and a > abs(b - c) and \
          b < a + c and b > abs(a - c) and \
          c < a + b and c > abs(a - b)

  def _angles_ok(self, a, b, c):
      return a + b + c == 180

triangle = Triangle(4, 5, 6, 35, 65, 80)
```

Python has full object-oriented programming (OOP) capabilities, however we can not cover all of them in this section, so if you need more information please refer to the Python docs on classes and OOP.

5.1.11 Modules

Now write this simple program and save it:

```
print("Hello world!")
```

As a check, make sure the file contains the expected contents on the command line:

```
$ cat hello.py
print("Hello world!")
```

To execute your program pass the file as a parameter to the python command:

```
$ python hello.py
Hello world!
```

Files in which Python code is stored are called **module**s. You can execute a Python module form the command line like you just did, or you can import it in other Python code using the import statement.

Let us write a more involved Python program that will receive as input the lengths of the three sides of a triangle, and will output whether they define a valid triangle. A triangle is valid if the length of each side is less than the sum of the lengths of the other two sides and greater than the difference of the lengths of the other two sides.:

```
"""Usage: check_triangle.py [-h] LENGTH WIDTH HEIGHT

Check if a triangle is valid.

Arguments:
  LENGTH     The length of the triangle.
  WIDTH      The width of the traingle.
  HEIGHT     The height of the triangle.

Options:
-h --help
"""
from docopt import docopt

if __name__ == '__main__':
  arguments = docopt(__doc__)
  a, b, c = int(arguments['LENGTH']),
            int(arguments['WIDTH']),
            int(arguments['HEIGHT'])
  valid_triangle = \
      a < b + c and a > abs(b - c) and \
      b < a + c and b > abs(a - c) and \
      c < a + b and c > abs(a - b)
  print('Triangle with sides %d, %d and %d is valid: %r' % (
      a, b, c, valid_triangle
  ))
```

Assuming we save the program in a file called `check_triangle.py`, we can run it like so:

```
$ python check_triangle.py 4 5 6
Triangle with sides 4, 5 and 6 is valid: True
```

Let us break this down a bit.

1. We are importing the print_function and division modules from python 3 like we did earlier in this section. It’s a good idea to always include these in your programs.
2. We’ve defined a boolean expression that tells us if the sides that were input define a valid triangle. The result of the expression is stored in the

valid_triangle variable. inside are true, and False otherwise.

3. We've used the backslash symbol \ to format are code nicely. The backslash simply indicates that the current line is being continued on the next line.
4. When we run the program, we do the check if `__name__ == '__main__'`. `__name__` is an internal Python variable that allows us to tell whether the current file is being run from the command line (value `__name__`), or is being imported by a module (the value will be the name of the module). Thus, with this statement we're just making sure the program is being run by the command line.
5. We are using the docopt module to handle command line arguments. The advantage of using this module is that it generates a usage help statement for the program and enforces command line arguments automatically. All of this is done by parsing the docstring at the top of the file.
6. In the print function, we are using Python's string formatting capabilities to insert values into the string we are displaying.

5.1.12 Lambda Expressions

As oppose to normal functions in Python which are defined using the `def` keyword, lambda functions in Python are anonymous functions which do not have a name and are defined using the `lambda` keyword. The generic syntax of a lambda function is in form of`lambda arguments: expression`, as shown in the following example:

```
greeter = lambda x: print('Hello %s!'%x)
print(greeter('Albert'))
```

As you could probably guess, the result is:

```
Hello Albert!
```

Now consider the following examples:

```
power2 = lambda x: x ** 2
```

The `power2` function defined in the expression, is equivalent to the following definition:

```
def power2(x):
    return x ** 2
```

Lambda functions are useful for when you need a function for a short period of time. Note that they can also be very useful when passed as an argument with other built-in functions that take a function as an argument, e.g. `filter()` and `map()`. In the next example we show how a lambda function can be combined with the `filer` function. Consider the array `all_names` which contains five words that rhyme together. We want to filter the words that contain the word `name`. To achieve this, we pass the function `lambda x: 'name' in x` as the first argument. This lambda function returns `True` if the word `name` exists as a sub-string in the string `x`. The second argument of `filter` function is the array of names, i.e. `all_names`.

```
all_names = ['surname', 'rename', 'nickname', 'acclaims', 'defame']
filtered_names = list(filter(lambda x: 'name' in x, all_names))
print(filtered_names)
# ['surname', 'rename', 'nickname']
```

As you can see, the names are successfully filtered as we expected.

In Python3, filter function returns a filter object or the iterator which gets lazily evaluated which means neither we can access the elements of the filter object with index nor we can use len() to find the length of the filter object.

```
list_a = [1, 2, 3, 4, 5]
filter_obj = filter(lambda x: x % 2 == 0, list_a)
# Convert the filer obj to a list
even_num = list(filter_obj)
print(even_num)
# Output: [2, 4]
```

In Python, we can have a small usually a single liner anonymous function called Lambda function which can have any number of arguments just like a normal function but with only one expression with no return statement. The result of this expression can be applied to a value.

Basic Syntax:

```
lambda arguments : expression
```

For an example: a function in python

```
def multiply(a, b):
    return a*b

#call the function
multiply(3*5) #outputs: 15
```

Same function can written as Lambda function. This function named as multiply is having 2 arguments and returns their multiplication.

Lambda equivalent for this function would be:

```
multiply = Lambda a, b : a*b

print(multiply(3, 5))
# outputs: 15
```

Here a and b are the 2 arguments and a*b is the expression whose value is returned as an output.

Also we don’t need to assign Lambda function to a variable.

```
(lambda a, b : a*b)(3*5)
```

Lambda functions are mostly passed as parameter to a function which expects a function objects like in map or filter.

5.1.12.1 map

The basic syntax of the map function is

```
map(function_object, iterable1, iterable2,...)
```

map functions expects a function object and any number of iterables like list or dictionary. It executes the function_object for each element in the sequence and returns a list of the elements modified by the function object.

Example:

```
def multiply(x):
    return x * 2

map(multiply2, [2, 4, 6, 8])
# Output [4, 8, 12, 16]
```

If we want to write same function using Lambda

```
map(lambda x: x*2, [2, 4, 6, 8])
# Output [4, 8, 12, 16]
```

5.1.12.2 dictionary

Now, lets see how we can interate over a dictionary using map and lambda Lets say we have a dictionary object

```
dict_movies = [
```

```
    {'movie': 'avengers', 'comic': 'marvel'},
    {'movie': 'superman', 'comic': 'dc'}]
```

We can iterate over this dictionary and read the elements of it using map and lambda functions in following way:

```
map(lambda x : x['movie'], dict_movies)  # Output: ['avengers', 'superman']
map(lambda x : x['comic'],  dict_movies)  # Output: ['marvel', 'dc']
map(lambda x : x['movie'] == "avengers", dict_movies)
# Output: [True, False]
```

In Python3, map function returns an iterator or map object which gets lazily evaluated which means neither we can access the elements of the map object with index nor we can use len() to find the length of the map object. We can force convert the map output i.e. the map object to list as shown next:

```
map_output = map(lambda x: x*2, [1, 2, 3, 4])
print(map_output)
# Output: map object: <map object at 0x04D6BAB0>
list_map_output = list(map_output)
print(list_map_output) # Output: [2, 4, 6, 8]
```

5.1.13 Iterators

In Python, an iterator protocol is defined using two methods: `__iter()__` and `next()`. The former returns the iterator object and latter returns the next element of a sequence. Some advantages of iterators are as follows:

- Readability
- Supports sequences of infinite length
- Saving resources

There are several built-in objects in Python which implement iterator protocol, e.g. string, list, dictionary. In the following example, we create a new class that follows the iterator protocol. We then use the class to generate `log2` of numbers:

```
from math import log2

class LogTwo:
    "Implements an iterator of log two"

    def __init__(self,last = 0):
        self.last = last

    def __iter__(self):
        self.current_num = 1
        return self

    def __next__(self):
        if self.current_num <= self.last:
            result = log2(self.current_num)
            self.current_num += 1
            return result
```

```
        else:
            raise StopIteration

L = LogTwo(5)
i = iter(L)
print(next(i))
print(next(i))
print(next(i))
print(next(i))
```

As you can see, we first create an instance of the class and assign its `__iter()__` function to a variable called `i`. Then by calling the `next()` function four times, we get the following output:

```
$ python iterator.py
0.0
1.0
1.584962500721156
2.0
```

As you probably noticed, the lines are `log2()` of 1, 2, 3, 4 respectively.

5.1.14 Generators

Before we go to Generators, please understand Iterators. Generators are also Iterators but they can only be interated over once. Thats because Generators do not store the values in memory instead they generate the values on the go. If we want to print those values then we can either simply iterate over them or use the for loop.

5.1.14.1 Generators with function

For example: we have a function named as multiplyBy10 which prints all the input numbers multiplied by 10.

```
def multiplyBy10(numbers):
    result = []
    for i in numbers:
        result.append(i*10)
    return result

new_numbers = multiplyBy10([1,2,3,4,5])

print new_numbers  #Output: [10, 20, 30, 40 ,50]
```

Now, if we want to use Generators here then we will make following changes.

```
def multiplyBy10(numbers):
    for i in numbers:
        yield(i*10)

new_numbers = multiplyBy10([1,2,3,4,5])
```

```
print new_numbers  #Output: Generators object
```

In Generators, we use yield() function in place of return(). So when we try to print new_numbers list now, it just prints Generators object. The reason for this is because Generators dont hold any value in memory, it yields one result at a time. So essentially it is just waiting for us to ask for the next result. To print the next result we can just say print next(new_numbers) , so how it is working is its reading the first value and squaring it and yielding out value 1. Also in this case we can just print next(new_numbers) 5 times to print all numbers and if we do it for 6th time then we will get an error StopIteration which meanns Generators has exausted its limit and it has no 6th element to print.

```
print next(new_numbers)  #Output: 1
```

5.1.14.2 Generators using for loop

If we now want to print the complete list of squared values then we can just do:

```
def multiplyBy10(numbers):
    for i in numbers:
        yield(i*10)

new_numbers = multiplyBy10([1,2,3,4,5])

for num in new_numbers:
    print num
```

The output will be:

```
10
20
30
40
50
```

5.1.14.3 Generators with List Comprehension

Python has something called List Comprehension, if we use this then we can replace the complete function def with just:

```
new_numbers = [x*10 for x in [1,2,3,4,5]]
print new_numbers  #Output: [10, 20, 30, 40 ,50]
```

Here the point to note is square brackets [] in line 1 is very important. If we change it to () then again we will start getting Generators object.

```
new_numbers = (x*10 for x in [1,2,3,4,5])
print new_numbers  #Output: Generators object
```

We can get the individual elements again from Generators if we do a for loop over new_numbers like we did previously. Alternatively, we can convert it into a list and then print it.

```
new_numbers = (x*10 for x in [1,2,3,4,5])
print list(new_numbers)  #Output: [10, 20, 30, 40 ,50]
```

But here if we convert this into a list then we loose on performance, which we will just see next.

5.1.14.4 Why to use Generators?

Generators are better with Performance because it does not hold the values in memory and here with the small examples we provide its not a big deal since we are dealing with small amount of data but just consider a scenario where the records are in millions of data set. And if we try to convert millions of data elements into a list then that will definitely make an impact on memory and performance because everything will in memory.

Lets see an example on how Generators help in Performance. First, without Generators, normal function taking 1 million record and returns the result[people] for 1 million.

```
names = ['John', 'Jack', 'Adam', 'Steve', 'Rick']
majors = ['Math',
          'CompScience',
          'Arts',
          'Business',
          'Economics']

# prints the memory before we run the function
memory = mem_profile.memory_usage_resource()
print (f'Memory (Before): {memory}Mb')

def people_list(people):
    result = []
    for i in range(people):
        person = {
                'id' : i,
                'name' : random.choice(names),
                'major' : randon.choice(majors)
                }
        result.append(person)
    return result

t1 = time.clock()
people = people_list(10000000)
t2 = time.clock()

# prints the memory after we run the function
memory = mem_profile.memory_usage_resource()
print (f'Memory (After): {memory}Mb')
print ('Took {time} seconds'.format(time=t2-t1))

#Output
Memory (Before): 15Mb
```

```
Memory (After): 318Mb
Took 1.2 seconds
```

I am just giving approximate values to compare it with next execution but we just try to run it we will see a serious consumption of memory with good amount of time taken.

```
names = ['John', 'Jack', 'Adam', 'Steve', 'Rick']
majors = ['Math',
          'CompScience',
          'Arts',
          'Business',
          'Economics']

# prints the memory before we run the function
memory = mem_profile.memory_usage_resource()
print (f'Memory (Before): {memory}Mb')
def people_generator(people):
    for i in xrange(people):
        person = {
            'id' : i,
            'name' : random.choice(names),
            'major' : randon.choice(majors)
        }
        yield person

t1 = time.clock()
people = people_list(10000000)
t2 = time.clock()

# prints the memory after we run the function
memory = mem_profile.memory_usage_resource()
print (f'Memory (After): {memory}Mb')
print ('Took {time} seconds'.format(time=t2-t1))

#Output
Memory (Before): 15Mb
Memory (After): 15Mb
Took 0.01 seconds
```

Now after running the same code using Generators, we will see a significant amount of performance boost with alomost 0 Seconds. And the reason behind this is that in case of Generators, we do not keep anything in memory so system just reads 1 at a time and yields that.

6 REFERENCES