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CAS Practical Machine Learning
Introduction

First Steps with Python

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Python

Language Overview

Python

Python (https://www.python.org/)

- current version 3.x
  - verify installation: `python --version`
- main features
  - interpreted language (no compiler)
    - interactive mode via command line
      - start: `python`
      - hello world: `print("hello world")`
      - end: `quit()`
  - object-oriented and/or functional programming
  - types
    - dynamic but strong typing (no variable declaration)
      - all variables are actually object references: `x = 2`
    - predefined complex types: `tuple`, `list`, `set` and `dict`
  - statements
    - control flow: `if…elif…else`, `for` and `while`
    - grouping via whitespace indentation (no braces, no delimiter)
  - many libraries
- see https://docs.python.org/

Python Hello World

```
x = 34 - 23 # A comment
y = "Hello"
z = 3.45
if z == 3.45 or y == "Hello":
    x += 1
    y = y + " World"
print("Result",x,y)
```

- assignment with `=`, comparison with `==`
- first assignment to a variable creates it
  - no explicit type declaration (but strong typing)
  - in fact `x` is a reference to an object of the corresponding type
  - `type(x)` shows type of `x`
  - `dir()` shows all variables in namespace
- for numbers `+ - * / %` are as expected
  - ordering as expected
  - use `( )` for custom order
- special use of `+` for string concatenation
- logical operators are words: `and`, `or`, `not`
- printing via `print` function
- definition statements (`if`) end with `:`
- blocks via indentation
- newline ends a line of code
  - use `\` to continue line of code on next line

Strings

- string literals are defined with `"bla"` or with `'bla'`
- strings are immutable
- special characters need to be escaped, e.g., `'\\', '\n'`
- search for substring
  - `str.find("this") # returns index or -1`
  - `"this" in str # returns True or False`
  - `str.startswith("this") # returns True or False`
- split: `str.split(".")`
- remove whitespaces: `str.strip()`
- replace substring: `str.replace(old,new)`
- from any type to string: `"Hello " + str(x)`
- from string to list: `li = str.split(',')`
- from list to string: `str = " ".join(['a','b','c'])`

Sequences: Strings, Tuples and Lists

- string
  - immutable sequence of characters: `myString = 'string'`
- tuple
  - ordered, immutable sequence of objects: `myTuple = (1,2)`
  - mixed types: `myTriple = (1,2,"3")`
- list
  - ordered, mutable sequence of objects: `myList = [1,2]`
  - adding elements: `myList.append(3)` and `myList.insert(0, 3)`
  - removing elements: `myList.remove(0, 3)`
- manipulation
  - length: `len(myList)`
  - indexes: `myString[0]` … `myString[len(myString)-1]`
  - slices create a copy of the original list: `subList = myList[start:end]`
    - `subList = myList[:end]`
    - `subList = myList[start:]`
    - `listCopy = myList[:] # different from listCopy = myList`
  - concatenation via `+`: `l3 = l1 + l2`
  - minimum, maximum: `min(myList), max(myList)`
  - contains element x? `if x in myList:`

Control Flow

- `if` *condition*:
  do something
  `elif` *condition2*:
  do something
  `else:`
  do something
- `while` *condition*:
  do something
- `for i in list:  # or: for i in range(len(list))`
  do something with i

- loops may be ended with `break` and skipped with `continue`

Conditions

- Boolean literals: `True`, `False`
- Boolean operators: `and`, `or`, `not`
- comparison operators (content): `<`, `<=`, `==`, `!=`
- object comparison: `is`, `is not`

Efficient List Processing

List Comprehension

- create a new list by processing all elements of an existing one
  - e.g. applying some function `func`

```
newList = [func(elem) for elem in oldList]
```

- a filter may be applied

```
newList = [func(elem) for elem in oldList if elem > 3]
```

Dictionaries

- dictionary stores key-value pairs (= hashset)
  - `hs = {'user1':'password1', 'user2':'password2'}`
  - keys are unique, can be any immutable type
  - values can be any type
- lookup: `print(hs['user1'])`
- adding: `hs['user3'] = 'pw3'`
- deleting: `hs.pop('user1')`
- list of all keys: `hs.keys()`
  - ```
    for k in hs.keys(): # or: for k in hs:
        print(k)
    ```
- list of all values: `hs.values()`
  - ```
    for v in hs.values():
        print(v)
    ```
- list of all key-value pairs: `hs.items()`
  - ```
    for k,v in hs.items():
        print(k,v)
    ```
    ```

Functions

```
def functionName(arg1, arg2, arg3=default):
    do something
    do something
    return result

result = functionName(a1, a2, a3)
```

- function names cannot be overloaded
  - as in other languages via argument variations
- functions without explicit return implicitly return `None`
- functions can be used as any other data type
  - assigned to variables
  - managed in tuples, lists, …
  - used as arguments and returns for function calls
- lambda: function without name

Classes

- everything is an object: `"hello".upper()`
- definition via `class`

```
class myClass:
  def __init__(self, arg1, arg2):
    self.var1 = arg1
    self.var2 = arg2
  def getVar1(self):
    return self.var1
```

- every class method needs the instance reference `self` as first argument
- class attributes are defined implicitly (as with all types)
- all constructors have the name `__init__`
- create instances: `myInstance = myClass(param1,param2)`
- calling a method: `result = myInstance.getVar1()`
- note that `self` is passed implicitly
- there is no destructor but an automatic garbage collection
- inheritance: `class mySubClass(myClass):`

Modules

- modules structure code (functions, classes) into larger units with separate namespaces
- module is a file with the name `module.py`
- can be used after `import` statement
  - `import module`
    - imports everything and keeps it in the module's namespace
      - *`module.func()`*
      - *`module.className.func()`*
  - `from module import *`
    - imports everything under the current namespace
      - *`func()`*
      - *`className.func()`*
    - (not recommended)
  - `from module import className`
    - selectively imports under the current namespace
      - *`className.func()`*
- standard modules: `math, os, sys`

Files

- open a file: `f = open("path/file","r")  # (r)ead, (w)rite, (a)ppend`
- read the entire file into a string: `fContent = f.read()`
- read a single line: `line = f.readline()`
- iterate linewise: `for line in f:`
- write: `f.write("bla")`
- close a file: `f.close()`
- manipulating files and directories via module `os`
  - list directory content: `l = os.listdir("/path")`
  - exists?: `os.path.exists("/path/file")`
  - is file?: `os.path.isfile("/path/file")`
- reading and writing python objects via module `pickle`
  - read: `object = pickle.load(file)`
  - write: `pickle.dump(object, file)`

Python Development Environment

Python Development Environment

1) Installation
   a) custom: Python core plus package managers plus Jupyter plus libraries
      - Python https://wiki.python.org/moin/BeginnersGuide/Download
      - Jupyter (Lab or Notebook) https://jupyter.org/install
   b) distribution: package with all of the above
      - e.g., Anaconda https://www.anaconda.com/
   c) Docker image
      - https://jupyter-docker-stacks.readthedocs.io/en/latest/using/selecting.html

2) Execution Environment
   a) single machine
      i. local/native: direct install on your machine
      ii. local (or cloud-based) virtual machine (VM): install on a guest OS
         - e.g., Linux VM (Ubuntu) via VirtualBox
      iii. local (or cloud-based) Docker container
   b) cluster
      i. Hadoop
      ii. Spark

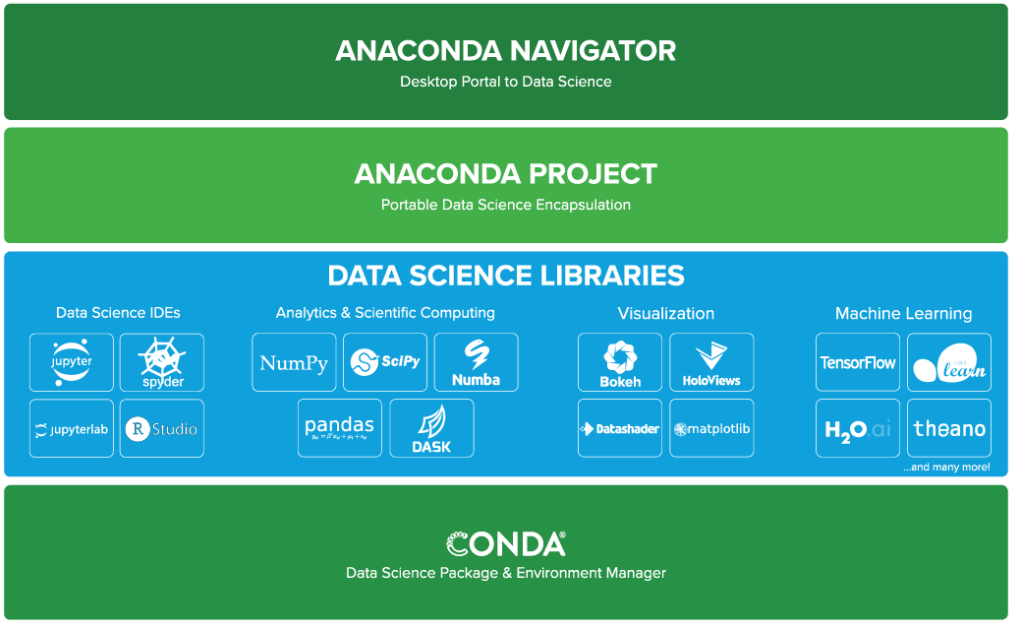
Hardware Requirements for Local Execution

- in most cases, a modern Laptop should be sufficient
  - hardware
    - CPU: 4+ cores recommended
    - RAM: 8GB+ recommended
    - GPU: for some use cases
    - Disk: SSD recommended
  - OS: Linux, Mac OS, or Windows
    - or VM
  - sufficient rights for installation required
- depending on data volume, complexity of feature engineering, and complexity of ML model, a more powerful machine is required (→ CAS Data Engineering)
  - private vs. cloud-based solution

Anaconda Distribution

Anaconda (https://www.anaconda.com/)

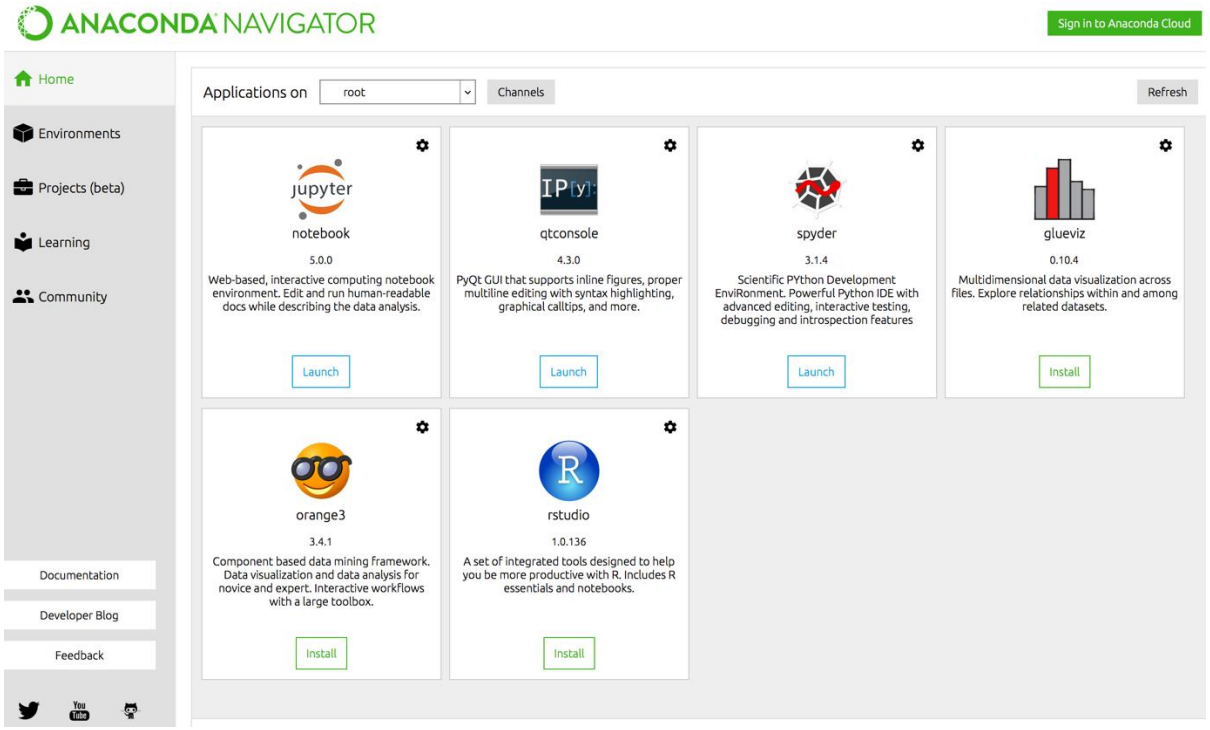
- offers a (free) Python distribution that includes the most important packages and tools for data science tasks
- company with a typical open source-based business model: additional tools, support, consulting, training and cloud hosting
- download free Python distribution via https://www.anaconda.com/download/



Anaconda Navigator

Anaconda Navigator (https://docs.anaconda.com/anaconda/navigator)

- manages Anaconda installation and included tools



pip

pip (https://pypi.org/project/pip/)

- package manager for Python packages (libraries)
- packages are retrieved from a repository
  - Python package index (https://pypi.org/)
- verify installation: `pip --version`
- list all installed packages: `pip list`
- install: `pip install [packagename]`
  - specific version: `pip install [packagename] == 2.1`
  - list of dependencies: `pip install -r [requirements.txt]`
- update: `pip install --upgrade [packagename]`
- see https://pip.pypa.io/en/stable/user_guide/

conda

conda (https://conda.io/docs/)

- package manager for Python (and other) packages (libraries)
- packages are retrieved from a repository
  - default and configurable repository
- supports multiple environments
  - specific set of packages with specific versions
  - configuration saved in `environment.yaml`
  - can be shared between machines / developers
  - stay in default environment `root` for now

  ```
  conda info --envs
  ```
- verify installation: `conda --version`
- list all installed packages: `conda list`
- install: `conda install [packagename]`
- update: `conda update [packagename]`

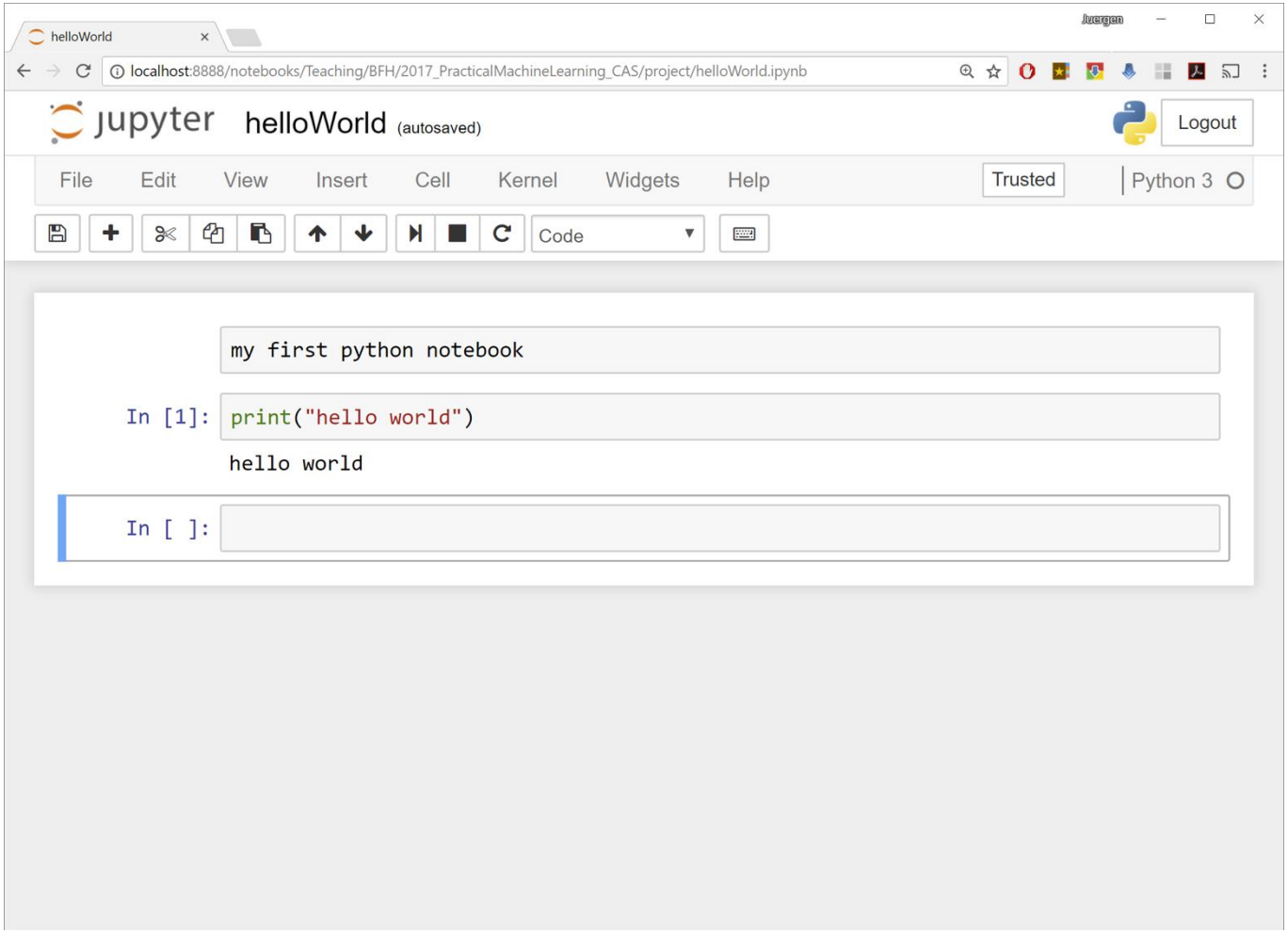
  ```
  conda update conda
  ```
- see https://conda.io/docs/user-guide/getting-started.html

Jupyter

Jupyter Notebook (https://jupyter.org/)

- notebook-style IDE: integrate code with text and interactive data visualizations, …
- Web application
  - start
    - Anaconda Navigator
    - command line: `jupyter notebook --port [port]`
    - set working directory for notebooks:
      `jupyter notebook --notebook-dir='[path]'`
  - runs on `http://localhost:[port]`
    - see running servers: `jupyter notebook list`
      - incl. authentication token
  - create new Notebook via Web UI
    - navigate to desired location and click `New` -> `Python3` notebook
    - file saved as `[name].ipynb`
    - notebook page should open automatically in browser

Jupyter Hello World



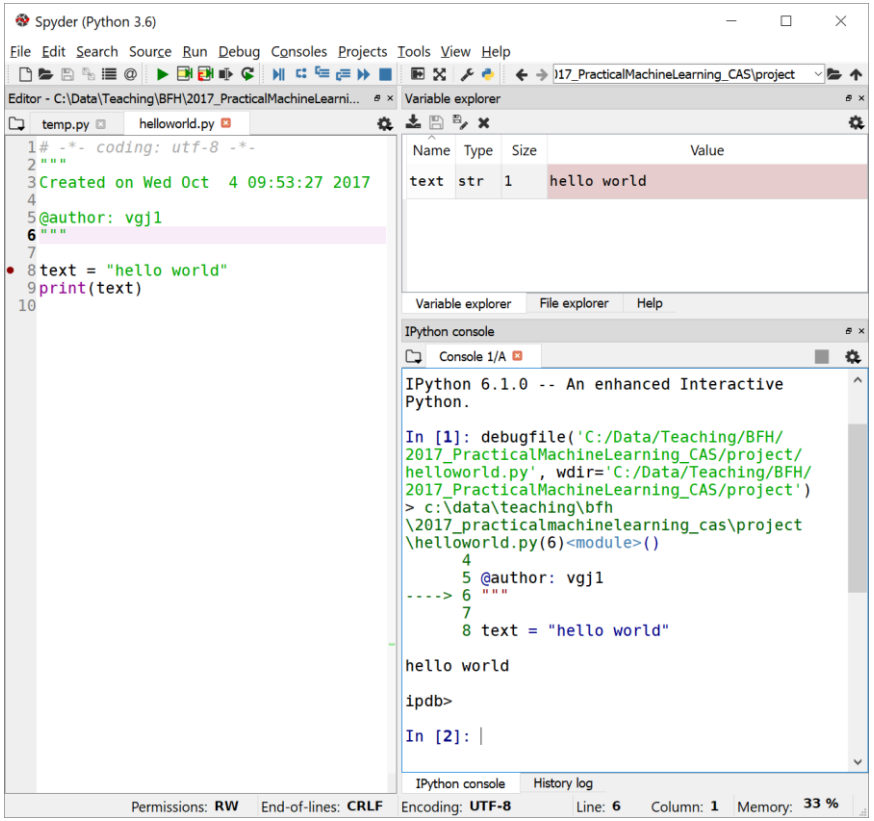
Jupyter

- stop notebook
  - in the notebook page: click `File` -> `Stop and Halt`
  - in the jupyter page: click `Running` and `Shutdown`
- stop server via killing the process
  - Linux
    - `netstat -tulpn` to retrieve pid
    - `kill [pid]`
  - Windows
    - `netstat -ano` to retrieve pid
    - `taskkill /PID [pid] /F`
- see https://jupyter.org/documentation.html

Spyder

Spyder (https://pythonhosted.org/spyder/)

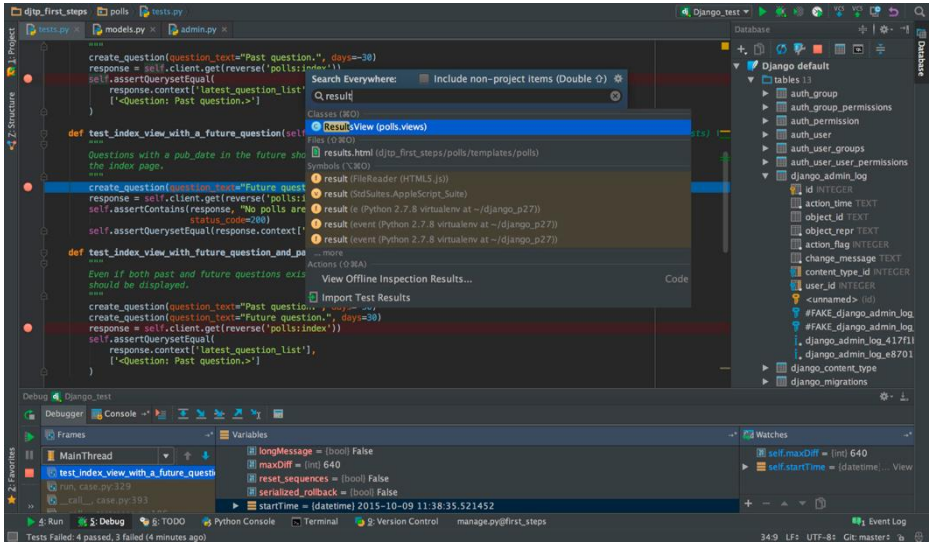
- classical IDE for python
  - editor with syntax highlighting and code completion
  - code analysis
    - Pylint (https://www.pylint.org/)
  - code execution and debugging
  - projects with version control
    - git (https://git-scm.com/)
- desktop application
  - start via Anaconda Navigator



PyCharm

PyCharm (https://www.jetbrains.com/pycharm/)

- traditional IDE for Python
  - code completion, highlighting, refactoring, and analysis
  - debugging
  - unit testing
  - version control
- by JetBrains
  - professional, educational, and open source licensing



Python Libraries for Machine Learning

Popular Python Libraries

- **NumPy**: vectors, matrices and linear algebra, …
- **SciPy**: linear algebra, integration, interpolation, …
- **Statsmodels**: statistical data analysis
- **pandas**: structured data and analysis
- **matplotlib**: visualize numerical data
- **scikit-learn**: machine learning
- **PyTorch**: deep learning
- **NLTK**: text analysis
- **Scrapy**: Web scraping
- **BeautifulSoup**: HTML and XML parsing
- …