Scientific Programming in Python

Inteligencia Artificial en los Sistemas de Control Autónomo
Máster Universitario en Ingeniería Industrial

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ISG

Objectives

1. Motivate the need of efficient matrix representations.
2. Introduce some Python scientific tools.
3. Handle data representations in Python.
4. Basic data visualization with Python.
5. Provide a background for scientific programming.

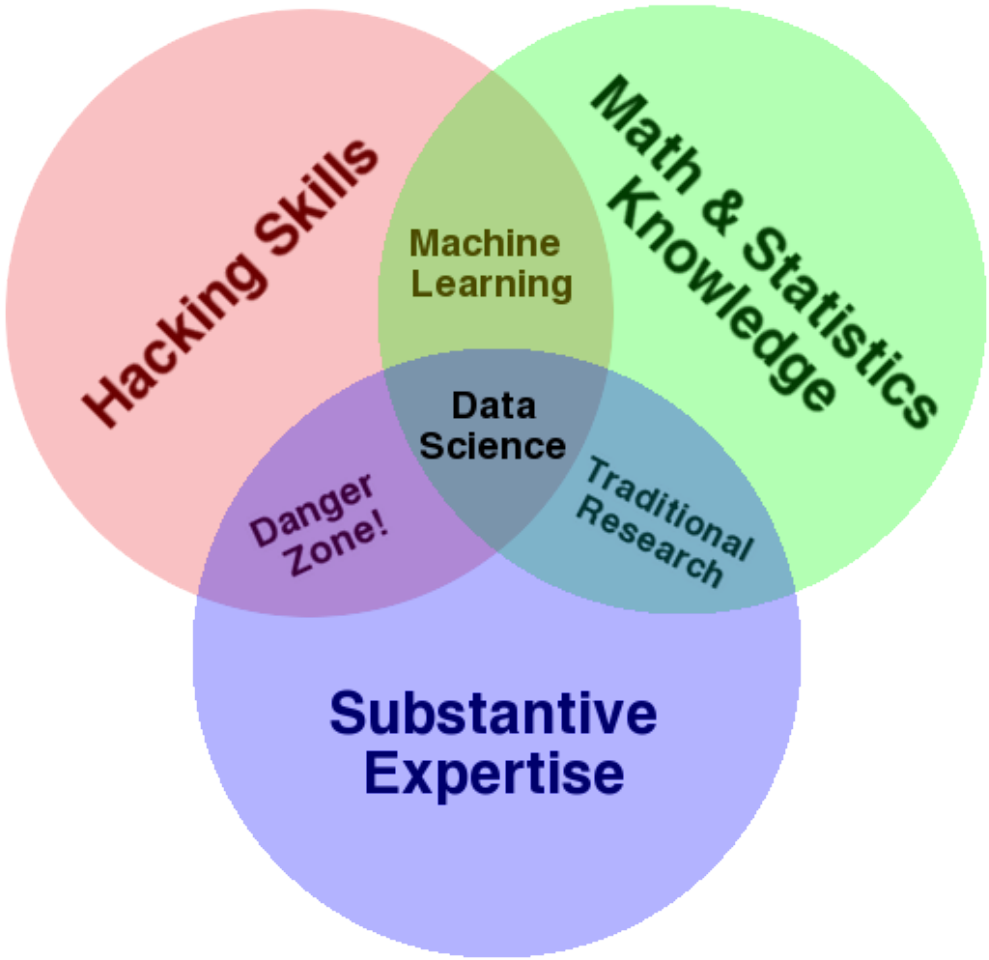
Bibliography

Jake VanderPlas. *Python Data Science Handbook*. Chapters 1, 2, 3 and 4. O'Reilly. (Link).

Table of Contents

Overview

Data Science



Data Science

The data scientist tookit (I)

Data science is about manipulating data

- Need of specialized tools
- Two main languajes: R and Python

Python is a general purpose programming language

- Easy integration
- Huge ecosystem of packages and tools

Need of data-oriented tools

- Features provided by third-party tools

Data Science

The data scientist tookit (II)

Tool	Type	Description
`iPython`	Software	Advaced Python interpreter
`Jupiter`	Software	Python notebooks (Python interpreter)
`Numpy`	Package	Efficient array operations
`Pandas`	Package	Dataframe support
`Matplotlib`	Package	Data visualization
`Seaborn`	Package	Data visualization with dataframes
`Scikit-learn`	Package	AI/ML package for Python

Data Science

Anaconda

All those tools are packaged in `Anaconda`

- Python distribution for Data Science

Anaconda provides `Spyder`

- Python IDE designed for Data Science

Other tools provided by Anaconda

- Conda: Packages management tool
- TensorFlow: Deep Learning
- Many others

Data Science

Python IDEs for Data Science (I)

iPython

iPython = Interactive Python

- Extended funcionality
- Enhanced UI
- External editor

Running iPython:

```
$ ipython
```

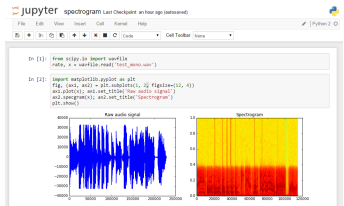
Jupyter

Python notebooks

- Web-based IDE
- Documentation
- Integration with GitHub
- Uses iPython

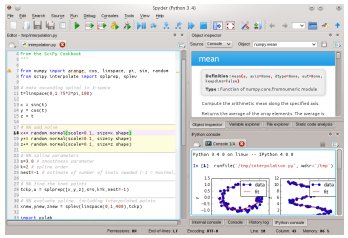
Running Jupyter:

```
$ jupyter notebook
```



Spyder

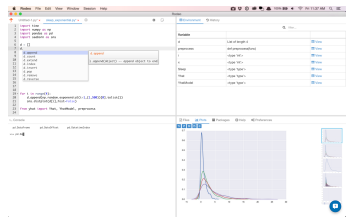
Matlab-like IDE



Rodeo

Python version of RStudio

- Good for R developers
- Uses iPython



Data Science

Python IDEs for Data Science (II)

Exercises

Write a Python script that shows the multiplication table of the number 5 with each one of the following environments:

1. iPython + text editor of your choice.
2. Jupiter. Bonus track: Publish the notebook in GitHub.
3. Spyder.
4. Rodeo.

The data scientist working environment

Imperative programming

Describes, by a set of instructions that change the program state, how the task should be implemented.

- **Procedural**: organizes the program using collections of subroutines related by means of invocations (C, Python).
  - Example: *The cooking process consists of 20 lines of code. When it is used, it only calls the function (1 line).*
- **Structural**: is based on nesting, loops, conditionals and subroutines. `GOTO` command is forbidden (C, Pascal).
  - Example: *reviewing products of a shopping list and add the item X to the shopping if it is available.*

Programming paradigms types (III)

Object-Oriented Programming

Evolves from imperative programming. It is based on objects that allow express the characteristics and behavior in a closer way to real life (Java, Python, C++).

- **Main characteristics**: abstraction, encapsulation, polymorphism, inheritance, modularity, etc.
- Example: *a car has a set of properties (color, fuel type, model) and a functionality (speed up, shift gears, braking).*

There are many other paradigms such as Event-Driven programming, Concurrent, Reactive, Generic, etc.

Programming paradigms types (IV)

Classification

Python supports the three major paradigms, although it stands out for the OOP and Imperative paradigms.

Object-Oriented Programming

Objectives

- **Reusability**: Ability of software elements to serve for the construction of many different applications.
- **Extensibility**: Ease of adapting software products to specification changes.
- **Maintainability**: Amount of effort necessary for a product to maintain its normal functionality.
- **Usability**: Ease of using the tool.
- **Robustness**: Ability of software systems to react appropriately to exceptional conditions.
- **Correction**: Ability of software products to perform their tasks accurately, as defined in their specifications.

Object-Oriented Programming

Concepts (II)

Atribute

Individual characteristics that determine the qualities of an object.

Object-Oriented Programming

Concepts (III)

Method

Function responsible for performing operations according to input parameters.

Object-Oriented Programming

Concepts (IV)

Object or instance

Specific representation of a class, namely, a class member with their corresponding attributes.

Object-Oriented Programming

Concepts(V)

Constructor

Method called when an object is created. It allows the initialization of attributes.

Object-Oriented Programming

Synthesizing OOP terminology

- Software objects mimics physical objects.
  - An object contains *attributes* (state) and a *behaviour*.
  - Example: A dog has a name (state) and may be a bit (behaviour).
- A class is a set of objects with common characteristics and behaviour.
- An object is called an Instance of a class.
- Members of a class:
  - Properties: Data describing an object.
  - Methods: What an object can do.

Source: http://www.teachitza.com/delphi/oop.htm

Characteristics

Inheritance

Concept

Mechanism of reusing code in OOP. Consists of generating child classes from other existing (super-class) allowing the use and adaptation of the attributes and methods of the parent class to the child class.

- *Superclass*: ``Father'' of a class.
- *Subclass*: ``Child'' of a class.
- A subclass inherits all the fields and methods from its superclass.
  - *Fields*: Variable that is part of an object.
- A subclass has one superclass.
- A superclass has at least one subclass.
- *Class hierarchy*: A set of classes related by inheritance.

Characteristics

Inheritance (II)

Types of inheritance

- If the child class inherits from a single class is called single inheritance.
- if it inherits from more classes is multiple inheritance.

Python allows both; simple and multiple inheritance.

Characteristics

Examples of simple inheritance (I)

Source: http://docs.oracle.com/javase/tutorial/java/concepts/object.html
Source: http://docs.oracle.com/javase/tutorial/java/concepts/inheritance.html

Characteristics

Examples of simple inheritance (II)

Figura 1: Example of simple Inheritance in OOP. Obtained from: `http://android.scenebeta.com`

Characteristics

Multiple Inheritance

Figura 2: Example of multiple Inheritance in OOP. Obtained from: `http://www.avizora.com`

Characteristics

Polymorphism (I)

Polymorphism

Mechanism of object-oriented programming that allows to invoke a method whose implementation will depend on the object that does it.

Figura 3: Example of polymorphism. Obtained from: `http://virtual.uaeh.edu.mx`

Characteristics

Polymorphism (II)

Figura 4: Example of polymorphism. Obtained from: `http://datateca.unad.edu.co`

Characteristics

Abstraction and encapsulation (I)

Abstraction

Mechanism that allows the isolation of the not relevant information to a level of knowledge.

- A driver does not need to know how the carburetor works.
- To talk on the phone does not need to know how the voice is transferred.
- To use a computer do not need to know the internal composition of their materials.

Characteristics

Abstraction and encapsulation (II)

Encapsulation

Mechanism use to provide an access level to methods and attributes for avoiding unexpected state changes. This mechanism is used to limit the visibility of the attributes and to create methods controlling them (`set()` y `get()`).

The most common access levels are:

- **public**: visible for everyone [default level in Python].
- **private**: visible for the creator class [start with a double underscore and does not end in the same manner].
- **protected**: visible for the creator class and its descendents [not exist in Python].

Characteristics

Abstraction and encapsulation (III). Example 1

Figura 5: Example of abstraction and encapsulation.Obtained from: `https://binalparekh.wordpress.com`

Characteristics(III)

Abstraction and encapsulation (IV). Example 2

Figura 6: Example of abstraction and encapsulation. Obtained from: `http://www.onlinebuff.com`

Classes in Python

Syntax (I)

- **Class**: Start with the word class followed by class name written in capital letter and a colon [Substantives].
- **Attributes**: A lowercase noun.
  - There is no need to declare attributes.
- **Inherited class**: Similar to a class but the class name followed by the class father in brackets.
- **Instance**: Object in lower case followed by the class assignment.

coche.py

Classes in Python

Syntax (II)

- **Method**: Start with the word def, and later the method, a verb, in lower case is written. Next, the parameter in brackets and a colon (`print_name()`).
  - Methods receive automatically a reference to the object (usually named `self`).
- **Constructor**: Method whose name is `__init__()`, the first attribute is `self` and then the class attributes are written.
- **main**: Method defined with `def main():`. In it, the wished commands are specified and after it, an exit condition is created. The `sys` module is required to be imported at the beginning.
- All methods and attributes are public.
  - By convention, private members begin with double underscore (`__varName`, `__method_name()`)

Classes in Python

Syntax (III). Example 1

main.py

Classes in Python

Syntax (IV). Example 2

bicicleta.py

Classes in Python

Syntax (V). Example 3

Time.py

Classes in Python

Class objects

Two operations on classes

Attribute references

Accesses an attribute value
Standard dot syntax

```
obj.name
```

Example

```
time.hour = 4
print(time.hour)
hour = time.hour
```

Instantiation

Creates a new object
Standard functional notation

```
x = MyClass()
```

Example

```
time = Time()
```

Constructors (I)

Instantiation creates empty objects

- We usually need to initialize attributes
- Initialization operations

Constructor: Method called when an object is created

- In Python, it is the `__init__()`
- A constructor can get arguments

Constructors (II)

Time.py with constructor

Other special methods

In addition to special method `__init__`, there are several others, including:

- `__str__(self)` It should return a string with `self` information. When `print()` is invoked with the object, if the method `__str__()` is defined, Python shows the result of running this method on the object.
- `__len__(self)` It should return the length or ``size" of object (number of elements if is a *set* or *queue*).
- `__add__(self, otro_obj)` It allows to apply the addition operator (+) to objects of the class in which it is defined.
- `__mul__(self, otro_obj)` It allows to apply the multiplication operator (*) to objects of the class in which it is defined.
- `__comp__(self, otro_obj)` It allows to apply the comparison operators (<, >, <=, >=, ==, !=) to objects of the class in which it is defined. It should return 0 if they are equal, -1 if `self` is smaller than `other_obj` and 1 if `self` is greater than `other_obj`.

Overriding methods (I)

Often we need to adapt an inheritanced method: Overriding

Overriding example

Overriding methods (II)

Still possible to get superclass' method with `super()`

`super()` example

Exercise statement

`Animal` class

1. Create the `animal` class.
2. Create the constructor. The class will have the attributes `tipo` and `patas`.
3. Create the get methods from both attributes which receive like own parameter the animal through `self` and return respectively the `tipo` and `patas`.
4. Create two instances of animals using the constructor.
5. Print the attributes of both instances.

Solved exercise

`Animal` class

animales.py

Solved exercise

`Animal` class

1. Create a `gato` class in the same file which inherits from the `animal` class.
2. Create the constructor and add the `sonido` attribute.
3. Create the method `maullar` which prints the sound MIAU.
4. Create a instance and check the methods.

Solved exercise

Class `Animals`

animales.py

Exercise statement

Class `Parcela`

1. Create a script containing the class `Parcela`.
2. Create the constructor. The class will have the attributes `uso_suelo` and `valor`.
3. Create the `valoracion` method to calculate the tax associated with the parcel as follows:
   - For single-family residential: *tasa* = 0.05 * *valor*
   - For multifamily residential: *tasa* = 0.04 * *valor*
   - For all other land uses: *tasa* = 0.02 * *valor*
4. Use the class from another *script* named `tasaparcela.py` which you create una instance of `Parcela` named `miparcela` using the constructor.
5. Print the attribute `uso_suelo` of the instance.
6. Use the method `valoracion` of `Parcel` to calculate the assessment of `miparcela`.

Solved exercise

Class `Parcela`

claseparcela.py

Solved exercise

Use of `Parcela`

tasaparcela.py

Source

Solved exercise. Serializando objetos `Parcela`

tasaparcela_pickle.py

Exercise statement

`Rio` class

1. Create the `Rio` class.
2. Create the constructor and add the `nombre` and `longitud` attributes.
3. `Longitud` attribute must be private.
4. Create the `setLongitud` method which receives self and `longitudR` and allows the set of any value for `longitud`.
5. Create the `getNombre` method which obtains the name of the river.
6. Create the `getLongitud` method which obtains the river length.
7. Create an instance and check the methods.
8. Try to do an assignment of `rio.nombre` and other assignment with `rio.longitud` What happen? It is correct to invoke the method named `rio.getLongitud()` out of the classes? How do you explain that?

Exercise statement

Establishment of hierarchies from `Rio` class

1. Add to the `Rio` class the attribute `caudal` and the method `trasvasar` which receives two rivers and transfers 5 liters from the first to the second.
2. Create the `Afluente` class which inherits from `Rio`.
3. Create the method `__init__` of `Afluente` which initializes its `nombre` and `longitud` and, also, `afluenteDeRio`, new attribute initialized with the name of the river which the affluent starts.
4. Is there any polymorphism in this sample?
5. Create the main and exit condition and try it. Does the main position affect to the application?
6. Experiment now with conditions and iterative structures limiting when a river can transfer water or try to do some transfer at the same time.

Y más...

Aprende más: [4]

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