TECHNISCHE UNIVERSITÄT DRESDEN

Faculty of Electrical and Computer Engineering Institute of Control Theory

PYTHON FOR ENGINEERS
PYTHONKURS FÜR INGENIEUR:INNEN
Object-Oriented Programming in Python
Objektorientierte Programmierung in Python

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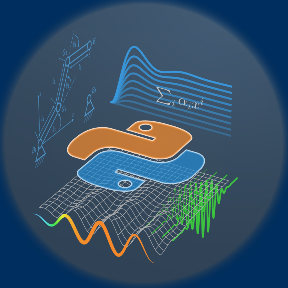
`https://tu-dresden.de/pythonkurs`
`https://python-fuer-ingenieure.de`

Dresden, 2022-11-11



Programming Paradigms (Overview)

- desired: reusability of already implemented functionality
- copy & paste?
    - frequent source of errors (forgetting some necessary changes)
    - later changes in many places required → effort

→ problem can be addressed with different **paradigms**

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- What is a programming paradigm?
  - set of rules for formal and structural code design
  - so far: procedural programming
  - here: object-oriented programming
  - also existing: functional programming (Lisp ♡ recursive functions calls)
- What is it used for?
  - support for creation of **good** code
  - suggest/prioritize a certain approach
- No dogma!
  - paradigm application depending on concrete problem (u. taste)
  - unlike e.g. Java, Python does not enforce a certain paradigm
  - combinations possible

Object-Oriented Programming (OOP)

- description of a complex system as an interaction of **objects**
- objects consist of
  - data (“**attributes**”)
  - associated functions (“**methods**”)
- objects are **instances** of a **class**

  i.e. an object is the concrete variable, the class is the data type

object-orientation is a large field

- enough details for a whole semester
- here: only clarify most important terms and principles

Simple Example

Suppose, you own a personal soccer ball

- The ball has the properties (attributes)
    - radius
    - material
    - color
    - ...
    - (nouns)

- The ball provides certain actions (methods)
    - throw ball (in direction (x, y, z)
    - roll ball (in direction x, y)
    - ...
    - (verbs)

Object Orientation in Python

Your personal soccer ball is a particular sphere

Listing: example-code/ex01_sphere.py

```python
class Sphere():
    """A class modeling a spherical objects"""

    def __init__(self, radius, midpoint=(0, 0, 0)):
        """
        Initialization method. Automatically executed when an object is created.
        Corresponds (approximately) to the 'constructor' in other programming
        languages.
        """

        # set attributes:
        self.radius = radius
        self.midpoint = midpoint

    def calc_volume(self):
        r = self.radius
        return (4/3)*np.pi*(r**3)
```

Instantiation

Other balls are spheres, too:

```
# Definition of the class
class Sphere():
    def __init__(self, radius, midpoint=(0,0,0)):
        ...
# instantiation of the class (create variables of that type)
# (arguments are passed to the `__init__` method)
soccer_ball = Sphere(radius=21)
tennis_ball = Sphere(3)
rubber_ball = Sphere(1)

print("radius of soccer:", soccer_ball.radius) # access to attribute
V = tennis_ball.calc_volume() # access to method
```

- class `Sphere` only is the “construction plan” or “blueprint”
- instantiation: creation of **concrete objects** according to the blueprint
- each object gets its own memory section

→ attribute values are independent of each other
(each `sphere` instance has its own radius, center, ...)

- each object has unique memory address (readable with `id(..)`)

Inheritance (in General)

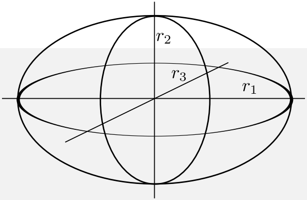
- creation of a new class based on an existing one
- only limited analogy to biological inheritance
- typical case: inheritance from the abstract to the specific
- representation: `base class` ← `child class` ("←" $\hat{=}$ "inherits from")
- example: `animal` ← `mamal` ← `dog`
- child class has all attributes/methods of base class
  - value/implementation can be overridden
- additional attributes/methods possible in child class

What is inheritance good for?

- sharing structure and code (attributes and methods)
  → reduces implementation effort
- documentation of similarities between classes

Inheritance (in Python)

The sphere is a special kind of ellipsoid



```
class Ellipsoid():
    def __init__(self, r1, r2, r3):
      ...

class Sphere(Ellipsoid):
    def __init__(self, radius):

        # In the constructor of child class we call the
        # constructor of the parent class:

        # Sphere is a Ellipsoid where all radii are equal
        Ellipsoid.__init__(self, radius, radius, radius)
```

- class `Sphere` here is derived from class `Ellipsoid`
- attributes and methods are inherited (if not specified explicitly in the child class)
- constructor `__init__` is overridden so that it accepts only one radius

Inheritance Hierarchy

```
class GeometricObject:  # (topmost) base class
    ...
class Cuboid(GeometricObject):  # level 1 subclass
    ...
class Ellipsoid(GeometricObject):  # level 1 subclass
    ...
class Sphere(Ellipsoid):  # level 2 subclass
    ...
soccer_ball = Sphere(21)  # instance
```

- base class `GeometricObject` implicitly is derived from `object` (builtin type)
- illustration with the help functions `isinstance(...)` und `issubclass(...)`

```
isinstance(soccer_ball, Sphere) # True
isinstance(soccer_ball, GeometricObject) # True
isinstance(soccer_ball, Cuboid) # False
issubclass(Sphere, Ellipsoid) # True
issubclass(Sphere, Cuboid) # False
```

Python-Speciality (1): `self`

- a **method** is a function belonging to an object
- when executed, it must be known to which **instance** this method belong

→ passing the instance as **implicit** first argument.

- Usually named (convention): `self`
- in other words:
  `self` is placeholder for the concrete instance at a time when it does not exist yet

Listing: exampl-code/ex02_self.py

```python
# Note: the id(...) function returns a unique identity-number for each object.
# Same number means: same object.

class ClassA():
  def m1(self):
      print(id(self))

  def m2(x):  # !! self argument missing
      print(x)

a = ClassA()  # create an instance

a.m1()  # no explicit argument (but implicitly a is passed)
print(id(a))  # this gives the same number

a.m2()  # no error (corresponds to print(id(a)), because x takes the role of self)
a.m2(123)  # Error: too many arguments passed (a (implicitly) and 123 (explicitly))
```

Speciality (2): everything is an object

- no “primitive data types” (as in Java or C++)
- everything* is an object (i. e. an instance of a class):
  - numbers (instances of `int`, `float`, `complex`, …)
  - strings (instances of `str`, `bytes`, …)
  - functions and classes:

```
class ClassA():
    pass

def function1():
    pass

type(ClassA) # -> classobj
type(function1) # -> function
```

- keywords, operators and other syntax elements are not objects!

```
type(while)  # SyntaxError
type(def)  # SyntaxError
type(class)  # SyntaxError
type(+)  # SyntaxError
```

Summary

presented terms

- class
- instance (= object)
- attribute
- method
- constructor
- base class
- inheritance

presented Python constructs

- `class`, `isinstance(...)`, `issubclass(...)`, `self`, `id(...)`, `type(...)`

other OOP related topics:

- multiple inheritance
- static methods
- operator overloading and "magic methods"
- ducktyping
- polymorphism
- encapsulation
- meta class programming
- difference between `__init__` and `__new__`
- class methods
- class variables
- data classes

OOP-Related Links

- official Python doc on classes, instances, `self` etc.
- demystifying `self`
- introductory blog post