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Scientific Programming with Python

OOP in Python Exercises

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Exercise 1: Ducks [basic]

Look again at the slides on the strategy pattern and use the code examples to define the following duck-classes¹:

- NormalDuck (use as base class)
- RedheadedDuck
- BlackDuck
- RubberDuck
- DecoyDuck

Once you defined these classes:

- (a) Write a script in which you create the following duck-instances: 3 normal, 3 red-headed, 1 black, 1 rubber and 1 decoy duck. Store all ducks in a list and then call `display` for each of the ducks.
- (b) In your script, let one of the normal ducks „break its wings”. (Replace the `flying_behaviour` of the unlucky duck-object.) Compare what happens when you call the flying-functions of the unlucky duck and one of the other normal ducks.
- (c) Change your duck classes such that you can give your individual ducks a name. Use that name when displaying the duck.
- (d) [*intermediate*] Change your duck classes such that they store their position (as a string). Let `fly_to` change the position and display the present position on take off and landing.
- (e) Add more functionality, be creative.

¹You are of course free to use real duck breeds (see https://en.wikipedia.org/wiki/List_of_duck_breeds) if you prefer.

Exercise 2: Vectors [basic]

The file `vector.py` contains an implementation of an n-dimensional vector. Some of the functions are not yet complete:

- (a) Implement the addition of two vectors via the magic function `__add__`. Make sure that the dimensions of the two vectors are aligned.
- (b) Do the same for the scalar product with the function `__mul__`.
- (c) Implement `__str__` which is the magic function to represent the vector as string (*i.e.* `str(v)`). Define a reasonable string representation.
- (d) Create the property `length` that
 - returns the Euclidean length of the vector
 - allows to scale the vector to a new length by `v.length = <new_length>`
 - sets the vector to zero via `del v.length`.
- (e) Create a subclass for three-dimensional vectors `Vector3D` with a suitable constructor and implement the magic function `__matmul__` (the operator `@`) as cross-product². Important: The implementation should NOT lead to any change in the parent class.

Exercise 3: Scatter plot [basic]

Take pen and paper and design a class representing scatter plots that can be drawn.

- What variables does a scatter plot have?
- What methods does it have?
- How do the signatures of these methods look like?

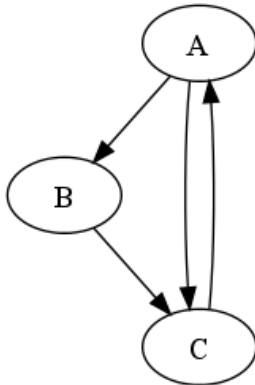
Exercise 4: Understanding OOP [basic]

The `graph` module (provided in the archive) contains a set of classes for representing graphs (*i.e.* nodes and edges connecting them). On a piece of paper reverse engineer its design:

- (a) Write down all class names, their methods and data attributes; try to understand what all of them do (read the documentation!).
- (b) Figure out how different classes are related. Where is inheritance used, where composition? Draw a simple diagram.

²The cross-product is defined as $v = v_1 \times v_2 = \begin{pmatrix} x_1 \\ y_1 \\ z_1 \end{pmatrix} \times \begin{pmatrix} x_2 \\ y_2 \\ z_2 \end{pmatrix} = \begin{pmatrix} y_1 z_2 - y_2 z_1 \\ z_1 x_2 - z_2 x_1 \\ x_1 y_2 - x_2 y_1 \end{pmatrix}$

(c) Use the classes to construct the following graph:



Exercise 5: Decorator Pattern [intermediate]

Look at the code in `starbuzz.py` and estimate the changes needed to add two more ingredients Cream and Sprinkles. Then adapt the code to use the Decorator Pattern.

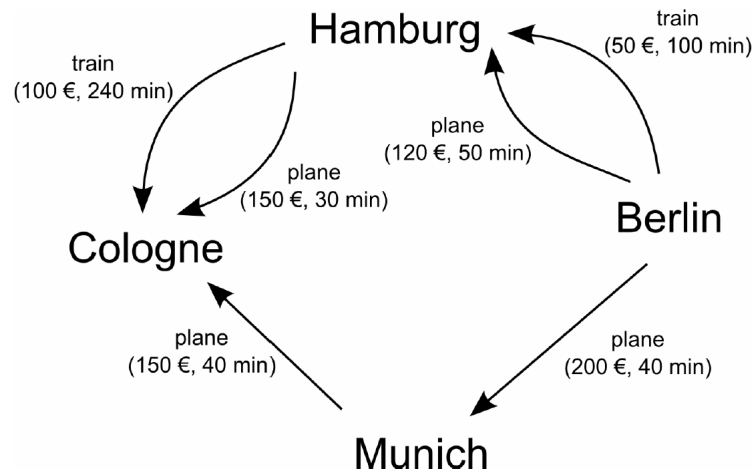
- Remove all the ingredients-code from `Beverage`.
- Use the `Ingredient` class given in the slides to define Milk and Sugar ingredients.
- Improve and simplify your code further. For Example by moving as much as possible of the functionality from the subclasses into `Ingredient` (instead of repeating it).
- Define two more ingredients Cream and Sprinkles.
- Use the ingredients to produce new drinks combinations.

Exercise 6: Extending Classes [advanced]

Extend the `graph` library to solve a search problem. In this exercise, your goal is to write a travel planning application based on the `graph` module. We want to represent a set of cities as nodes in a graph, with edges between nodes representing different kinds of transportation.

- Define a class `CityNode` which extends the `Node` class by a new property `name` which is defined on class instantiation.
- Define a class `TransportationEdge` extending the `Edge` class. The edges should be directed and have two kinds of weights: travel `time` and `cost`. Furthermore, they should have a short `description` defining the means of transportation.

- (c) Implement the following city graph as an example:



- (d) Now we want to find the quickest path from Berlin to Cologne. Open the `shortest_path.py` file. It contains a `SearchAlgorithm` class, which implements the Dijkstra algorithm for finding the shortest path in a graph.
- (e) Define a new class `SearchGraph` extending the `Graph` class with methods for searching the shortest path. Which design pattern(s) can you use in the example?
- (f) Define new search algorithms to find the cheapest and fastest paths.
- (g) Find the cheapest and fastest paths between Berlin and Cologne.

This exercise sheet is based on the exercises written by Bartosz Telenczuk, Niko Wilbert for the *Advanced Scientific Programming in Python School 2011*