UNIVERSITÄT BIELEFELD
Faculty of Technology

Programming

Advanced Programming

Daniel Dörr

Faculty of Technology, Bielefeld University

Recap

Databases Overview

SQL databases

- … are relational databases
- developed in the 1970s
- general

noSQL databases

… are more purpose-specific:

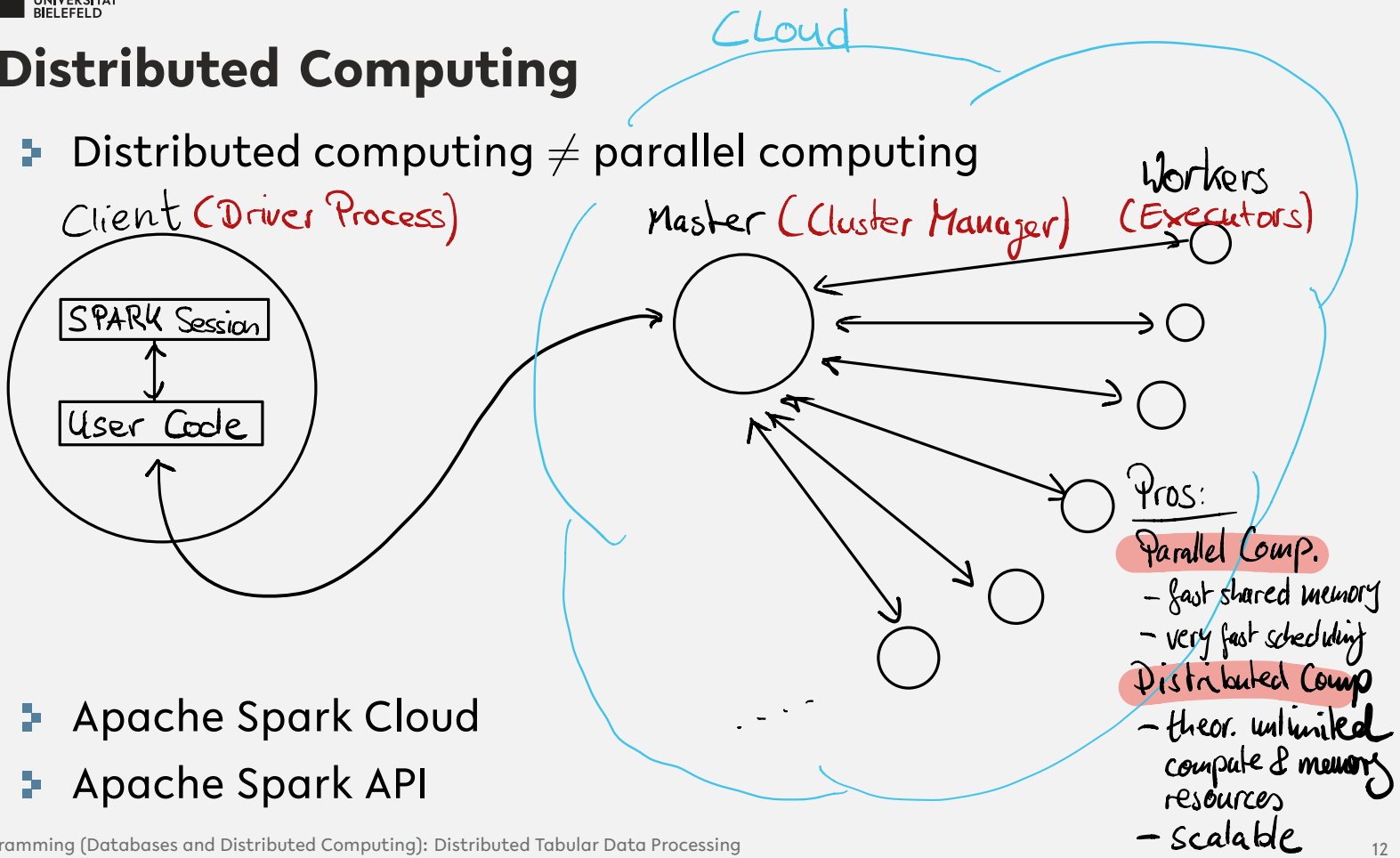
- Key-value
- Graph
- Document-oriented
- Object-oriented

MongoDB

- Document-oriented database
- Each DB entry corresponds to a JSON document
- Popular in web-based applications
- “Community” edition is open-source

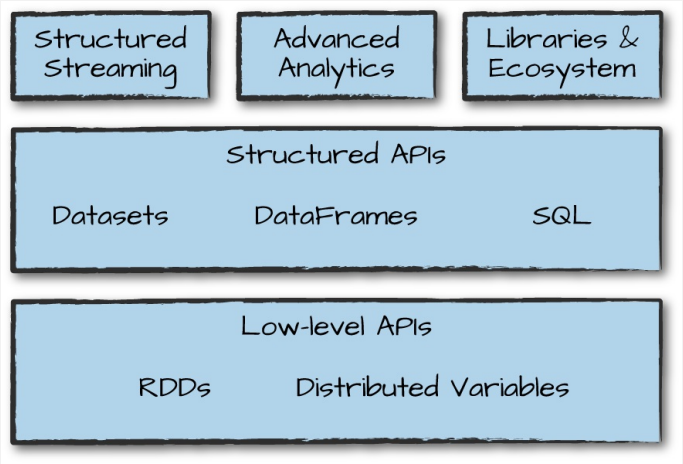
Distributed Computing

- Distributed computing ≠ parallel computing



- Apache Spark Cloud
- Apache Spark API

Apache Spark API



source: Bill Chambers, Matei Zaharia, Spark: The Definitive Guide. O'Reilly Media (2018)

API available in

- Scala
- Python
- R
- SQL

Functional Programming

Lazy Evaluation

Object-oriented Programming

Functional Programming

Recursion

A resursive function is a function that calls itself. This example is from Lecture 03.

In [1]:
```
def fun(x):
    if len(x) > 1:
        return fun(x[1:])
    return x

fun([1, 2, 3, 4])
```

Out[1]:
```
[4]
```

Functions as objects

In Python everything is an object, including functions:

In [2]:
```
def makeList(a, b):
    return [a, b]

myVariable = makeList
```

We can now call the variable that points to the function:

In [3]:
```
myVariable(1, 2)
```

Out[3]:
```
[1, 2]
```

This also allows us to pass functions on to other functions:

In [4]:
```
def applyFunction(fun, a, b):
    return fun(a, b)

applyFunction(makeList, 1, 2)
```

Out[4]:
```
[1, 2]
```

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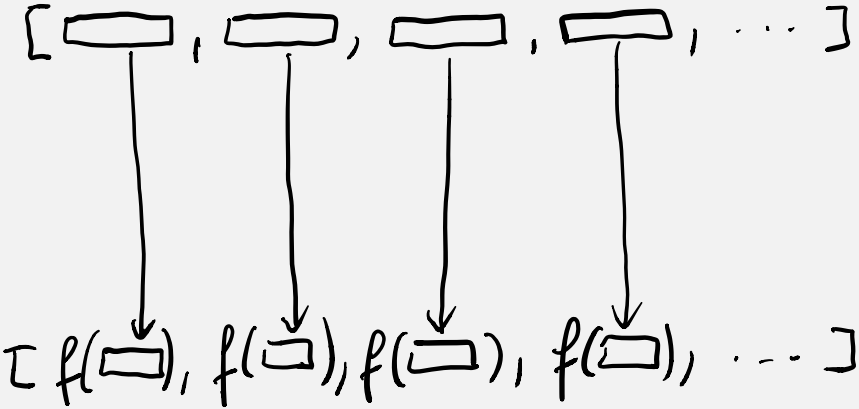
Map

map(f, collection)



returns

<footer>Programming (Advanced Programming): Functional Programming 7</footer>

Mapping

Mapping is a very powerful concept:

In [5]:
```
def myMapper(f, collection):
    res = list()
    for el in collection:
        res.append(f(el))
    return res

myMapper(str, [1, 2, 3, 4, 5])
```

Out[5]:
```
['1', '2', '3', '4', '5']
```

A `map` function is already implemented in Python:

In [6]:
```
map(str, range(1, 6))
```

Out[6]:
```
<map at 0x10620d210>
```

In [7]:
```
list(map(str, range(1, 6)))
```

Out[7]:
```
['1', '2', '3', '4', '5']
```

An example how `map` can be used in practice:

In [8]:
```
import numpy as np

ary = np.random.random(3)
ary
```

Out[8]:
```
array([0.92042043, 0.02694656, 0.8786    ])
```

In [9]:
```
list(map(str, ary))
```

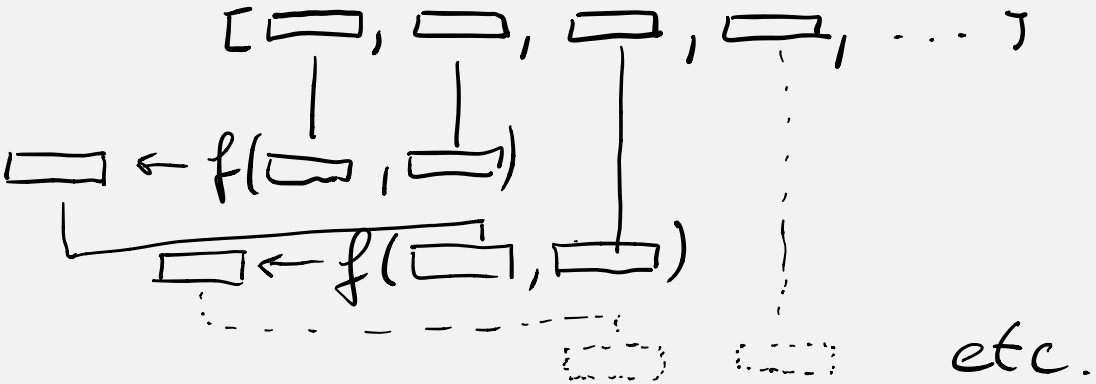
Out[9]:
```
['0.9204204259735078', '0.026946558375632645', '0.8786000025464282']
```

Reduce

reduce(f, collection)

↑ f(x, y)

Iterative reduction of collection through f



Outcome of the last application of f will be returned

Reducing

Another very powerful concept:

In [10]:
```
from functools import reduce

def addition(a, b):
    return a + b

reduce(addition, range(10))
```

Out[10]:
```
45
```

Lambda functions

Lambda functions is just a very convenient way of defining a function in a single line:

In [11]:
```
myFunction = lambda x: f'this value is {x}'

list(map(myFunction, range(3)))
```

Out[11]:
```
['this value is 0', 'this value is 1', 'this value is 2']
```

Here are practical examples, where lambda functions are useful:

In [12]:
```
ary = np.random.random(7)
ary
```

Out[12]:
```
array([0.24786278, 0.13696996, 0.78356076, 0.84696087, 0.7122092 ,
       0.08724698, 0.38522756])
```

In [13]:
```
list(map(lambda x: f'{x:.2f}', ary))
```

Out[13]:
```
['0.25', '0.14', '0.78', '0.85', '0.71', '0.09', '0.39']
```

In [14]:
```
reduce(lambda x, y: x + y, range(10))
```

Out[14]:
```
45
```

Lambda functions can contain conditional statements:

In [15]:
```
myFun = lambda x: x > 10 and 'larger 10' or 'smaller 10'

list(map(myFun, range(8, 13)))
```

Out[15]:
```
['smaller 10', 'smaller 10', 'smaller 10', 'larger 10', 'larger 10']
```

In [16]:
```
list(filter(lambda x: x > 10, range(8, 13)))
```

Out[16]:
```
[11, 12]
```

In [17]:
```
lst = [(4, 'a'), (1, 'a'), ('3', 'c'), (1, 'b'), (2, 'd'), (3, 'e')]

sorted(lst, key = lambda x: x[1])
```

Out[17]:
```
[(4, 'a'), (1, 'a'), (1, 'b'), ('3', 'c'), (2, 'd'), (3, 'e')]
```

List comprehension

In [18]:
```
[x for x in range(10)]
```

Out[18]:
```
[0, 1, 2, 3, 4, 5, 6, 7, 8, 9]
```

List comprehension with conditional (filter) statement:

In [19]:
```
my_list = [1, 'c', 1.0, 'hello world', 'a', 2, 4, 'b', 3.9]

[x for x in my_list if type(x) == str]
```

Out[19]:
```
['c', 'hello world', 'a', 'b']
```

List comprehension where control variable is further modified prior to output:

In [20]:
```
[[x]  for x in my_list if type(x) == str]
```

Out[20]:
```
[['c'], ['hello world'], ['a'], ['b']]
```

Quiz

- *True* or *false?*
  - The `map` functions applies a function to each element of a collection
  - The `filter` function discards all elements which satisfy a given condition
  - The `reduce` function reduces a collection by summing up its elements
  - List comprehensions enable easy list constructions in one line of code
- What is the result of the follwoing expressions?
  - `list(map(lambda x: x*x-x, range(5)))`
  - `list(filter(lambda x: x%2 == 1, range(10)))`
  - `reduce(lambda x,y: x-y, range(5,0,-1))`
  - `[x-1 for x in range(10)if x%2 == 1]`

Quiz

- *True* or *false?*
  - The `map` functions applies a function to each element of a collection — true
  - The `filter` function discards all elements which satisfy a given condition — false
  - The `reduce` function reduces a collection by summing up its elements — false
  - List comprehensions enable easy list constructions in one line of code — true
- What is the result of the follwoing expressions?
  - `list(map(lambda x: x*x-x, range(5)))` — `[0, 0, 2, 6, 12]`
  - `list(filter(lambda x: x%2 == 1, range(10)))` — `[1, 3, 5, 7, 9]`
  - `reduce(lambda x,y: x-y, range(5,0,-1))` — `-5`
  - `[x-1 for x in range(10)if x%2 == 1]` — `[0, 2, 4, 6, 8]`

Functional Programming

Lazy Evaluation

Object-oriented Programming

Lazy Evaluation

Lazy evaluation means that code statements are not executed until their results are really needed.

List comprehensions are turned into generators by using the round brackets.

In [21]:
```
([x]  for x in my_list if type(x) == str)
```

Out[21]:
```
<generator object <genexpr> at 0x10a1a2a50>
```

Using the `next()` function, the currently iterated element of a generator can be retrieved.

In [22]:
```
my_gen = ([x]  for x in my_list if type(x) == str)

next(my_gen)
```

Out[22]:
```
['c']
```

In each call of `next()`, a generator advances its pointer to the current element and returns it, unless the last element has been already reached. In that case, a `StopIteration` exception is thrown.

In [23]:
```
print(next(my_gen))
print(next(my_gen))
print(next(my_gen))
```

```
['hello world']
['a']
['b']
```

In [24]:
```
my_gen = ([x]  for x in my_list if type(x) == str)

try:
    while True:
        print(next(my_gen))
except StopIteration:
    pass
```

```
['c']
['hello world']
['a']
['b']
```

Python uses lazy evaluation wherever possible:

In [25]:
```
rng = range(1, 6)
print(rng)

map_generator = map(str, rng)
print(map_generator)
```

```
range(1, 6)
<map object at 0x10a1a4c10>
```

In [26]:
```
from itertools import repeat

map(str, repeat(1))
```

Out[26]:
```
<map at 0x107efc550>
```

You can create own generator using the `yield` command to return intermediate results in a function.

In [27]:
```
def myMapper(fun, collection):
    for el in collection:
        yield fun(el)
    return res

my_gen = myMapper(str, repeat(1))
my_gen
```

Out[27]:
```
<generator object myMapper at 0x10625c450>
```

To demonstrate the power of lazy evaluation, a mapping has been applied to an infinite sequence (`repeat(1)`). You can obtain the first `x` elements of a sequence using another generator function called `islice` :

In [28]:
```
from itertools import islice

list(islice(my_gen, 10))
```

Out[28]:
```
['1', '1', '1', '1', '1', '1', '1', '1', '1', '1']
```

It is important to understand that generators can only be iterated over once:

In [29]:
```
map_generator = map(str, range(1, 6))
list(map_generator)
```

Out[29]:
```
['1', '2', '3', '4', '5']
```

In [30]:
```
list(map_generator)
```

Out[30]:
```
[]
```

Quiz

- *True* or *false?*
  - Lazy Evaluation makes it possible to retrieve elements from an infinite sequence
  - Generators can be iterated over an arbitrary number of times
  - `range`, `map` and `filter` return generators

Quiz

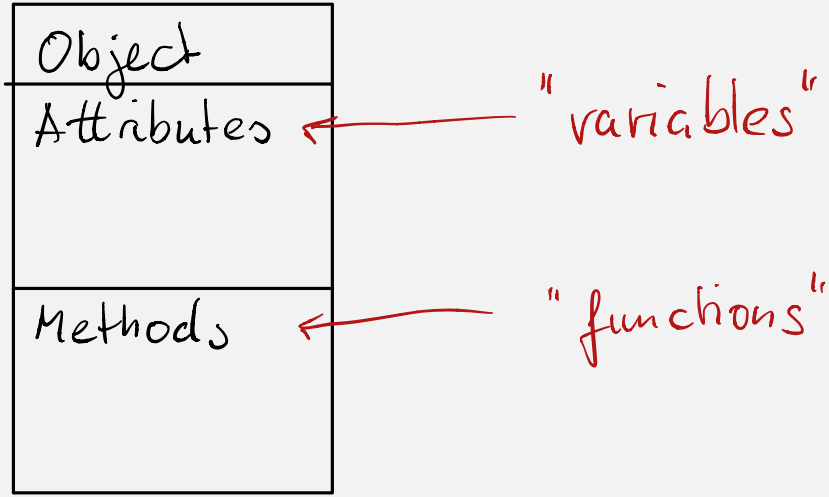
- *True* or *false?*
  - Lazy Evaluation makes it possible to retrieve elements from an infinite sequence — true
  - Generators can be iterated over an arbitrary number of times — false
  - `range`, `map` and `filter` return generators — true

Functional Programming

Lazy Evaluation

Object-oriented Programming

What is an object?



An object is an instance of a class

instance

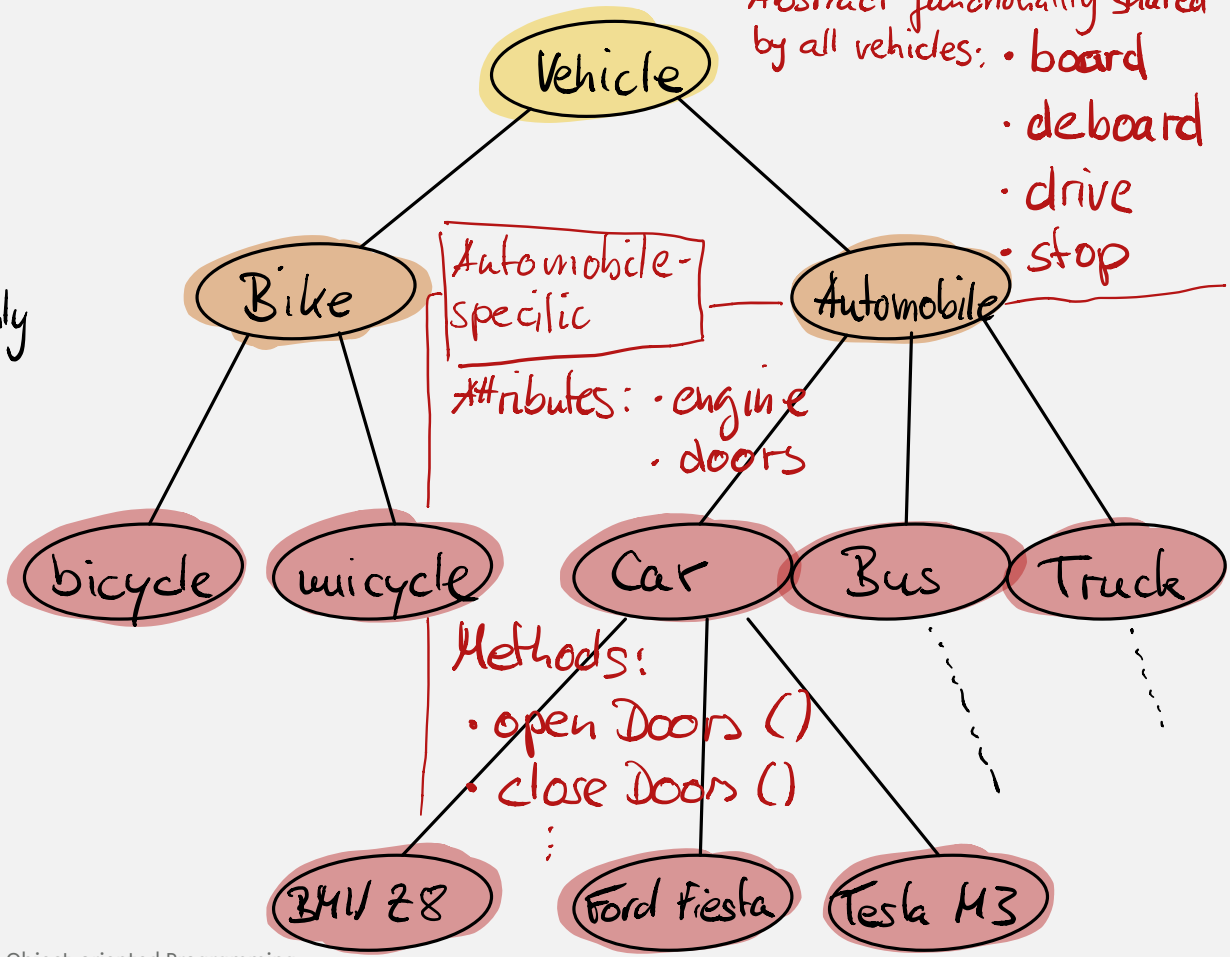
blueprint

Inheritance

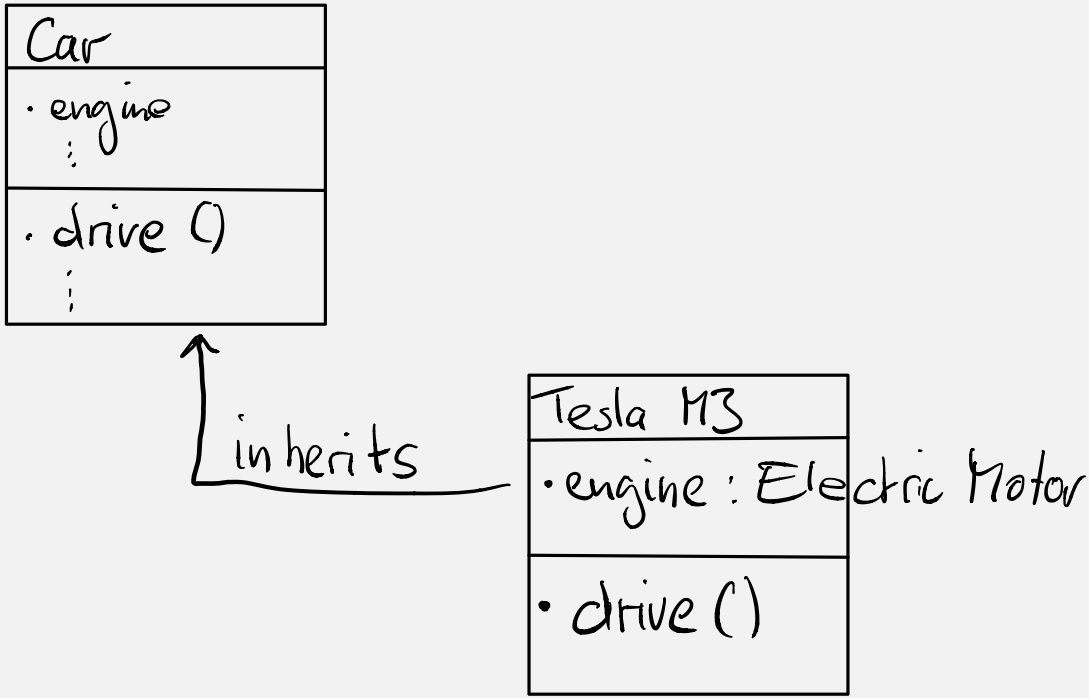
Interface
- no impl.
- typically methods only

Abstract Class
- partial impl.

Class
- specific implement.



Overwriting methods and attributes



Design principles of software development

SOLID

- **S**ingle responsibility principle: a class should have only a single responsibility
- **O**pen/closed principle: “software entities [..] should be open for extension, but closed for modification”
- **L**iskov substitution principle: “objects in a program should be replaceable with instances of their subtypes without altering the correctness of that program”
- **I**nterface segregation principle: “many client-specific interfaces are better than one general-purpose interface”
- **D**ependency inversion principle: one should “depend upon abstractions, [not] concretions”

source: https://en.wikipedia.org/wiki/SOLID

Naming conventions

Methods/attributes of the type:

- `some_name` or `someName`: *public*
- `_some_name` or `_someName`: *weak internal use*
- `__some_name` or `__someName`: *strong internal use*
- `__some_name__`: *Python "magic" attribute/function*

Variable named _, e.g.

```
1 for _ in range(10):
2     ...
```

... indicates that it will never be used

Object-oriented Programming

Every class that you create will be inherited from the `object` class, even if you don't specify explicity, as done in this example.

In [31]:
```
class MyObject(object):
    pass

', '.join(dir(MyObject))
```

Out[31]:
```
'__class__, __delattr__, __dict__, __dir__, __doc__, __eq__, __format__, __ge_
_, __getattribute__, __gt__, __hash__, __init__, __init_subclass__, __le__, __
lt__, __module__, __ne__, __new__, __reduce__, __reduce_ex__, __repr__, __seta
ttr__, __sizeof__, __str__, __subclasshook__, __weakref__'
```

Overwriting inherited methods is simple:

In [32]:
```
class MyObject2(object):
    def __str__(self):
        return 'It\'s my object!'

myObj  = MyObject()
myObj2 = MyObject2()

str(myObj), str(myObj2)
```

Out[32]:
```
('<__main__.MyObject object at 0x10a1bc1d0>', "It's my object!")
```

In [33]:
```
print(myObj2)
```

```
It's my object!
```

Inheritance

This example showcases the use of interfaces, abstract classes, and (ordinary) classes.

The `Vehicle` interface:

In [34]:
```
class Vehicle:

    def board(self, driver):
        raise NotImplementedError()

    def deboard(self):
        raise NotImplementedError()

    def drive(self):
        raise NotImplementedError()

    def stop(self):
        raise NotImplementedError()
```

Abstract class `Automobile` provides a partial implementation of `Vehicle`:

In [35]:
```
class Automobile(Vehicle):

    def __init__(self, name):
        self.name = name
        self.doors = 'generic doors'
        self.driver = None
        self.engine = None

    def board(self, driver):
        if self.driver != None:
            raise Exception('This automobile is already boarded!')
        self.openDoors()
        print(f'seating driver {driver}')
        self.driver = driver
        self.closeDoors()

    def deboard(self):
        if self.driver == None:
            raise Exception('This automobile is not boarded!')
        self.openDoors()
        print(f'deboarding driver {self.driver}')
        self.driver = None
        self.closeDoors()

    def openDoors(self):
        print(f'opening {self.doors}')

    def closeDoors(self):
        print(f'closing {self.doors}')
```

Example of an "implemented" class, ready to be be instantiated:

In [36]:
```
class Engine:
    def start(self):
        print(f'starting {self}')

    def stop(self):
        print(f'stopping {self}')

class Car(Automobile):

    def __init__(self, name, engine):
        super().__init__(name)
        self.engine = engine

    def drive(self):
        if self.driver == None:
            raise Exception('Car has no driver!')
        self.engine.start()
        print(f'driving forward')

    def stop(self):
        print('hitting breaks')
        self.engine.stop()
```

Derivations of the class, that extend the `Car` class by specific implementations:

In [37]:
```
class ElectricEngine(Engine):
    pass

class TeslaM3(Car):

    def __init__(self):
        super().__init__('Tesla M3', ElectricEngine())

    def drive(self):
        if self.driver == None:
            print('setting autonomous driving mode')
            self.board('Autonomous Driver')
        self.engine.start()
        print(f'driving forward')
```

In [38]:
```
my_tesla = TeslaM3()
my_tesla
```

Out[38]:
```
<__main__.TeslaM3 at 0x10a19f510>
```

In [39]:
```
my_tesla.name
```

Out[39]:
```
'Tesla M3'
```

In [40]:
```
my_tesla.board('Elon Musk')
```

```
opening generic doors
seating driver Elon Musk
closing generic doors
```

In [41]:
```
my_tesla.deboard()
```

```
opening generic doors
deboarding driver Elon Musk
closing generic doors
```

In [42]:
```
my_tesla.drive()
```

```
setting autonomous driving mode
opening generic doors
seating driver Autonomous Driver
closing generic doors
starting <__main__.ElectricEngine object at 0x10a19fcd0>
driving forward
```

In [43]:
```
my_tesla.stop()
```

```
hitting breaks
stopping <__main__.ElectricEngine object at 0x10a19fcd0>
```

In plain Python, inheritance from explicit interfaces is not necessary. Functionality of objects is defined merely by presence of the corresponding functions. Here is an example of the "Iterator" interface:

In [44]:
```
class RepeatIterator:
    def __init__(self, repetitions, value):
        """ Constructor: requires repetitions (integer) and the value that will be
        repeated """
        self.counter = repetitions
        self.val = value

    def __iter__(self):
        """ Implementation of the Iter interface, returns object itself."""
        return self

    def __next__(self):
        """ Will return the repeated element as long as the number of repetitions
        is not exceeded. """
        if self.counter > 0:
            self.counter -= 1
            return self.val

        raise StopIteration
```

In [45]:
```
myIt = RepeatIterator(10, 'Hello World')

print(myIt)

for x in myIt:
    print(x)
```

```
<__main__.RepeatIterator object at 0x10a1cb810>
Hello World
Hello World
Hello World
Hello World
Hello World
Hello World
Hello World
Hello World
Hello World
Hello World
```

In [46]:
```
myIt = RepeatIterator(10, 'Hello World')

next(myIt)
```

Out[46]:
```
'Hello World'
```

Functions are objects that implement a `__call__` function:

In [47]:
```
class MyCallable:

    def __call__(self, *args):
        """ Implementation of the Call interface, returns passed on parameters"""
        return args

myCall = MyCallable()

print(myCall)
```

```
<__main__.MyCallable object at 0x10a1cec90>
```

In [48]:
```
myCall('Hello', 1, 2, 3)
```

Out[48]:
```
('Hello', 1, 2, 3)
```

Quiz

- *True* or *false?*
  - Every function in Python is an object
  - Methods of parent class cannot be overridden
  - All classes are derived from the same base class
  - Classes inherit all variables and functions from the parent class
  - Python's "magic" functions can't be overridden.
- Order the variable names by increasing privacy.
  - `_some_name`
  - `some_name`
  - `__some_name`

Quiz

- *True* or *false?*
  - Every function in Python is an object — true
  - Methods of parent class cannot be overridden — false
  - All classes are derived from the same base class — true
  - Classes inherit all variables and functions from the parent class — true
  - Python's "magic" functions can't be overridden. — false
- Order the variable names by increasing privacy.
  - `_some_name` — 2.
  - `some_name` — 1.
  - `__some_name` — 3.

Recap

Summary

- Functional programming
  - Map, reduce, …
  - Lambda functions
  - List comprehension
- Lazy evaluation
  - Generators and iterators
- Object-oriented programming
  - Inheritance
  - Conventions
  - Python’s “magic” functions