# Programming

## Advanced Programming


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# Recap

# Databases Overview

## SQL databases

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

## noSQL databases

... are more purpose-specific:

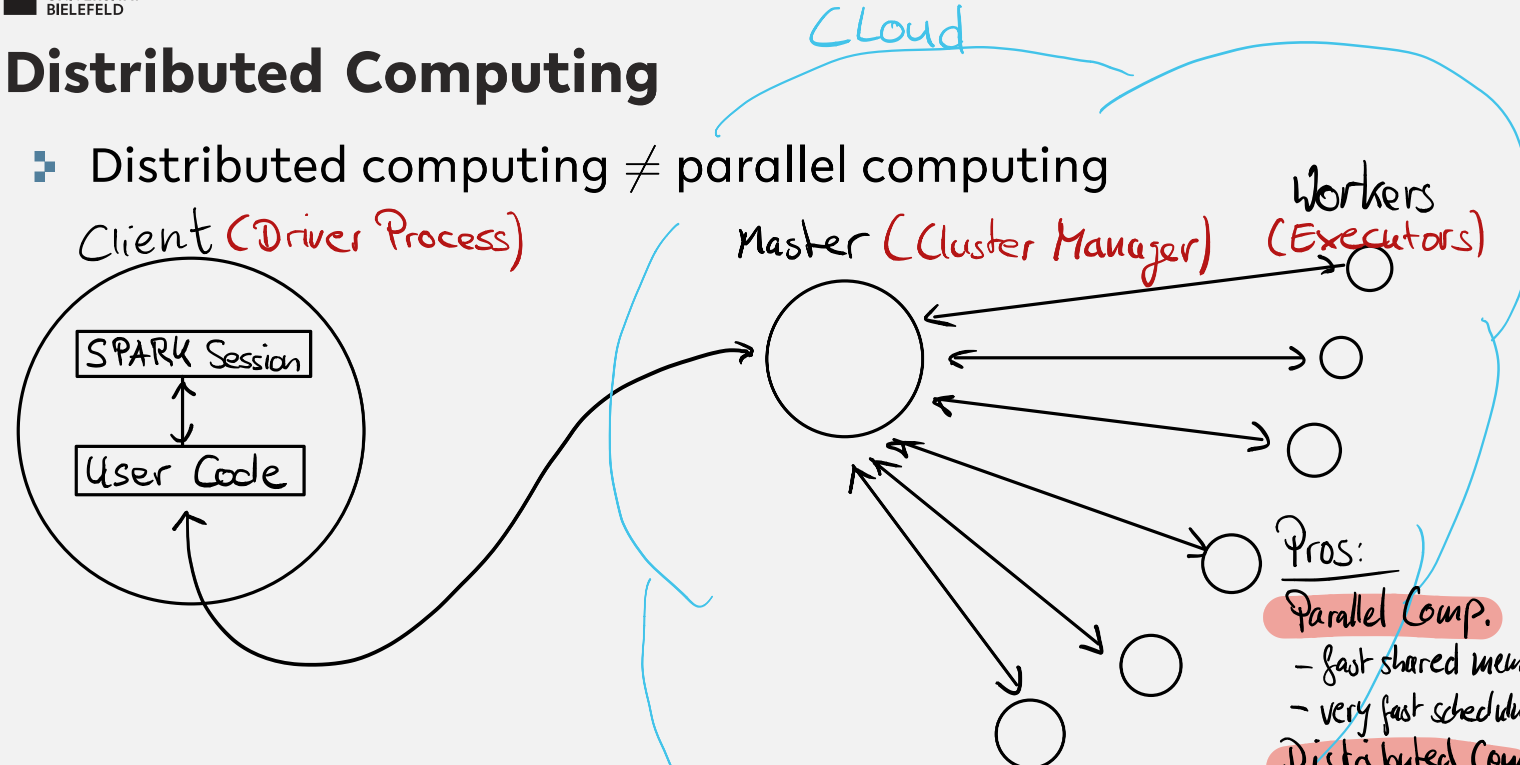
- Key-value
- Graph
- Document-oriented
- Object-oriented

# 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 $\neq$ parallel computing



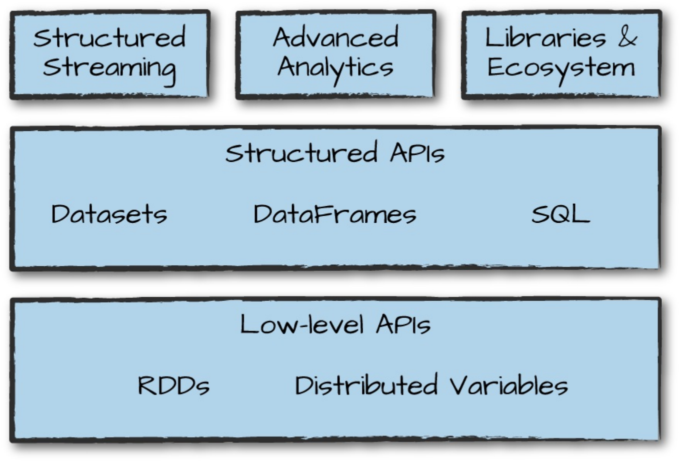

Pros:

Parallel Comp.
- fast shared memory
- very fast scheduling

Distributed Comp
- theor. unlimited compute & memory resources
- scalable

- 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]:
```python
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]:
```python
def makeList(a, b):
    return [a, b]

myVariable = makeList
```

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

In [3]:
```python
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

$$\mathrm{map}(f, \text{collection})$$

$$[\square, \square, \square, \square, \dots]$$

returns $[f(\square), f(\square), f(\square), f(\square), \dots]$

## Mapping

Mapping is a very powerful concept:

In [5]:
```python
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    ])
```

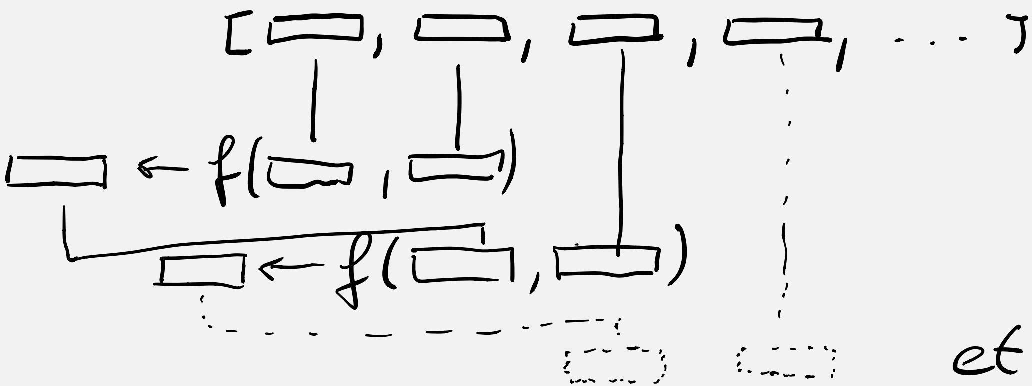
```
In [9]: list(map(str, ary))

Out[9]: ['0.9204204259735078', '0.02694658375632645', '0.8786000025464282']
```

# Reduce

reduce(f, collection)

$\uparrow$ f(x, y)

Iterative reduction of collection through f



etc.

Outcome of the last application of f will be returned

## Reducing

Another very powerful concept:

In [10]:
```python
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]:
```python
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

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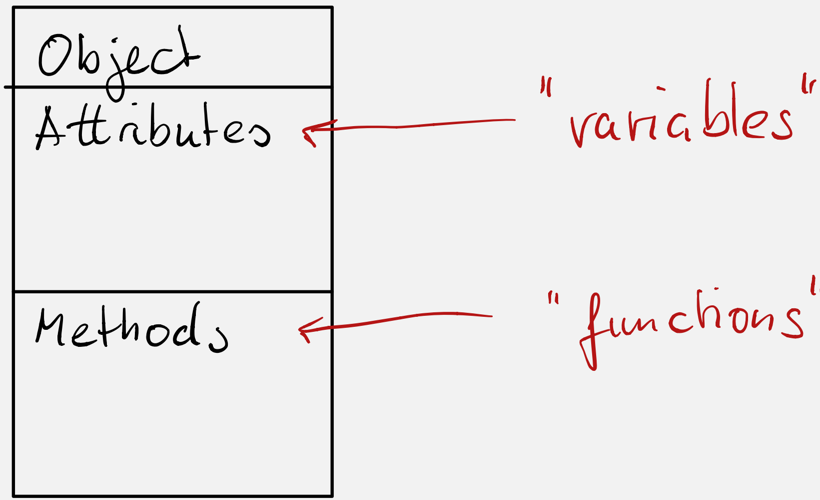
**Functional Programming**

**Lazy Evaluation**

**Object-oriented Programming**

# What is an object?




An object is an instance of a class

instance

blueprint

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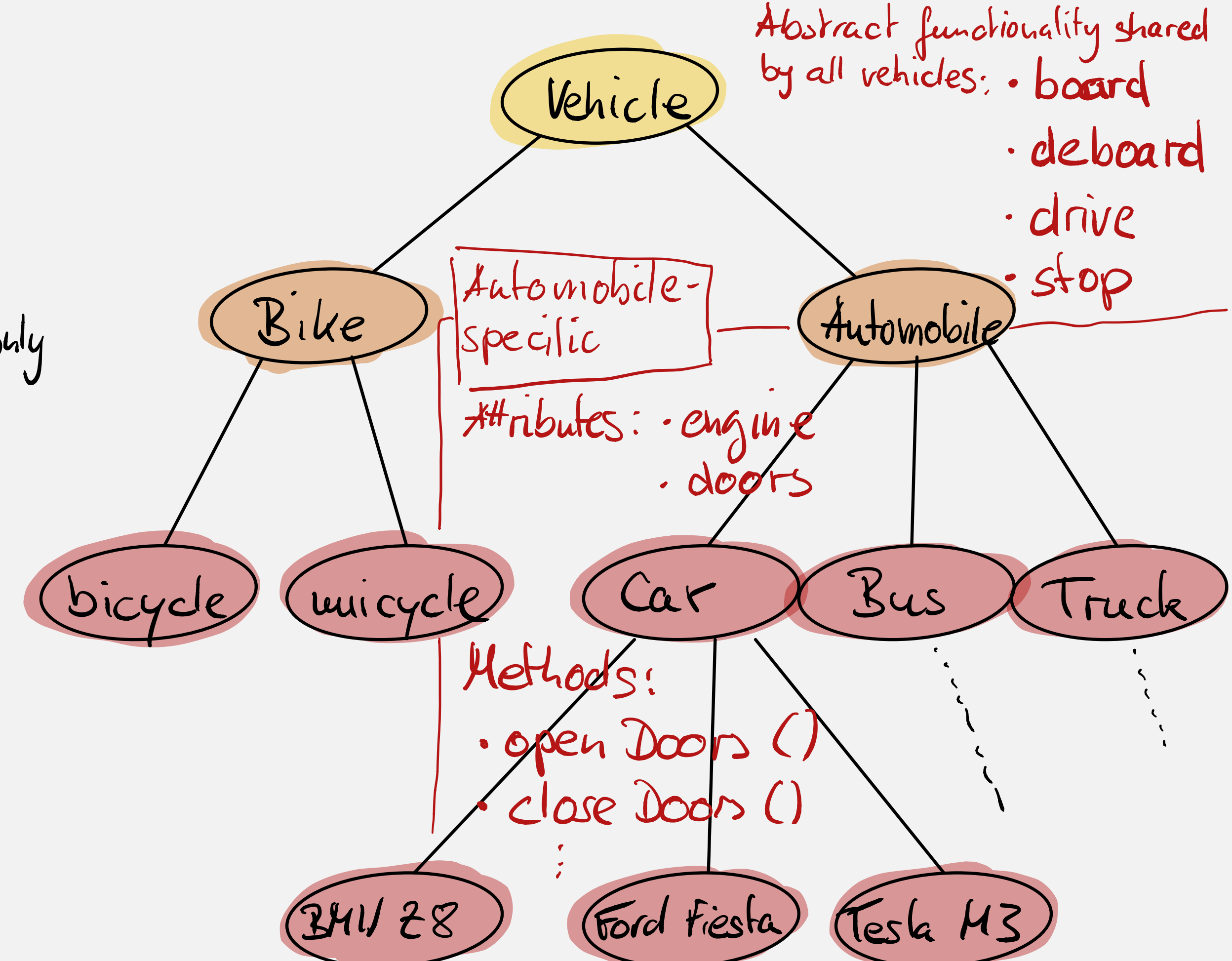
# Inheritance

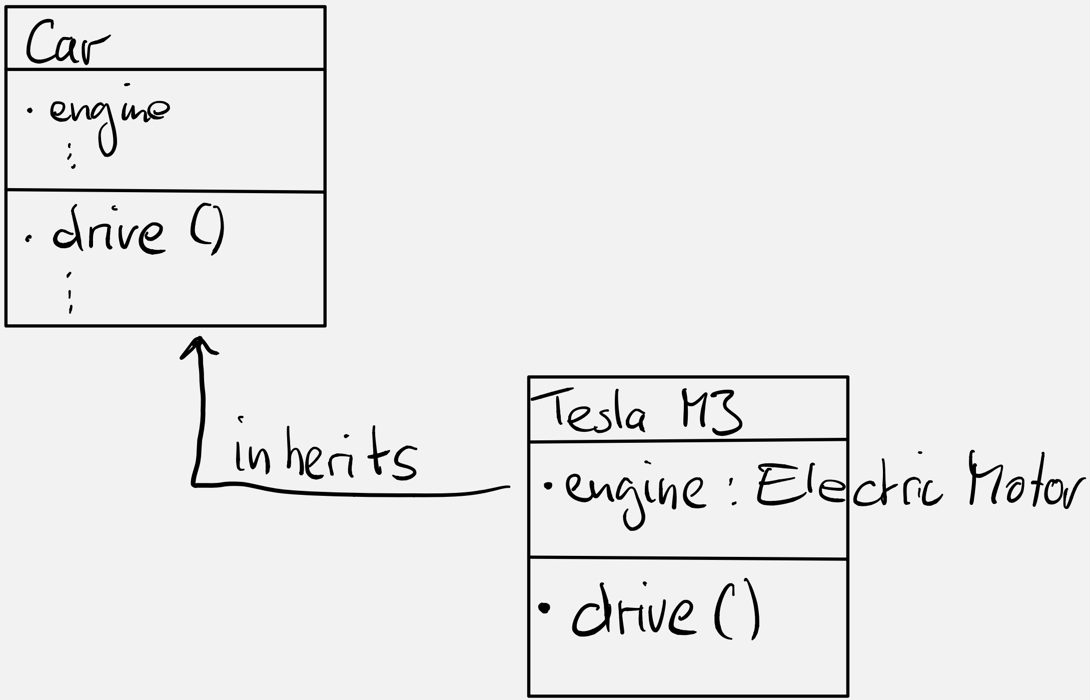
**Interface**
- no impl.
- typically methods only

**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.

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

... 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]:
```python
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]:
```python
print(myObj2)
```

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

## Inheritance

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

The `Vehicle` interface:

In [34]:
```python
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]:
```python
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]:
```python
my_tesla.board('Elon Musk')
```

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

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

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

In [42]:
```python
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]:
```python
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

# What comes next?

- Have a look at the Jupyter Notebook of this lecture
- Revisit APIs of software package `numpy`, `pandas`, `scikit-learn`, and `pyspark` and discover further functional programming aspects
- Further reading:
  - Functional Programming HOWTO
    `https://docs.python.org/3/howto/functional.html`
  - Dusty Phillips, Python 3 Object-oriented Programming, Packt Publishing, 2015

*Next lecture: Algorithms & Complexity*