Computational Structures in Data Science

Object-Oriented Programming

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Announcements

- **Midterm Grades: By the end of the week**
  - Working through them as fast as possible. ☺
- **Please be respectful during lecture**

Computational Structures in Data Science

Object-Oriented Programming

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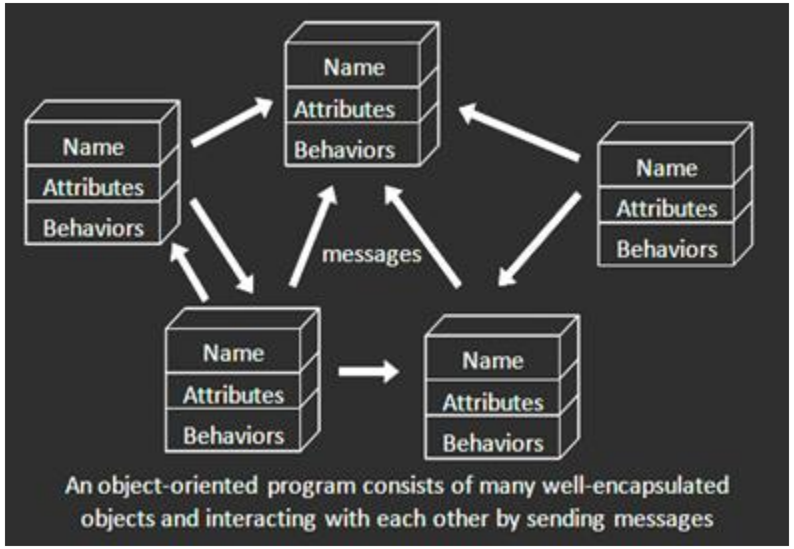
Learning Objectives

- Learn how to make a class in Python
  - `class` keyword
  - `__init__` method
  - `self`

Object-Oriented Programming (OOP)

- **<u>Objects</u>** as data structures
  - With <u>methods</u> you ask of them
    - These are the behaviors
  - With <u>local state</u>, to remember
    - These are the attributes
- **<u>Classes</u>** & **<u>Instances</u>**
  - Instance an example of class
  - E.g., Fluffy is instance of Dog
- **<u>Inheritance</u>** saves code
  - Hierarchical classes
  - e.g., a Tesla is a special case of an Electric Vehicle, which is a special cade of a car
- Other Examples (though not pure)
  - Java (CS61B), C++



An object-oriented program consists of many well-encapsulated objects and interacting with each other by sending messages

`www3.ntu.edu.sg/home/ehchua/programming/java/images/OOP-Objects.gif`

Object-Oriented Programming is About *Design*

"In my version of computational thinking, I imagine an abstract machine with just the data types and operations that I want. If this machine existed, then I could write the program I want.

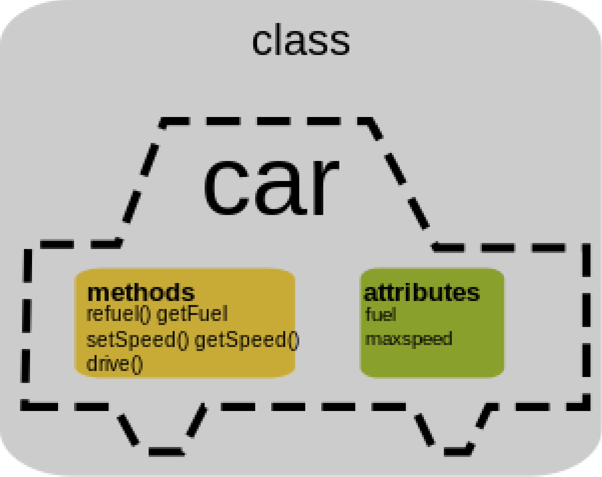
But it doesn't. Instead I have introduced a bunch of subproblems — the data types and operations — and I need to figure out how to implement them. I do this over and over until I'm working with a real machine or a real programming language. That's the art of design."

— Barbara Liskov,
Turing Award Winner, UC Berkeley '61.
Full interview

Classes

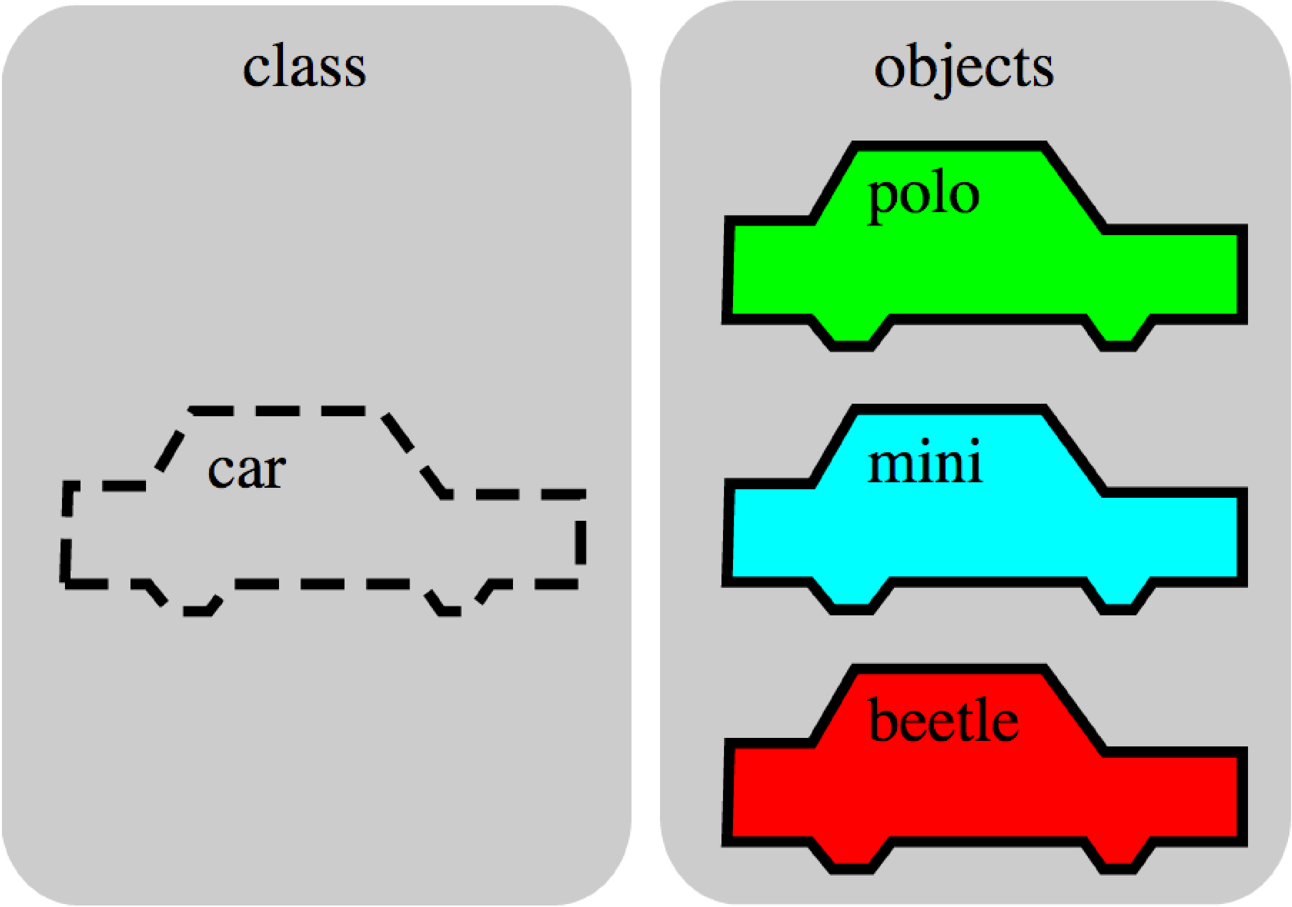
- Consist of data and behavior, bundled together to create abstractions
  - Abstract Data Types use functions to create abstractions
  - Classes define a new **type** in a programming language
    - They make the "abstract" data type concrete.
- A class has
  - attributes (variables)
  - methods (functions)

  that define its behavior.



Objects

- An **object** is the instance of a class.



Objects

- Objects are concrete instances of classes in memory.
- They have *state*
  - mutable vs immutable (lists vs tuples)
- Methods are functions that belong to an object
  - Objects do a collection of **related** things
- In Python, *everything* is an object
  - All objects have attributes
  - Manipulation happens through methods
  - Methods are attributes that are functions

Python class statement

```
class ClassName:
    def __init__(self):
         <initialization steps>
    .
    .
    .
    <statement-N>


# Coming Next Week:
class ClassName ( inherits ):
    <statement-1>
    .
    .
    .
    <statement-N>
```

From ADTs to Classes

- An ADT is an *abstract* representation of a *type* of Data.

```
def points(x, y) # our point ADT
    return { 'x': x, 'y': y}

class Point:
    def __init__(self, x, y):
        self.x = x
        self.y = y
    def subtract(self, other):
        return Point(self.x - other.x, self.y - 
other.y)
```

From ADTs to Classes (Usage)

```
>>> origin = point(0, 0)    # Using the ADT
>>> type(origin)
<class 'dict'>
>>> origin
{'x': 0, 'y': 0}
>>> my_house = Point(5, 5)  # Using the class
>>> my_house.x
5
>>> type(my_house)
<class '__main__.Point'>
>>> my_house
<__main__.Point object at 0x104fdc710>
```

What's Going On?

- We initialize objects through constructors which return a new instance
  - `origin = Point(0, 0)`
  - `my_house = Point(5, 3)`
  - `campus = Point(8, 8)`
- We access attributes using 'dot notation'
  - `origin.x == 0`
  - `my_house.x == 5`
- We also call methods (functions) using dot notation:
  - `new_point = campus.substract(my_house)`

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A Basic Bank Account

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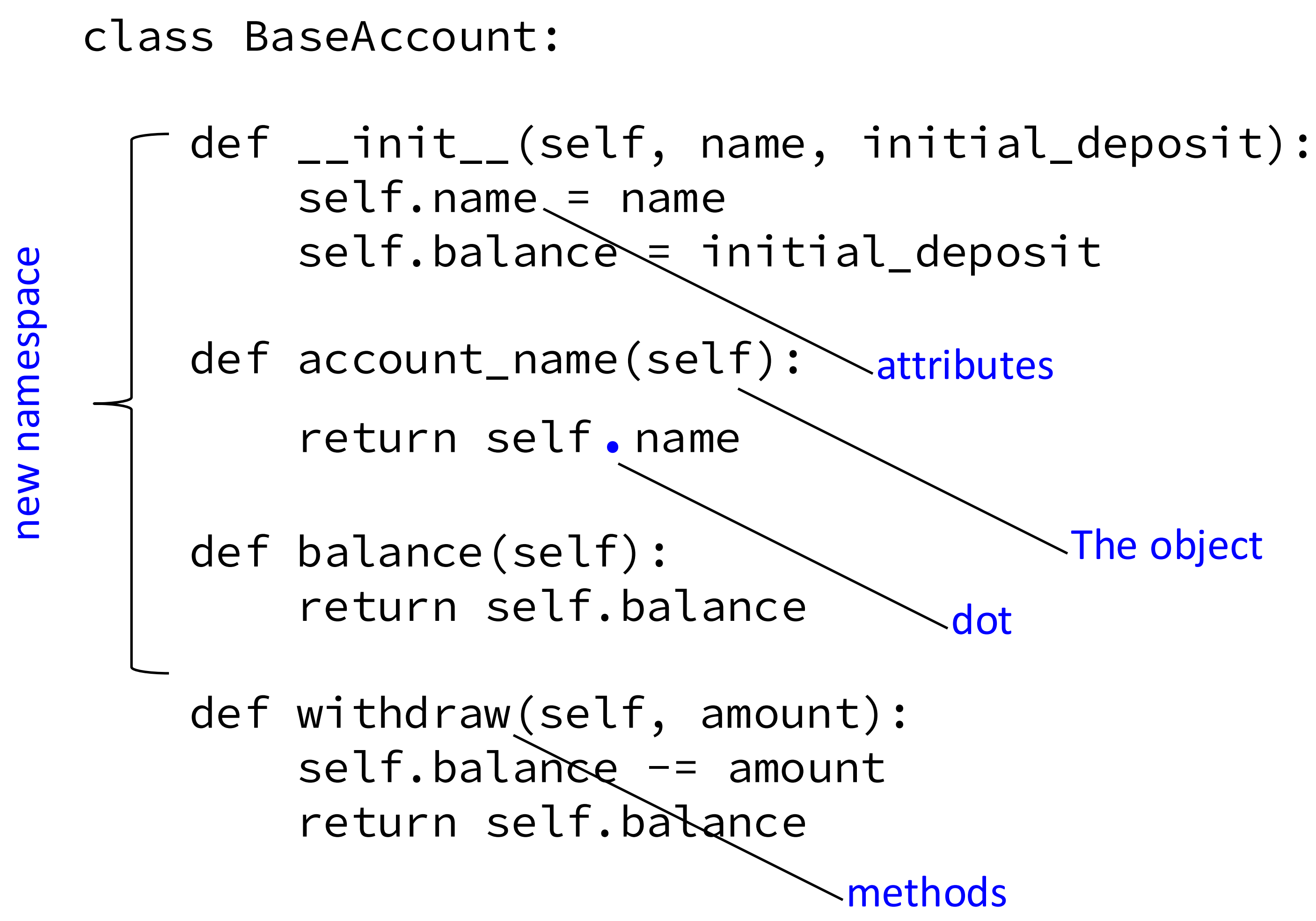
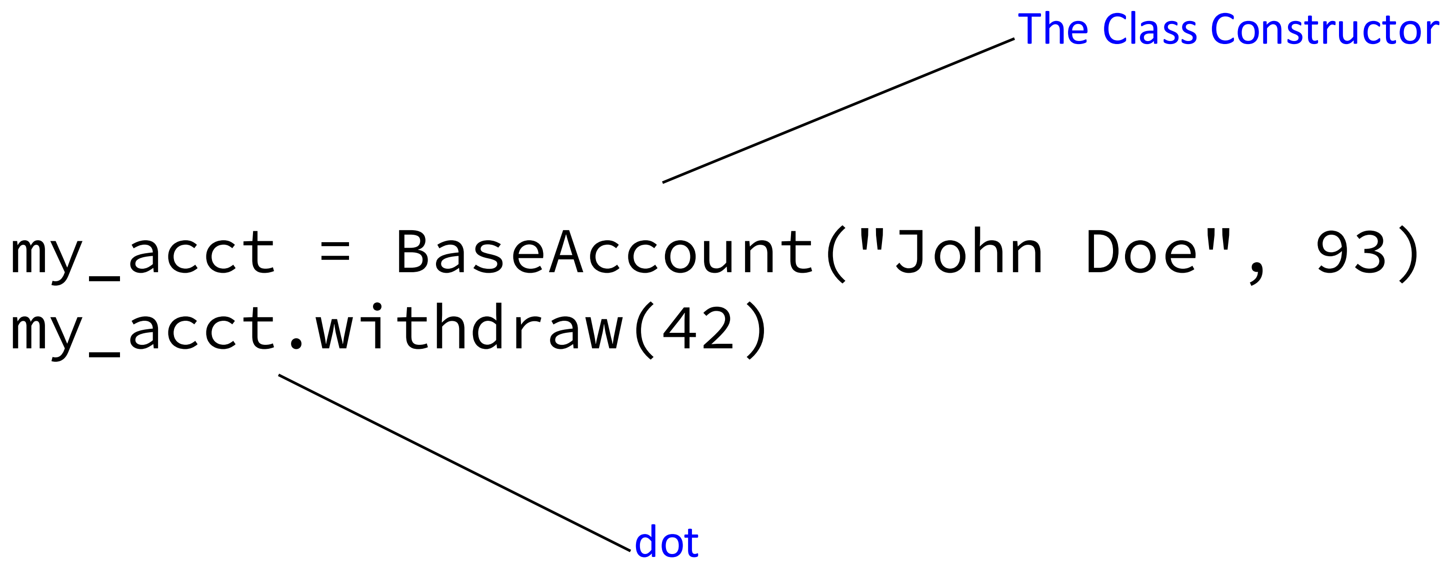
Example: Account



```
class BaseAccount:

    def __init__(self, name, initial_deposit):
        self.name = name
        self.balance = initial_deposit

    def account_name(self):

        return self.name

    def balance(self):
        return self.balance

    def withdraw(self, amount):
        self.balance -= amount
        return self.balance
```

Creating an object, invoking a method



The Class Constructor

```
my_acct = BaseAccount("John Doe", 93)
my_acct.withdraw(42)
```

dot

Special Initialization Method

```
class BaseAccount:

    def __init__(self, name, initial_deposit):
        self.name = name
        self.balance = initial_deposit

    def account_name(self):

        return self.name

    def balance(self):
        return self.balance

    def withdraw(self, amount):
        self.balance -= amount
        return self.balance
```

return None

Demo Where Does self come from?

- Python *binds* methods to each instance
- These two calls are the same:

```
my_account.withdraw(10)

BaseAccount.withdraw(my_account, 10)
```

More on Attributes

- Attributes of an object accessible with ‘dot’ notation

```
obj.attr
```

- You can distinguish between ”public” and “private” data.
  - Used to clarify to programmers how you class should be used.
  - In Python an _ prefix means “this data is internal”
  - **`_foo` and `__foo` do different things inside a class.**
  - More for the curious.
- Class variables vs Instance variables:
  - Class variable set for all instances at once
  - Instance variables per instance value

Example

```
class BaseAccount:

    def __init__(self, name, initial_deposit):
        self.name = name
        self.balance = initial_deposit

    def name(self):
        return self.name

    def balance(self):
        return self.balance

    def withdraw(self, amount):
        self.balance -= amount
        return self.balance
```

Example: Suggested “private” attributes

```
class BaseAccount:
    def __init__(self, name, initial_deposit):
        self._name = name
        self._balance = initial_deposit

    def name(self):
        return self._name

    def balance(self):
        return self._balance

    def withdraw(self, amount):
        self._balance -= amount
        return self._balance
```

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Object-Oriented Programming: Class Attributes

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Example: class attribute

```
class BaseAccount:
    account_number_seed = 1000

    def __init__(self, name, initial_deposit):
        self._name = name
        self._balance = initial_deposit
        self._acct_no = BaseAccount.account_number_seed
        BaseAccount.account_number_seed += 1

    def name(self):
        return self._name

    def balance(self):
        return self._balance

    def withdraw(self, amount):
        self._balance -= amount
        return self._balance
```

More class attributes

```
class BaseAccount:
    account_number_seed = 1000
    accounts = []

    def __init__(self, name, initial_deposit):
        self._name = name
        self._balance = initial_deposit
        self._acct_no = BaseAccount.account_number_seed
        BaseAccount.account_number_seed += 1
        BaseAccount.accounts.append(self)

    def name(self):
        ...

    def show_accounts():
        for account in BaseAccount.accounts:
            print(account.name(),
                  account.account_no(),account.balance())
```

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Object-Oriented Programming: "Magic" Methods

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Learning Objectives

- Python's Special Methods define built-in properties
  - `__init__ # Called when making a new instance`
  - `__sub__ # Maps to the – operator`
  - `__str__ # Called when we call print()`
  - `__repr__ # Called in the interpreter`

Special Initialization Method

`__init__` is called automatically when we write:

```
my_account = BaseAccount('me', 0)
```

```
class BaseAccount:

    def __init__(self, name, initial_deposit):
        self.name = name
        self.balance = initial_deposit

    def account_name(self):

        return self.name

    def account_balance(self):
        return self.balance

    def withdraw(self, amount):
        self.balance -= amount
        return self.balance
```

return None

More special methods

```
class BaseAccount:
      … (init, etc removed)
    def deposit(self, amount):
        self._balance += amount
        return self._balance
```

Goal: unambiguous

```
    def __repr__(self):
        return '< ' + str(self._acct_no) +
               '[' + str(self._name) + '] >'
```

Goal: readable

```
    def __str__(self):
        return 'Account: ' + str(self._acct_no) +
               '[' + str(self._name) + ']'

    def show_accounts():
        for account in BaseAccount.accounts:
            print(account)
```

More Magic Methods

- We will **not** go through an exhaustive list!
- Magic Methods start and end with "double underscores" `__`
- They map to built-in functionality in Python. Many are logical names:
  - `__init__` → Class Constructor
  - `__add__` → + operator
  - `__sub__` → - operator
  - `__getitem__` → [] operator
  - `__repr__ and __str__` → control output
- A longer list for the curious:
  - https://docs.python.org/3/reference/datamodel.html