OBJECT ORIENTED PROGRAMMING

(download slides and .py files to follow along!)

6.0001 LECTURE 7

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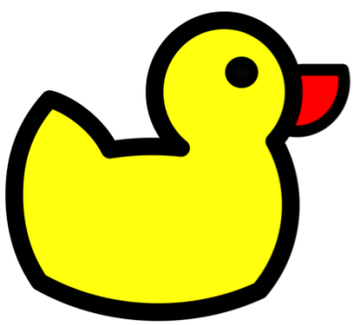
If you missed last lecture, come grab a duck on Wednesday to help you debug



So far

- Basics of programming, variables, control flow
- Use simple and complex datatypes
(int, string, lists, dictionaries, etc.)
- Define new computation via functions
  - Abstraction

Motivation for creating new datatypes

- Fractional numbers
- Mathematical vectors, matrices
- Student record
- DNA
- Algebraic formula
- Neural network
- 3D shape
- Photograph
- Magical electronic white board

What are object and classes?

- Datatypes that bundle
  - Storage
  - Computation (behavior)

OBJECTS

- Python supports many different kinds of data

```
1234      3.14159     "Hello"     [1, 5, 7, 11, 13]
{"CA": "California", "MA": "Massachusetts"}
```

- Each is an **object**, and every object has:
  - An internal **data representation** (primitive or composite)
  - A set of procedures for **interaction** with the object
- An object is an **instance** of a **type (class)**
  - `1234` is an instance of an `int`
  - `"hello"` is an instance of a string

CLASSES vs. Objects

- A Class is a type
  e.g. int, string, list
- An object is a value, i.e. an instance of a class
  e.g. 3, “object”, [1, 2, 3]
- But the term object is sometimes used to refer to anything related to objects and classes

OBJECTS

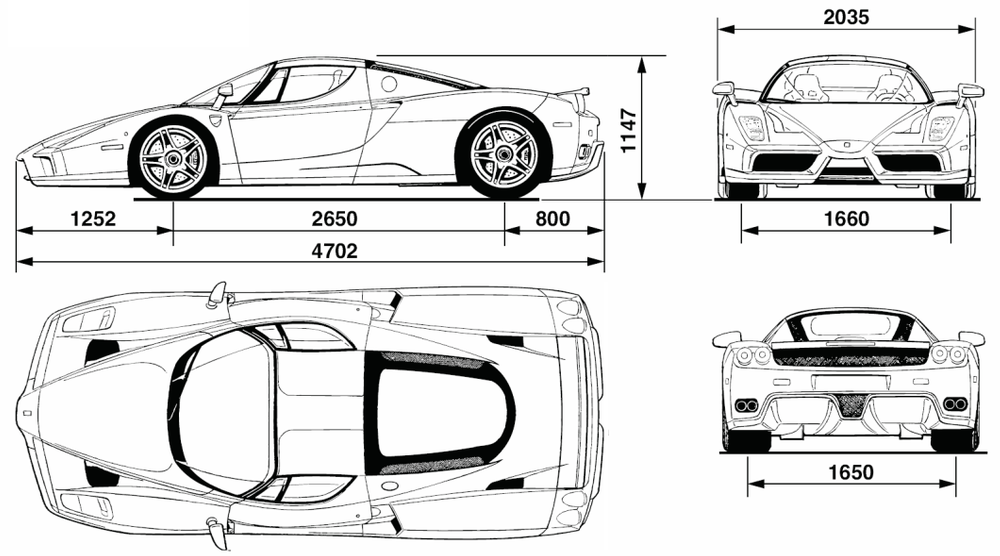
- **EVERYTHING IN PYTHON IS AN OBJECT**
(and has a type, aka class)
- Can **create new objects** of some type
- Can **manipulate objects**
- Can **destroy objects**
  - Explicitly using `del` or just "forget" about them
  - Python system will reclaim destroyed or inaccessible objects – called "garbage collection"

OBJECT ORIENTED PROGRAMMING (OOP)

- Objects are **a data abstraction** that captures…

(1) An **interface** for interacting with object

- Through methods (aka procedures/functions)
- Defines behaviors but (ideally) hides implementation



OBJECT ORIENTED PROGRAMMING (OOP)

- Objects are **a data abstraction** that captures…

(1) An **interface** for interacting with object
  - Through methods (aka procedures/functions)
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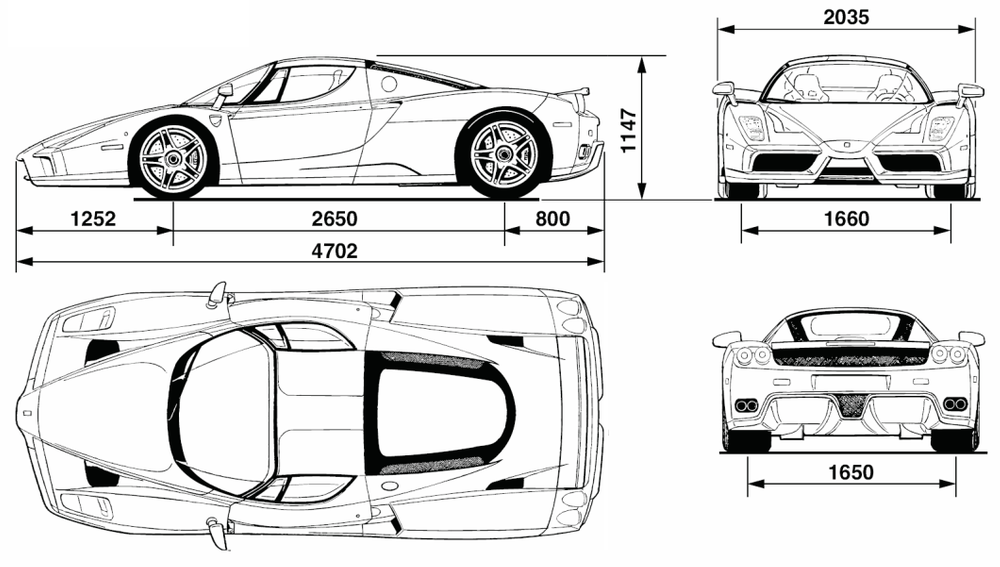
(2) An **internal representation**
  - Through data attributes

(3) An **internal implementation**
  - Through methods body



EXAMPLE of ABSTRACTION: [1,2,3,4] has type list

- How to **manipulate** lists?
  - `L[i], L[i:j], +`
  - `len(), min(), max(), del(L[i])`
  - `L.append(),L.extend(),L.count(),L.index(), L.insert(),L.pop(),L.remove(),L.reverse(), L.sort()`
- Internal representation and implementation should (ideally) be private

ADVANTAGES OF OBJECT ORIENTED PROGRAMMING (OOP)

- **Bundle data into packages** together with procedures that work on them through well-defined interfaces
- **Divide-and-conquer** development
  - Implement and test behavior of each class separately
  - Increased modularity reduces complexity
- **Classes** make it easy to **reuse** code
  - Many Python modules define new classes
  - Each class has a separate environment (no collision on function names)
  - Inheritance allows subclasses to redefine or extend a selected subset of a superclass' behavior

CREATING AND USING YOUR OWN TYPES WITH CLASSES

- Make a distinction between **creating a class** and **using an instance** of the class
- **Creating** the class involves
  - Defining the class name
  - Defining class attributes
  - *for example, someone wrote code to implement a list class*
- **Using** the class involves
  - Creating new **instances** of the class
  - Doing operations on the instances
  - *for example,* `L=[1,2]` *and* `len(L)`

DEFINE YOUR OWN TYPES

- Use the `class` keyword to define a new type

name I have chosen for my class

```
class Coordinate(object):
    #define attributes here
```

← parent class will make sense next lecture

DEFINE YOUR OWN TYPES

- Use the `class` keyword to define a new type

class definition — name/type — class parent

```
class Coordinate(object):
    #define attributes here
```

- Similar to `def`, indent code to indicate which statements are part of the **class definition**
- The word `object` means that `Coordinate` is a Python object and **inherits** all its attributes (inheritance next lecture)
  - `Coordinate` is a subclass of `object`
  - `object` is a superclass of `Coordinate`

WHAT ARE ATTRIBUTES?

- Data and procedures that "**belong**" to the class
- **Data attributes**
  - Think of data as other objects that make up the class
  - *for example, a coordinate is made up of two numbers*
- **Methods** (procedural attributes)
  - Think of methods as functions that only work with this class
  - How to interact with the object
  - *for example you can define a distance between two coordinate objects but there is no meaning to a distance between two list objects*

DEFINING HOW TO CREATE AN INSTANCE OF A CLASS

- First have to define **how to create an instance** of class
- Use a **special method called `__init__`** to initialize some data attributes or perform initialization operations

```
class Coordinate(object):
    def __init__(self, x, y):
        self.x = x
        self.y = y
```

always

actual values for 2 Cartesian coordinates

DEFINING HOW TO CREATE AN INSTANCE OF A CLASS

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```
class Coordinate(object):
    def __init__(self, x, y):
        self.x = x
        self.y = y
```

special method to create an instance — __ is double underscore

what data initializes a Coordinate object

parameter to refer to an instance of the class

two data attributes for every Coordinate object

dot : refers to the object

ACTUALLY CREATING AN INSTANCE OF A CLASS

class name

```
c = Coordinate(3,4)
print(c.x)
```

→ 3

c → x: 3, y: 4

- Data attributes of an instance are called **instance variables**
- Don't provide argument for `self`, Python does this automatically

ACTUALLY CREATING AN INSTANCE OF A CLASS

calls __init__

```
c = Coordinate(3,4)
origin = Coordinate(0,0)
print(c.x)
print(origin.x)
```

create a new object of type Coordinate and pass in 3 and 4 to the __init__

use the dot to access an attribute of instance c

- Data attributes of an instance are called **instance variables**
- Don't provide argument for `self`, Python does this automatically

WHAT IS A METHOD?

- Procedural attribute, like a **function that works only with this class**
- Python always passes the object as the first argument
  - Convention is to use **`self`** as the name of the first argument of all methods
- The "**.**" **operator** is used to access any attribute
  - A data attribute of an object
  - A method of an object

self

- Refers to the object instance upon which a method is called
- Always first argument when **defining** method
- Never provide when **using** method

DEFINE A METHOD FOR THE `Coordinate` CLASS

```
class Coordinate(object):
    def __init__(self, x, y):
        self.x = x
        self.y = y
    def distance(self, other):
        x_diff_sq = (self.x-other.x)**2
        y_diff_sq = (self.y-other.y)**2
        return (x_diff_sq + y_diff_sq)**0.5
```

- Other than `self` and dot notation, methods behave just like functions (take params, do operations, return)

DEFINE A METHOD FOR THE `Coordinate` CLASS

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        return (x_diff_sq + y_diff_sq)**0.5
```

use it to refer to any instance

another parameter to method

dot notation to access data

- Other than `self` and dot notation, methods behave just like functions (take params, do operations, return)

HOW TO USE A METHOD

```
def distance(self, other):
    # code from prev slide here
```

method def

```
c = Coordinate(3,4)
zero = Coordinate(0,0)
```

print (c.distance(zero))

→ 5.0

HOW TO USE A METHOD

```
def distance(self, other):
    # code from prev slide here
```

method def

Using the class:

- Conventional way

```
c = Coordinate(3,4)
zero = Coordinate(0,0)
print(c.distance(zero))
```

object to call method on

name of method

parameters not including self (self is implied to be c)

- Equivalent to

```
c = Coordinate(3,4)
zero = Coordinate(0,0)
print(Coordinate.distance(c, zero))
```

name of class

name of method

parameters, including an object to call the method on, representing self

PRINT AN OBJECT

```
>>> c = Coordinate(3,4)
>>> print(c)
<__main__.Coordinate object at 0x7fa918510488>
```

- **Uninformative** print representation by default

PRINT AN OBJECT

```
>>> c = Coordinate(3,4)
>>> print(c)
<__main__.Coordinate object at 0x7fa918510488>
```

- **Uninformative** print representation by default
- Define a **`__str__` method** for a class
- Python calls the `__str__` method when used with `print` on your class object
- You choose what it does! Say that when we print a `Coordinate` object, want to show

```
>>> print(c)
<3,4>
```

CONTROLLING HOW YOUR OBJECT PRINTS OR CASTS TO STRING

```
class Coordinate(object):
    def __init__(self, x, y):
        self.x = x
        self.y = y
    def distance(self, other):
        x_diff_sq = (self.x-other.x)**2
        y_diff_sq = (self.y-other.y)**2
        return (x_diff_sq + y_diff_sq)**0.5
    def __str__(self):
        return "<"+str(self.x)+","+str(self.y)+">"
```

CONTROLLING HOW YOUR OBJECT PRINTS OR CASTS TO STRING

```
class Coordinate(object):
    def __init__(self, x, y):
        self.x = x
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        return (x_diff_sq + y_diff_sq)**0.5
    def __str__(self):
        return "<"+str(self.x)+","+str(self.y)+">"
```

name of special method

must return a string

→ <3, 4>

WRAPPING YOUR HEAD AROUND TYPES AND CLASSES

- Can ask for the type of an object instance

```
>>> c = Coordinate(3,4)
>>> print(c)
<3,4>
>>> print(type(c))
<class __main__.Coordinate>
```

- This makes sense since

```
>>> print(Coordinate)
<class __main__.Coordinate>
>>> print(type(Coordinate))
<type 'type'>
```

- Use `isinstance()` to check if an object is a `Coordinate`

```
>>> print(isinstance(c, Coordinate))
True
```

WRAPPING YOUR HEAD AROUND TYPES AND CLASSES

- Can ask for the type of an object instance

```
>>> c = Coordinate(3,4)
>>> print(c)
<3,4>
>>> print(type(c))
<class __main__.Coordinate>
```

return of the __str__ method

the type of object c is a class Coordinate

- This makes sense since

```
>>> print(Coordinate)
<class __main__.Coordinate>
>>> print(type(Coordinate))
<type 'type'>
```

a Coordinate is a class

a Coordinate class is a type of object

- Use `isinstance()` to check if an object is a `Coordinate`

```
>>> print(isinstance(c, Coordinate))
True
```

SPECIAL OPERATORS

SPECIAL OPERATORS

- +, -, ==, <, >, len(), print, and many others

https://docs.python.org/3/reference/datamodel.html#basic-customization

- Like `print`, can override these to work with your class
- Define them with double underscores before/after

```
__add__(self, other)    →    self + other
__sub__(self, other)    →    self - other
__eq__(self, other)     →    self == other
__lt__(self, other)     →    self < other
__len__(self)           →    len(self)
__str__(self)           →    print self
```

... and others

EXAMPLE: FRACTIONS

- Create a **new type** to represent a number as a fraction
- **Internal representation** is two integers
  - Numerator
  - Denominator
- **Interface** a.k.a. **methods** a.k.a **how to interact** with `Fraction` objects
  - Add, sub, mult, div to work with +, -, *, /
  - Print representation, convert to a float
  - Invert the fraction
- Let's write it together!

THE POWER OF OBJECT ORIENTED PROGRAMMING

- **Bundle together objects** that share
  - Common attributes and
  - Procedures that operate on those attributes
- Use **abstraction** to make a distinction between how to implement an object vs how to use the object
- Build **layers** of object abstractions that inherit behaviors from other classes of objects
- Create our **own classes of objects** on top of Python's basic classes

5 Min Break, then Quiz Time!

- Sit at a seat, **not on the floor**
- No aids allowed, **only MITx and your IDE**
- If you finish early, **stay in your seat** (no phones, external websites, etc)
- **Checkout password given in the last 2 mins of exam**

Exam link:

http://bit.ly/60001-mq2-s20

checkout code:

ducks