

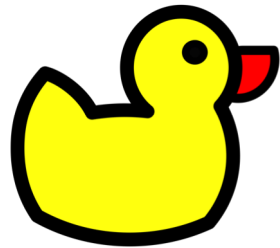
OBJECT ORIENTED PROGRAMMING

(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

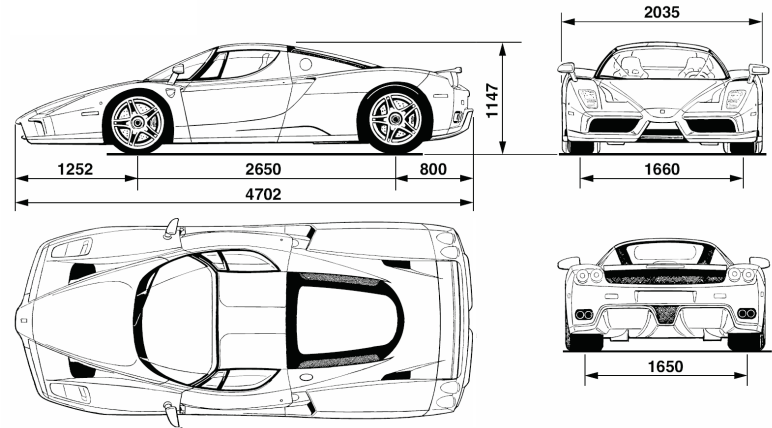
OBJECTS

- **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...

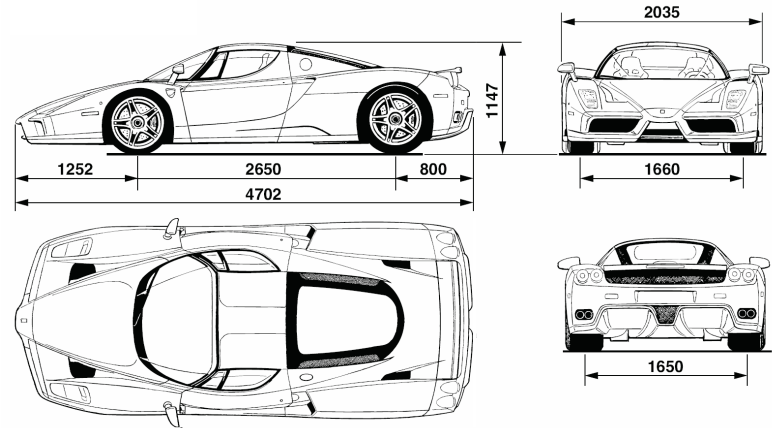
- (1) An **interface** for interacting with object
 - Through methods (aka procedures/functions)
 - Defines behaviors but (ideally) hides implementation



OBJECT ORIENTED PROGRAMMING (OOP)

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

- (1) An **interface** for interacting with object
 - Through methods (aka procedures/functions)
 - Defines behaviors but (ideally) hides implementation
- (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

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

DEFINE YOUR OWN TYPES

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

class definition
`class` *name/type* `Coordinate` (*class parent* `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
```


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

two data attributes
for every
Coordinate object

what data initializes a
Coordinate object

parameter to
refer to an
instance of the
class

ACTUALLY CREATING AN INSTANCE OF A CLASS

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

- 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

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

use the dot to
access an attribute
of instance c

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

- 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

```
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
```

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)
```


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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    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) + ">"
```

name of
special
method

must return
a string

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

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

... 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>