Object-Oriented Programming

Learning Goals

- Understand the concept of OOP
- Implement OOP in Python
- Use OOP in Python

Procedural Programming

- Design emphasis is on setting up the logic of the program and its supporting functions.
  - We can improve things if we structure the program to make use of functions to do things we do a lot.
- Define or input the data you want to operate on.
  - Write read and write functions
  - Set up structures for the data
- Generally, you need to know a lot about the procedures and the data structures to make use of the program or modify it.
- Ultimately provide some output....

```
import numpy as np
import matplotlib.pyplot as pl

def falling_ball(x0,v0,g,t):
    return x0 + v0*t + 0.5*g*t**2

def main():
    #  set variables
    x0 = 100.
    v0 = 0.
    g = 9.8
    t = np.arange(101.)

    #  defne output array
    x = np.zeros(101)

    #  compute
    for i,tt in enumerate(t):
        x[i] = falling_ball(x0,v0,g,tt)

    #  now do something, like plot... e.g.
    pl.plot(t,x)

main()
```

Define a function we'll call a lot.

Initialize variables (data) we need to do the calculation.

Set up a structure to hold the result. Note that we have to be careful about Making x the correct size.

Now do the calculation. Again we have to be careful to write our program so that things come out even.

Finally we want to do something with the result

Object Oriented Programming

- Emphasis is on writing “objects”
- Objects contain data; data is maintained in a structure
- Objects contain “methods” which operate on the data.
- Objects have well defined ways to interface to other objects and programmers.
- Individual Objects can belong to the same “class” of objects. The same thing … just different data and properties.

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:
  - a **type**
  - an internal **data representation** (primitive or composite)
  - a set of procedures for **interaction** with the object
- an object is an **instance** of a type
  - `1234` is an instance of an `int`
  - `"hello"` is an instance of a string

Object Oriented Programming (Oop)

- **EVERYTHING IN PYTHON IS AN OBJECT** (and has a type)
- 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”

What are objects?

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

(1) an **internal representation**

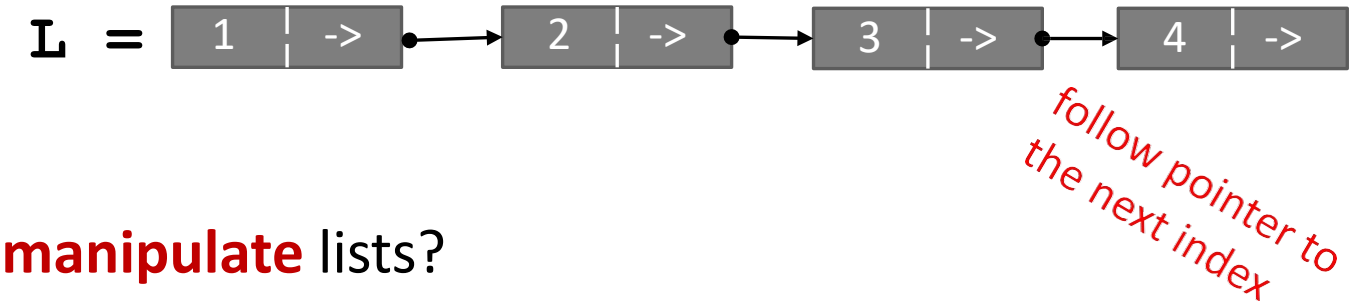
- through data attributes

(2) an **interface** for interacting with object

- through methods (aka procedures/functions)
- defines behaviors but hides implementation

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

- how are lists **represented internally**? linked list of cells



- 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 should be private
- correct behavior may be compromised if you manipulate internal representation directly

Advantages of oop

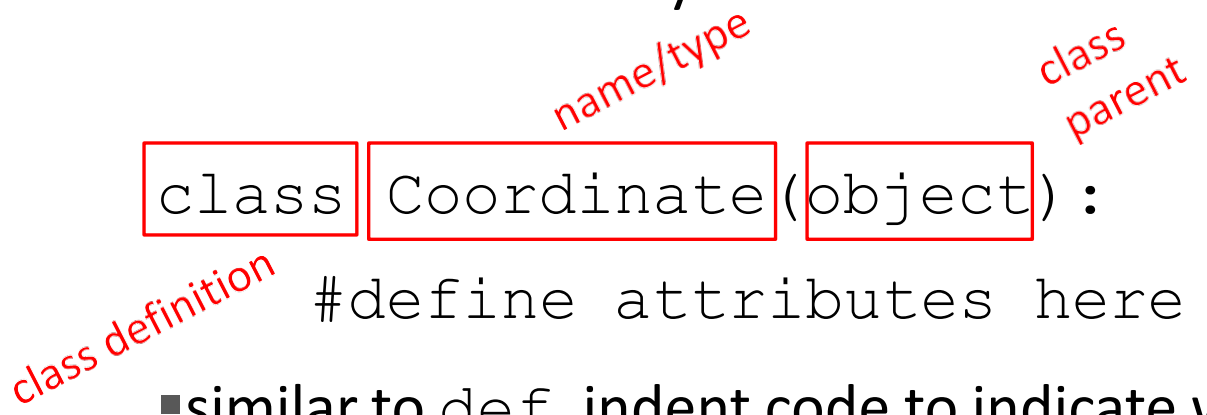
- **bundle data into packages** together with procedures that work on them through well-defined interfaces
- **divide-and-conquer** development
  - implement and test behavior of each class separately
  - increased modularity reduces complexity
- classes make it easy to **reuse** code
  - many Python 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 objects
  - 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



- 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 object
- use a **special method called `__init__`** to initialize some data attributes

```
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

Actually creating an instance of a class

```
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

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 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 representation of 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>
```

Defining your own print method

```
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)+">"
```

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>
```

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

- +, -, ==, <, >, 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, subtract
  - print representation, convert to a float
  - invert the fraction
- the code for this is in the handout, check it out!

The power of oop

- 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