HA NOI UNIVERSITY OF SCIENCE AND TECHNOLOGY
SCHOOL OF INFORMATION AND COMMUNICATION TECHNOLOGY

# Chapter 8:
# Object-oriented Programming

# Contents

# 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)

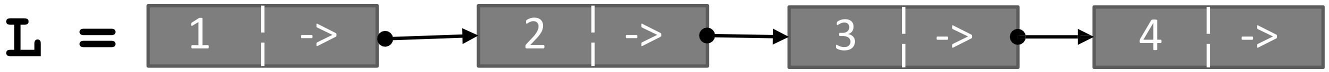
- EVERYTHING IN PYTHON IS AN OBJECT (and has a type)
- can create new objects of some type
- can manipulate objects
- can destroy objects
  - ✓ explicitly using `del` or just "forget" about them
  - ✓ python system will reclaim destroyed or inaccessible objects – called "garbage collection"

# What are objects?

- objects are a data abstraction
- that captures…
- an internal representation
    - ✓through data attributes
- 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




follow pointer to the next index

- 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

name/type

class parent

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

class definition

- 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
```

what data initializes a `Coordinate` object

special method to create an instance is double __ underscore

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

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

```
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

# 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 printon 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 and 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

# Implementing the class vs using the class

- write code from two different perspectives

**implementing** a new object type with a class

- ✓ **define** the class
- ✓ define **data attributes** (WHAT IS the object)
- ✓ define **methods** (HOW TO use the object)

**using** the new object type in code

- ✓ create **instances** of the object type
- ✓ do **operations** with them

# Class definition of an object type vs instance of a class

- class name is the type

  `class Coordinate(object)`

- class is defined generically
  - ✓ use self to refer to some instance while defining the class

    `(self.x – self.y)**2`

  - ✓ self is a parameter to methods in class definition
- class defines data and methods common across all instances

- instance is one specific object

  `coord = Coordinate(1,2)`

- data attribute values vary between instances

  ```
  c1 = Coordinate(1,2)
  c2 = Coordinate(3,4)
  ```

  - ✓ `c1` and `c2` have different data attribute values `c1.x` and `c2.x` because they are different objects
- instance has the structure of the class

# Why use OOP and classes of objects?

- mimic real life
- group different objects part of the same type

Jelly
1 year old
brown

5 years old
brown

Tiger
2 years old
brown

Bean
0 years old
black

2 years old
white

1 year old
b/w

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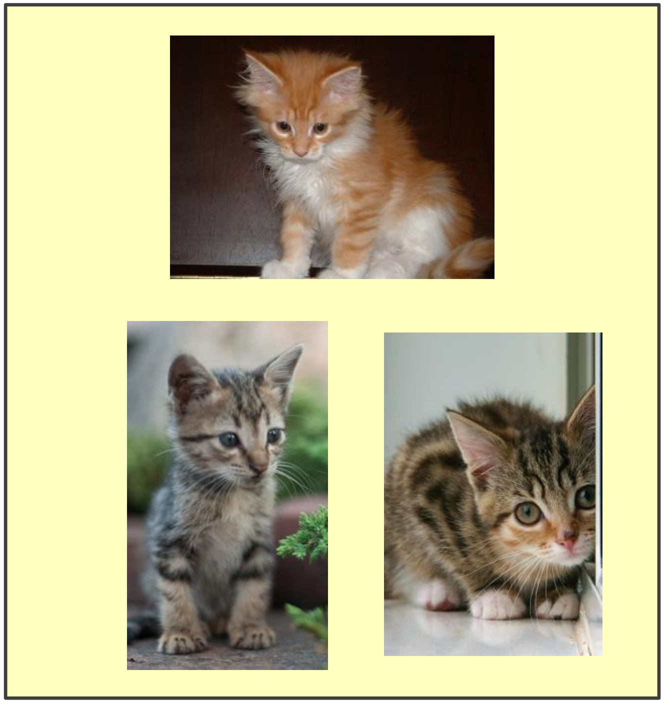
# Why use OOP and classes of objects?

- mimic real life
- group different objects part of the same type



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# Groups of objects have attributes (recap)

- data attributes
  - how can you represent your object with data?
  - what it is
  - for a coordinate: x and y values
  - for an animal: age, name
- procedural attributes (behavior/operations/methods)
  - how can someone interact with the object?
  - what it does
  - for a coordinate: find distance between two
  - for an animal: make a sound

# How to define a class (recap)

class definition

name

class parent

variable to refer to an instance of the class

```
class Animal(object):
    def __init__(self, age):
        self.age = age
        self.name = None
```

what data initializes an `Animal` type

special method to create an instance

`name` is a data attribute even though an instance is not initialized with it as a param

```
myanimal = Animal(3)
```

one instance

mapped to `self.age` in class def

# Getter and setter methods

- **getters and setters** should be used outside of class to access data attributes

```
class Animal(object):
    def __init__ (self, age):
        self.age = age
        self.name = None
```

getter

```
    def get_age(self):
        return self.age
    def get_name(self):
        return self.name
```

setter

```
    def set_age(self, newage):
        self.age = newage
    def set_name(self, newname=""):
        self.name = newname
    def str (self):
        return "animal:"+str(self.name)+":"+str(self.age)
```

# An instance and Dot notation (recap)

- instantiation creates an instance of an object

```
a = Animal(3)
```

- **dot notation** used to access attributes (data and methods) though it is better to use getters and setters to access data attributes

```
a.age
```

```
a.get_age()
```

- access data attribute
- allowed, but not recommended

- access method
- best to use getters and setters

# Information hiding

- author of class definition may **change data attribute** variable names

replaced age data attribute by years

```
class Animal(object):
    def __init__(self, age):
        self.years = age
    def get_age(self):
        return self.years
```

- if you are **accessing data attributes** outside the class and class **definition changes**, may get errors

- outside of class, use getters and setters instead use `a.get_age()` NOT `a.age`
  - ✓ good style
  - ✓ easy to maintain code
  - ✓ prevents bugs

# Python not great at information hiding

- allows you to access data from outside class definition

```
print(a.age)
```

- allows you to write to data from outside class definition

```
a.age = 'infinite'
```

- allows you to create data attributes for an instance from outside class definition

```
a.size = "tiny"
```

- it’s not good style to do any of these!

# Default arguments

- **default arguments** for formal parameters are used if no actual argument is given

```
def set_name(self, newname=""):
    self.name = newname
```

- default argument used here

```
a = Animal(3)
a.set_name()
print(a.get_name())
```

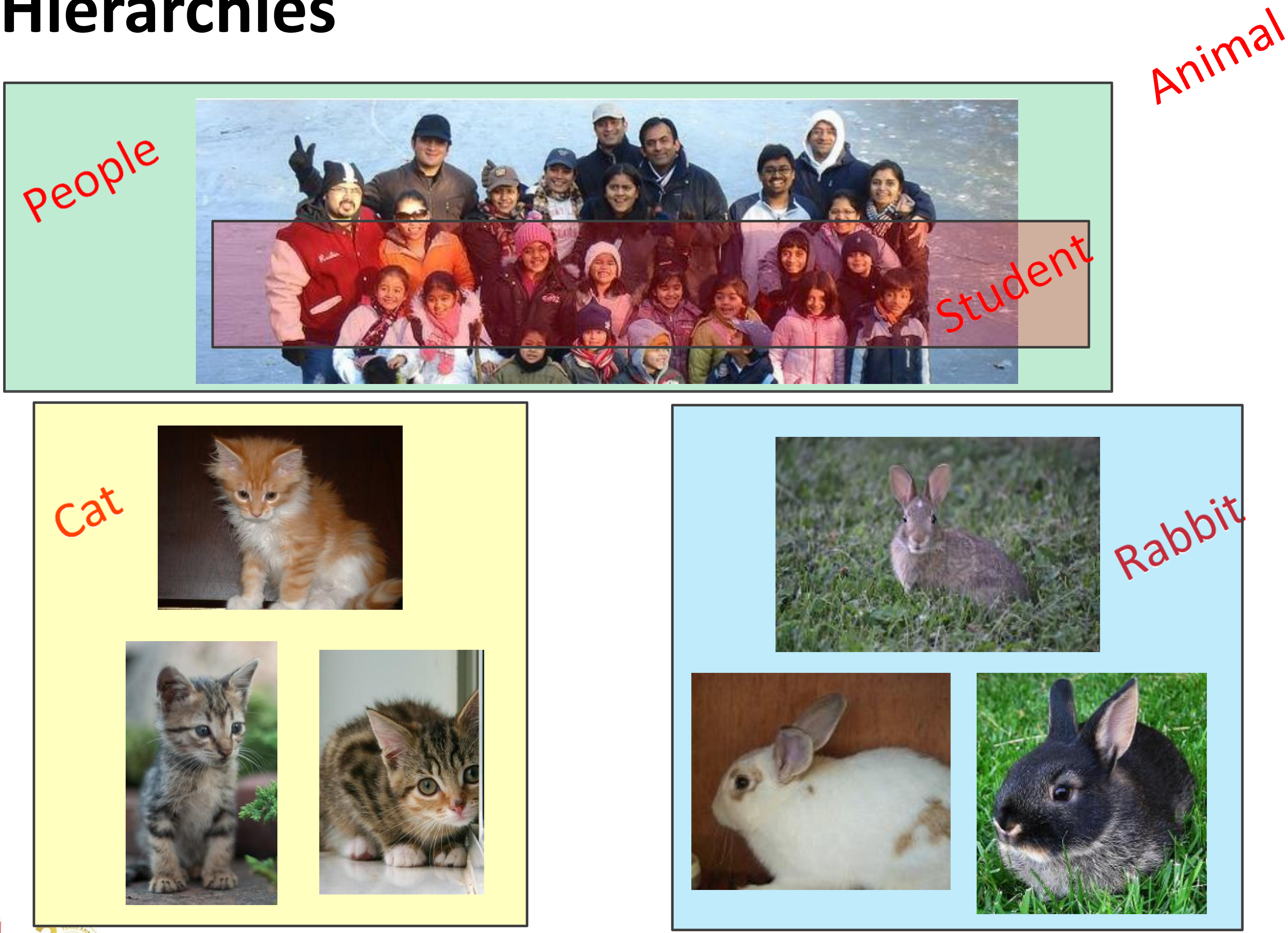
prints ""

- argument passed in is used here

```
a = Animal(3)
a.set_name("fluffy")
print(a.get_name())
```

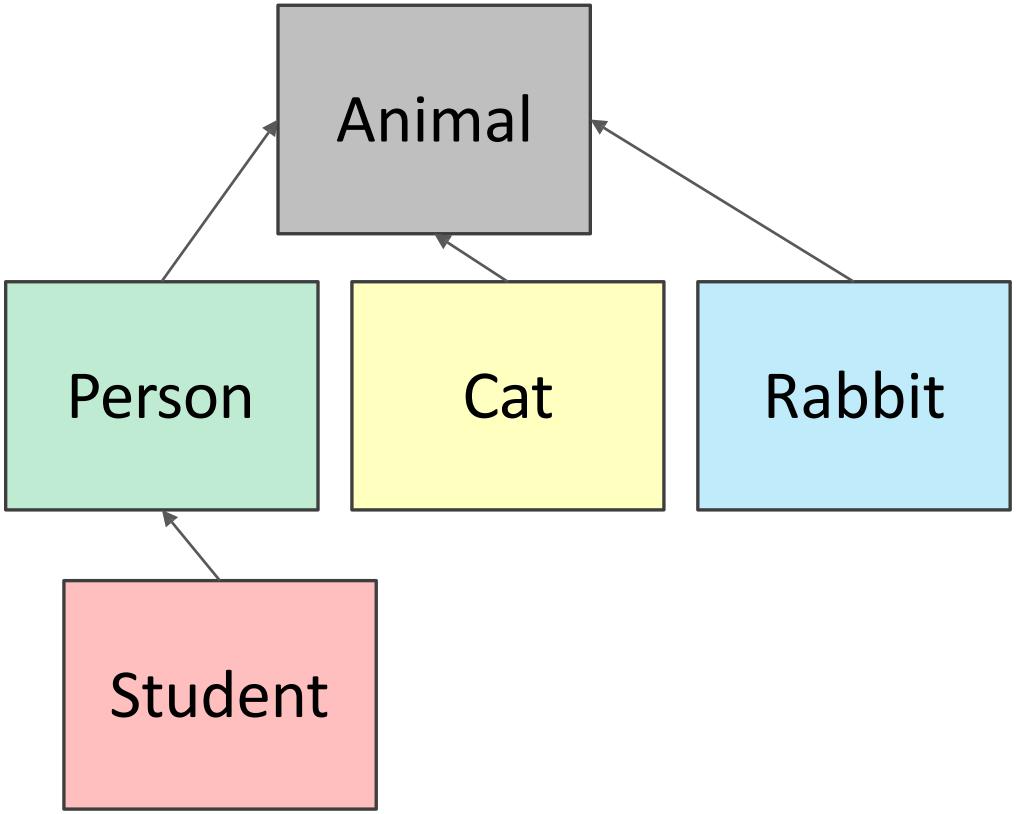
prints "fluffy"

# Hierarchies



# Hierarchies

- **parent class** (superclass)
- **child class** (subclass)
  - ✓ **inherits** all data and behaviors of parent class
  - ✓ **add** more **info**
  - ✓ **add** more **behavior**
  - ✓ **override** behavior



# Inheritance: parent class

```
class Animal(object):
    def __init__ (self, age):
        self.age = age
        self.name = None
    def get_age(self):
        return self.age
    def get_name(self):
        return self.name
    def set_age(self, newage):
        self.age = newage
    def set_name(self, newname=""):
        self.name = newname
    def  __str__ (self):
        return "animal:"+str(self.name)+":"+str(self.age)
```

everything is an object
- class object
implements basic
operations in Python, like
binding variables, etc

# Inheritance: subclass

inherits all attributes of Animal:
__init__()
age, name
get_age(), get_name()
set_age(), set_name()
__str__()

```
class Cat(Animal):
    def speak(self):
        print("meow")
    Def __str__(self):
        return "cat:"+str(self.name)+":"+str(self.age)
```

add new functionality via speak method

overrides __str__

- add new functionality with speak()
  - ✓ instance of type Cat can be called with new methods
  - ✓ instance of type Animalthrows error if called with Cat's new method
- __init__ is not missing, uses the Animalversion

# Which method to use?

- subclass can have methods with same name as superclass
- for an instance of a class, look for a method name in current class definition
- if not found, look for method name up the hierarchy (in parent, then grandparent, and so on)
- use first method up the hierarchy that you found with that method name

```python
class Person(Animal):
    def __init__(self, name, age):
        Animal.__init__(self, age)
        self.set_name(name)
        self.friends = []
    def get_friends(self):
        return self.friends
    def add_friend(self, fname):
        if fname not in self.friends:
            self.friends.append(fname)
    def speak(self):
        print("hello")
    def age_diff(self, other):
        diff = self.age - other.age
        print(abs(diff), "year difference")
    Def __str__(self):
        return "person:"+str(self.name)+":"+str(self.age)
```

parent class is Animal

call Animal constructor

call Animal's method

add a new data attribute

new methods

override Animal's __str__ method

```python
import random
class Student(Person):
    def __init__ (self, name, age, major=None):
        Person.__init__(self, name, age)
        self.major = major
    def change_major(self, major):
        self.major = major
    def speak(self):
        r = random.random()
        if r < 0.25:
            print("i have homework")
        elif 0.25 <= r < 0.5:
            print("i need sleep")
        elif 0.5 <= r < 0.75:
            print("i should eat")
        else:
            print("i am watching tv")
    def __str__ (self):
        return "student:"+str(self.name)+":"+str(self.age)+":"+str(self.major)
```

bring in methods from `random` class

inherits `Person` and `Animal` attributes

adds new data

- I looked up how to use the `random` class in the python docs
- `random()` method gives back float in [0, 1)

# Class variables and the Rabbit subclass

- **class variables** and their values are shared between all instances of a class

```
class Rabbit(Animal):
    tag = 1
    def __init__(self, age, parent1=None, parent2=None):
        Animal.__init__(self, age)
        self.parent1 = parent1
        self.parent2 = parent2
        self.rid = Rabbit.tag
        Rabbit.tag += 1
```

parent class

class variable

instance variable

access class variable

incrementing class variable changes it for all instances that may reference it

- `tag` used to give **unique id** to each new rabbit instance

# Rabbit GETTER methods

```
class Rabbit(Animal):
    tag = 1
    def __init__(self, age, parent1=None, parent2=None):
        Animal.__init__(self, age)
        self.parent1 = parent1
        self.parent2 = parent2
        self.rid = Rabbit.tag
        Rabbit.tag += 1
    def get_rid(self):
        return str(self.rid).zfill(3)
    def get_parent1(self):
        return self.parent1
    def get_parent2(self):
        return self.parent2
```

method on a string to pad the beginning with zeros for example, 001 not 1

- getter methods specific for a `Rabbit` class
- there are also getters `get_name` and `get_age` inherited from `Animal`

# Working with your own types

```
def __add__ (self, other):
    # returning object of same type as this class
    return Rabbit(0, self, other)
```

`recall Rabbit's init (self, age, parent1=None, parent2=None)`

- define + operator between two `Rabbit` instances
  - define what something like this does: `r4 = r1 + r2`
- where `r1` and `r2` are `Rabbit` instances
  - `r4` is a new `Rabbit` instance with age 0
  - `r4` has self as one parent and `other` as the other parent
  - in `__init__`, parent1 and parent2 are of type Rabbit

# Special method to compare two Rabbits

- decide that two rabbits are equal if they have the **same two parents**

booleans

```
def __eq__(self, other):
    parents_same = self.parent1.rid == other.parent1.rid \
                   and self.parent2.rid == other.parent2.rid
    parents_opposite = self.parent2.rid == other.parent1.rid \
                       and self.parent1.rid == other.parent2.rid
    return parents_same or parents_opposite
```

- compare ids of parents since **ids are unique** (due to class var)
- note you can't compare objects directly
    - for ex. with `self.parent1 == other.parent1`
    - this calls the `__eq__` method over and over until call it on `None` and gives an `AttributeError` when it tries to do `None.parent1`

# Object oriented programming

- create your own **collections of data**
- **organize** information
- **division** of work
- access information in a **consistent** manner
- add **layers** of complexity
- like functions, classes are a mechanism for **decomposition** and **abstraction** in programming

# Abstract class

- An abstract class can be considered as a blueprint for other classes. It allows you to create a set of methods that must be created within any child classes built from the abstract class. A class which contains one or more abstract methods is called an abstract class.
- An abstract method is a method that has a declaration but does not have an implementation. While we are designing large functional units we use an abstract class. When we want to provide a common interface for different implementations of a component, we use an abstract class.

# Why use Abstract Base Classes and how they work?

- By defining an abstract base class, you can define a common Application Program Interface(API) for a set of subclasses.
- By default, Python does not provide abstract classes. Python comes with a module that provides the base for defining Abstract Base classes(ABC) and that module name is ABC. ***ABC*** works by decorating methods of the base class as abstract and then registering concrete classes as implementations of the abstract base. A method becomes abstract when decorated with the keyword @abstractmethod.

# Abstract class example

```python
from abc import ABC, abstractmethod

class Polygon(ABC):

    @abstractmethod
    def noofsides(self):
        pass

class Triangle(Polygon):

    # overriding abstract method
    def noofsides(self):
        print("I have 3 sides")

class Pentagon(Polygon):

    # overriding abstract method
    def noofsides(self):
        print("I have 5 sides")

class Hexagon(Polygon):

    # overriding abstract method
    def noofsides(self):
        print("I have 6 sides")

class Quadrilateral(Polygon):

    # overriding abstract method
    def noofsides(self):
        print("I have 4 sides")
```

```python
# Driver code
R = Triangle()
R.noofsides()

K = Quadrilateral()
K.noofsides()

R = Pentagon()
R.noofsides()

K = Hexagon()
K.noofsides()
```

# Abstract class example

```python
# Python program showing
# abstract base class work

from abc import ABC, abstractmethod
class Animal(ABC):

    def move(self):
        pass

class Human(Animal):

    def move(self):
        print("I can walk and run")

class Snake(Animal):

    def move(self):
        print("I can crawl")

class Dog(Animal):

    def move(self):
        print("I can bark")

class Lion(Animal):

    def move(self):
        print("I can roar")
```

```python
# Driver code
R = Human()
R.move()

K = Snake()
K.move()

R = Dog()
R.move()

K = Lion()
K.move()
```

# References

1. [MIT Introduction to Computer Science and Programming in Python]

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# Thank you for your attention!

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