# CS 3101-1 - Programming Languages: Python

## Lecture 3: OOP, Modules, Standard Library I

Daniel Bauer (bauer@cs.columbia.edu)

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# Object Oriented Programming in Python

- Object Oriented Programming (OOP) is at the core of Python.
  - Everything is an object!
  - Operations are methods on objects.
  - Modularization.
- We have seen examples of objects already:
  - Objects of built-in data types (int, str, list, dict ... ).
  - Functions.
- Can create our own types (classes).
- Python does not enforce OOP (unlike Java), but we need to understand at least what is going on.

# Objects, Attributes, Methods, Classes

- **Classes**:
  - User defined types of objects (including their methods, attributes, relations to other objects).
  - Can be instantiated into an object / is a 'blueprint' that describes how to build an object.

```
Knights can eat, sleep, have a favorite color, and a title.
```

- **Objects:** Grouping of data and behavior (code) into a functional 'package'.

```
l = Knight()
```

- **Attributes:** data fields of the object.

```
l.name = "Launcelot", l.title = "the brave" ...
```

- **Methods:** functions that belong to the object and can access and manipulate the object's data. All Methods are attributes.

```
launcelot.eat(food), launcelot.sleep() ...
```

# Class Definitions with `class`

- Class definitions contain methods (which are functions defined in the class' scope), class attributes, and a docstring.

```
class Knight(object):
    """ A knight with two legs,
        who can eat food.
    """

    legs = 2  # attribute

    def __init__(self):
        self.stomach = []

    def eat(self, food):
        self.stomach.append(food)
        print('Nom nom.')
```

- Classes are objects too. Methods and attributes are are *attributes of the class object!*

```
>>> Knight.legs
2
>>> Knight.eat
<unbound method
    Knight.eat>
```

# Instantiating a Class to an Instance Object

```
class Knight(object):

    legs = 2

    def __init__(self):
        self.stomach = []

    def eat(self, food):
        self.stomach.append(food)
        print('Nom nom.')
```

- Functions are instantiated into instance objects by calling a class object.

```
>>> k = Knight()
>>> k
<__main__.Knight object at 0x100e82c10>
>>> type(knight)
<class '__main__.knight'>
```

# Calling Bound Methods on Instance Objects

```
class Knight(object):

    legs = 2

    def __init__(self):
        self.stomach = []

    def eat(self, food):
        self.stomach.append(food)
        print('Nom nom.')
```

- Instance objects contain bound methods as attributes.
- The first parameter in a method definition ('self') is bound to the instance object when a bound method is called.

```
>>> k = Knight()
>>> k.eat("cheese")
Nom Nom.
>>> k.stomach
["cheese"]
```

# Setting Up Instance Attributes and `__init__`

```
class Knight(object):

    legs = 2

    def __init__(self, name):
        self.stomach = []
        self.name = name

    def eat(self, food):
        self.stomach.append(food)
        print('Nom nom.')
```

- The special method `__init__` is called automatically when an instance is created.
- Main purpose: `__init__` sets up attributes of the instance.

```
>>> k = Knight("galahad")
>>> k.name
"galahad"
```

# Class vs. Instance Attributes

```
class Knight(object):

    legs = 2

    def __init__(self, name):
        self.stomach = []
        self.name = name

    def eat(self, food):
        self.stomach.append(food)
        print('Nom nom.')
```

```
>>> k=Knight("black")
>>> k.legs
2
>>> k.legs = 0
>>> k.legs
0
>>> Knight.legs
2
```

- Class attributes are visible in instances.
- re-binding attribute names in an instance creates a new instance attribute that hides the class attribute.

# Inheritance

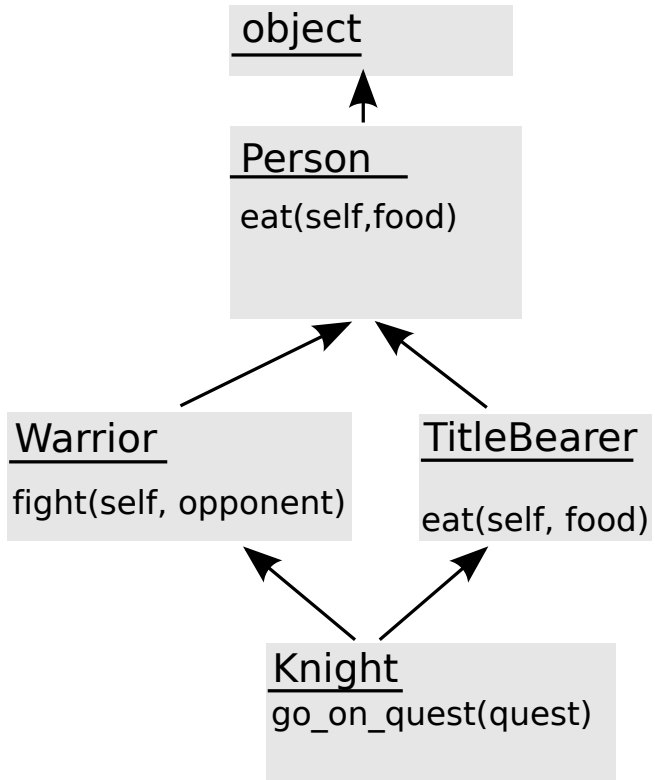
- Classes inherit from one or more base classes.
- Look up methods and class attributes in base classes if not found in class.

```
class Knight(Warrior, TitleBearer):

    def __init__(self, name):
        ...

    def go_on_quest(self,quest):
        ...
```

```
>>> k1 = Knight("Galahad")
>>> k2 = Knight("Robin")
>>> k1.fight(k2)
>>> k2.eat("coconut")
```



# Multiple Inheritance - Method Resolution Order

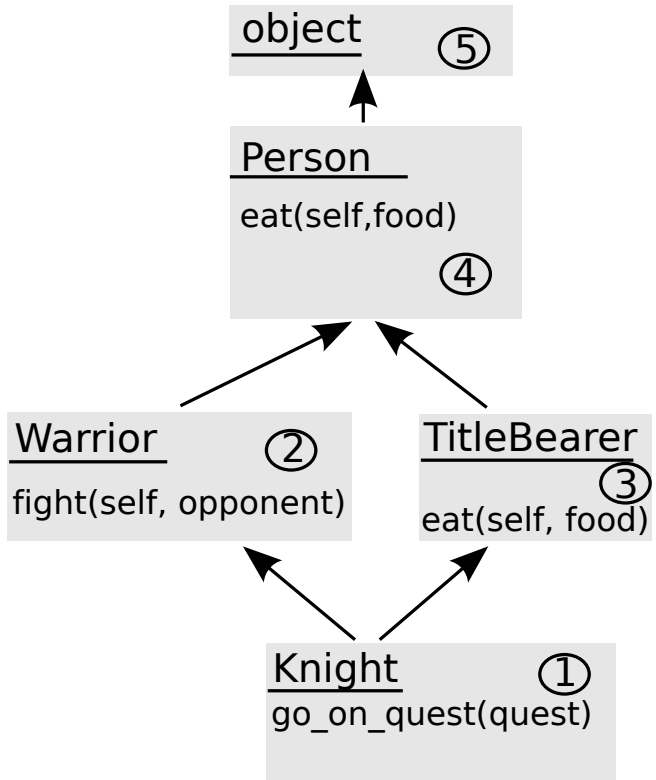
- Problem: Which eat method to use?
- Use first attribute found according to method resolution order.

```
class Knight(Warrior, TitleBearer):

    def __init__(self, name):
        ...

    def go_on_quest(self,quest):
        ...
```

```
>>> k1 = Knight("Galahad")
>>> k2 = Knight("Robin")
>>> k1.fight(k2)
>>> k2.eat("coconut")
```



# Built-in Types as Base Classes

```
class FlipDict(dict):
    """ A dictionary that can be inverted.
    """
    def flip(self):
        """ Return a dictionary of values to
            sets of keys.
        """
        res = {}
        for k in self:
            v = self[k]
            if not v in res:
                res[v] = set()
            res[v].add(k)
        return res
```

```
>>> x = FlipDict((1,'a'), (2,'b'), (3,'a'))
>>> x
{1: 'a', 2: 'b', 3: 'a'}
>>> x.flip()
{'a': set([1, 3]), 'b': set([2])}
```

# Polymorphism (1)

```
class Shape(object):
    def perimeter():
        """ abstract
            method
        """
        return
```

```
class Square(Shape):
    def perimeter():
        return self.side ** 2

class Circle(Shape):
    def perimeter():
        return self.radius * 2 * \
            math.pi
```

- Inheritance allows to override methods of base classes in different ways.
- May only know exact type of objects at runtime.
- Can verify if type has a certain (transitive) base class.

```
>>> x = Circle()
>>> isinstance(x, Shape)
True
```

# Calling Base Class Implementations of Overloaded Methods

- Sometimes we want to call the base class version of a method.
- This is often the case for `__init__`.
- Use unbound method attribute of the base class.

```
class Animal(object):
    def __init__(self, heads, tails,
        legs):
        self.heads = heads
        self.tails = tails
        self.legs = legs

class Cat(Animal):
    def __init__(self):
        Animal.__init__(self, 1, 1, 4)
```

```
>>> x = Cat()
>>> x.tails
1
```

# Polymorphism (2) - Duck Typing

- Python is dynamically typed. Any variable can refer to any object.
- Explicit type checking (`isinstance`) at runtime is considered bad style.
- Instead use 'duck typing'! (plus error handling).

## Duck Typing

*"When I see a bird that walks like a duck and swims like a duck and quacks like a duck, I call that bird a duck."*

- As long as an object implements functionality, its type does not matter.
- Example: Equality (==), convert to string (`str()`, iterators)

# Special methods (1)

- `__init__(self)` is called when an instance is created.
- `__str__(self)` returns a string representation of the object.
- `__repr__(self)` returns the 'official' string representation.

```
class FarmersMarket(object):
    def __init__(self, name, state, town, zipc):
        self.name = name
        self.state,self.town,self.zipc = state,town,\
            zipc
    def __str__():
        return '{0}\n{1}, {2} {3}'.format(name,town,
            state, zipc)
    def __repr__():
        return 'FarmersMkt:<{0}:{1},{2} {3}>'.format(
            name, town, state, zipc)
```

```
>>> str(mkt1)
CU Greenmarket
New York, NY 10027
>>> mkt1
FarmersMkt:<CU Greenmarket:New York,NY 10027>
```

# Special methods (2) - Comparisons

- `__eq__(self, other)` used for $==$ comparisons.
- `__lt__(self, other)` used for $<$ comparisons.
- `__le__`, `__gt__`, `__ge__`, `__ne__`

```
class Shape(object):
    def __eq__(self, other):
        return self.area() == other.area()
    def __neq__(self, other):
        return self.area() != other.area()

class Rectangle(Shape):
    def __init__(self, l, w):
        self.l, self.w = l, w
    def area(self):
        return self.l * self.w
```

```
>>> Rectangle(2,3) == Rectangle(1,6)
True
```

# Special methods (3) - Comparisons

- If none of the previous comparisons is defined, `__cmp__(self, other)` is called.
  - Return 0 of `self` and `other` are equal
  - negative integer if `self` $<$ `other`
  - positive integer if `self` $>$ `other`

```
class Shape(object):
    def __cmp__(self, other):
        return self.area() - other.area()

class Circle(Shape):
    def __init__(self, r):
        self.r = r
    def area(self):
        return self.r * 2 * math.pi
```

```
>>> Circle(1) < Rectangle(4,2)
True
```

# Special methods (4) - Hash functions

- `__hash__(self)` returns a hash code for the object.
- Hash code is used to index dictionaries / sets.
- Default: object id `id(object)`
- Every function that implements __hash__ has to implement __cmp__ or __eq__ and all equal object must have the same hash code.

```
class Rectangle(object):
    def __init__(self, w, h):
        self.w, self.h = w, h
    def __hash__(self):
        return 17 * self.h + 31 * self.w
    def __eq__(self, other):
        return self.__hash__() == other.__hash__()
    def __repr__(self):
        return "Rect:({0},{1})".format(self.w, self.h)
```

```
>>> set([Rectangle(1,2), Rectangle(1,2), Rectangle
    (2,1)])
set([Rect:(1,2), Rect:(2,1)])
```

# Special methods (4) - Hash functions

- `__hash__(self)` returns a hash code for the object.
- Hash code is used to index dictionaries / sets.
- Default: object id `id(object)`
- Every function that implements __hash__ has to implement __cmp__ or __eq__ and all equal object must have the same hash code.

```
class Rectangle(object):
    def __init__(self, w, h):
        self.w, self.h = w, h
    def __hash__(self):
        return 17 * self.h + 31 * self.w
    def __eq__(self, other):
        return self.__hash__() == other.__hash__()
    def __repr__(self):
        return "Rect:({0},{1})".format(self.w, self.h)
```

```
>>> set([Rectangle(1,2), Rectangle(1,2), Rectangle
    (2,1)])
set([Rect:(1,2), Rect:(2,1)])
```

# Implementing Iterators - The Iterator Protocol

- Need an `__iter__(self)` method that returns the iterator itself.
- Need a `next(self)` method that returns the next element.
  - If no element is left, calling `next(self)` raises a `StopIteration` exception.

```
class ReverseIterLst(list):
    def __iter__(self):
        self.index = len(self)
        return self
    def next(self):
        if self.index == 0:
            raise StopIteration
        else:
            self.index -= 1
            return \
             self[self.index]
```

```
>>> l = \
 ReverseIterLst([1,2,3])
>>> for x in l:
...     print x
...
3
2
1
```

Object Oriented Python

# Modules

# Modules

- Program can consist of multiple `modules` (in multiple files).
  - Independent groupings of code and data.
  - Can be re-used in other programs.
  - Can depend on other modules recursively.
- So far we have used a single module:
  - Used the interpreter's interactive mode.
  - Written single-file python programs.
- We have seen examples:

```
import sys
import random
import antigravity
```

# Structure of a Module File

- A module corresponds to any Python source file (no special syntax).
- The module 'aname' is typically in file 'name.py'.
- File can contain class and function definitions, code.
- Can contain a doc string (string in first nonempty line).

example_module.py

```
""" A module to illustrate modules.
"""
class A(object):
    def __init__(self, *args):
        self.args = args

def quadruple(x):
    return x**4

x = 42
print("This is an example module.")
```

# Importing and Using a Module

- `import modulename [as new_name]` imports a module and creates a module object (use near top of file).
- Unindented top-level code in module is executed (including class and function definitions).
- All defined variables/names (including class and function names) become attributes of the module.

```
>>> import example_module as ex
This is an example module.
>>> ex.x
42
>>> a = ex.A(1,2,3)
```

# Importing Specific Attributes of a Module

- `from modulename import attr [as new_name]` loads the module and makes `attr` (a class, function, variable...) available in the namespace of the importing module.

```
>>> from example_module import A
This is an example module.
>>> a = A(1,2,3)
>>> testmodule  # we don't get a module object
NameError: name 'testmodule' is not defined
```

- Can also import all attributes (considered bad style!)

```
>>> from example_module import *
This is an example module.
>>> a = A(1,2,3)
```

# Main Functions

- Problem: Modules often contain some test code that we do not want to run every time it is imported.
- Modules contain a special attribute `__name__`
- `__name__ == '__main__'` if this module is the first one loaded (i.e. passed to the interpreter on the command line).
- Always use the following main function idiom:

somemodule.py

```
def main():
    ...

if __name__ == "__main__:
    main()
```

# Packages

- Packages are modules that contain other modules as attributes.
- Packages therefore span trees of modules.
- A package corresponds to a directory. (i.e. the package `graphtools.directed.tree` is in the file `graphtools/directed/tree.py`).
- Package directories must contain a file `__init__.py` containing the module code (even if its empty).