Lecture 7.1: Introducing object-oriented programming

Classes and objects we have already met

- We have so far been programming with various built-in types: booleans, integers, floats, strings, lists, tuples, dictionaries, sets, etc.
- These are all *class types*. This means any particular example of a boolean, integer, float, etc. is an *object* of the *class* boolean, integer, float, etc.
- *Everything in Python is an object*, or equivalently, *everything in Python is an instance of a particular class*.
- In other words every integer object, e.g. 5, is an *instance* of the class integer and every string object, e.g. 'daisy', is an *instance* of the class string, etc. Let's use Python to verify this is indeed the case:

```python
a = False
print(type(a))
```

```
<class 'bool'>
```

```python
b = 5
print(type(b))
```

```
<class 'int'>
```

```python
c = 3.3
print(type(c))
```

```
<class 'float'>
```

```python
d = 'daisy'
print(type(d))
```

```
<class 'str'>
```

```python
e = [1, 2, 3]
print(type(e))
```

```
<class 'list'>
```

```python
f = (1, 2, 3)
print(type(f))
```

```
<class 'tuple'>
```

```python
g = {'name':'Joe'}
print(type(g))
```

```
<class 'dict'>
```

```python
h = {1, 2, 3}
print(type(h))
```

```
<class 'set'>
```

Interacting with objects through methods

- To implement some operation on a particular object we invoke one of its *methods* (in other words *we invoke a method on the object*).
- This involves writing `object_name.method_name(method_arguments)`.
- Which methods can be invoked on any particular object? Well that depends on the class of the object.
- It is the class that defines the behaviours, i.e. methods, that instances of that class support.
- The list of methods defined by a class tells us the things we can do with an instance of that class.
- To see a list of all the methods a particular object supports use `help(class_name)`, e.g. `help(str)` or `help(list)`.
- We have seen previously but, for review purposes, let's invoke some string methods on a particular string object:

```python
s = 'This is a string object, an instance of the string class'

print(s.count('a')) # Invoke the count method on object s

print(s.endswith('class')) # Invoke the endswith method on object s

print(s.find('string')) # Invoke the find method on object s

print(s.isnumeric()) # Invoke the isnumeric method on object s

print(s.split()) # Invoke the split method on object s

print(s.swapcase()) # Invoke the swapcase method on object s
```

```
4
True
10
False
['This', 'is', 'a', 'string', 'object,', 'an', 'instance', 'of', 'the', 'string', 'cla
tHIS IS A STRING OBJECT, AN INSTANCE OF THE STRING CLASS
```

Adding a new type to a program

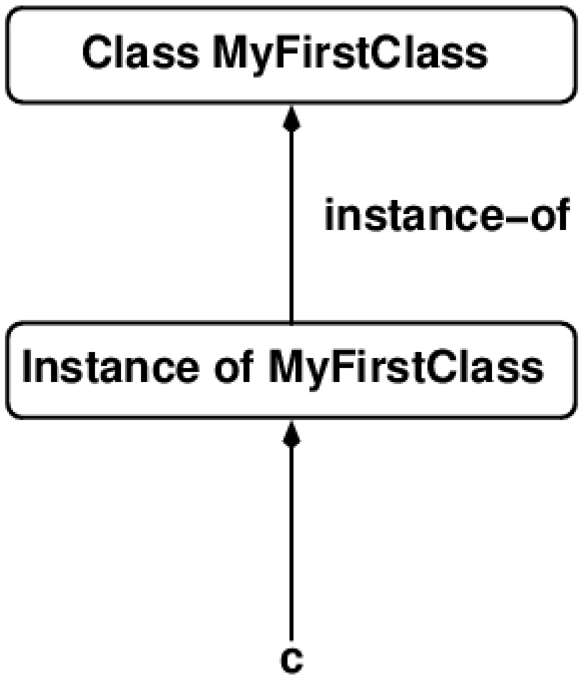
- Knowledge of Python's built-in types and their capabilities is essential to being a good Python programmer.
- However, sometimes, in order to solve a particular problem, Python's built-in types may not entirely suit and we would like to *add our own types* to programs in order to elegantly solve a particular problem.
- Since everything in Python is an object, i.e. an instance of some class type, so too our new types will also be class types.
- How do we define a new class in Python? With the `class` keyword.

```python
class MyFirstClass(object):
   pass
```

- The code above defines a new class called `MyFirstClass`.
- The class is empty (it contains only a place-holder `pass` statement so supports only trivial functionality) but it is still a valid class definition.
- (We ignore the `object` reference in the brackets and simply accept that, for now, all of our new class definitions will include it.)
- Note that in Python `class` statements are executable.
- Any `class` statements in a module are executed when that module is imported.
- Once a `class` statement has been executed a new type is defined and objects of that class type can be *instantiated* (i.e. created).
- To create an object of type `MyFirstClass` we call the class as if it were a function (see below).
- Calling the class as a function will instantiate an instance of that class and return a reference to it.
- Here we assign the reference to the variable *c*.
- Inspecting the type of the object *c* shows it is indeed an instance of the `MyFirstClass` class.

```python
c = MyFirstClass() # Invoke the class as a function to make an object
print(type(c))
```

```
<class '__main__.MyFirstClass'>
```



Adding another new type to a program

- Let’s define a (slightly more useful) class to represent the time in 24-hour format.
- This class defines a method (*functions* inside class definitions are called *methods*) that allows us to set the time on `Time` objects.

```
class Time(object):

   def set_time(time_object, hour, minute, second):
      time_object.hour = hour
      time_object.minute = minute
      time_object.second = second
```

- The `set_time()` method specifies four parameters i.e. it requires four arguments be passed to it in order for it to do its job:

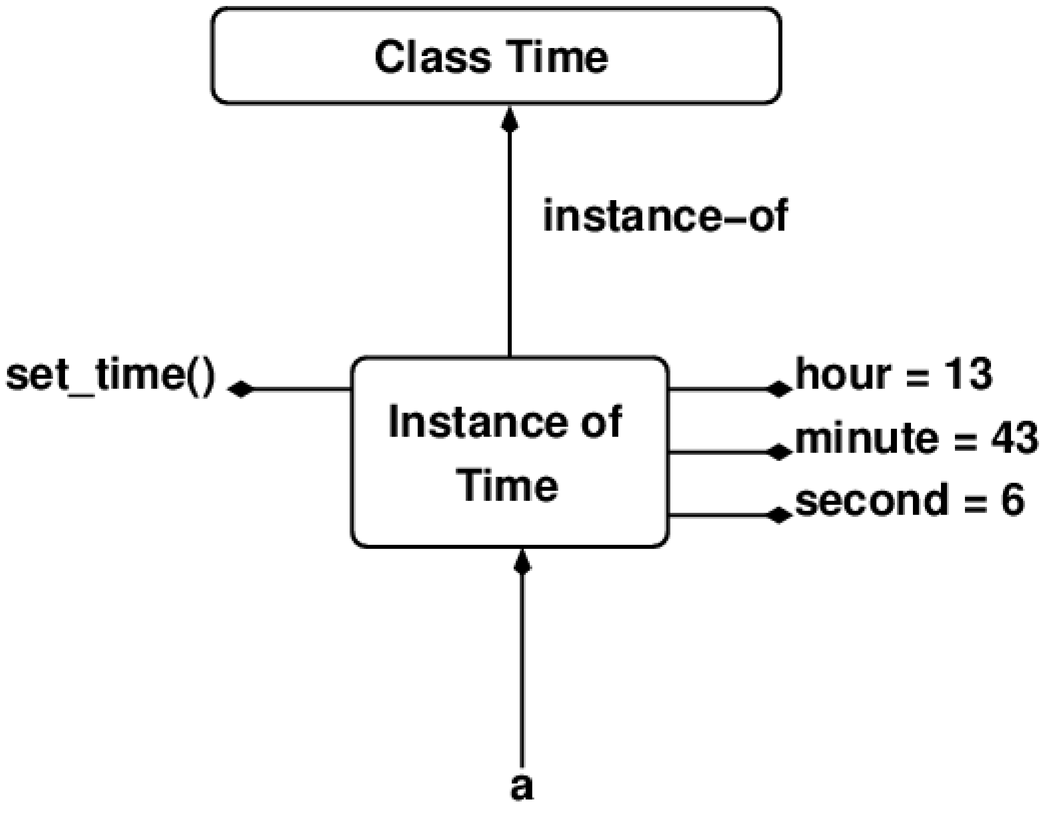
  1. The `time_object` whose time we are setting,
  2. the `hour` we want to set on the `time_object`,
  3. the `minute` we want to set on the `time_object`,
  4. the `second` we want to set on the `time_object`.

- As illustrated above, we access the hour, minute and second *attributes* of the `time_object` using the period operator, e.g. `time_object.minute = minute`.
- Do not confuse the `hour`, `minute` and `second` in the parameter list with `time_object.hour`, `time_object.minute` and `time_object.second`. The former are local variables while the latter are attributes attached to the `time_object`. There is no name clash.
- How can we use this new method? We can do so by writing `class_name.method_name(method_arguments)`.

```python
a = Time()
Time.set_time(a, 13, 43, 6)
print(a.hour)
print(a.minute)
print(a.second)
```

```
13
43
6
```

- We invoke the `set_time()` method of the `Time` class on the `a` object.
- The `a` argument to `set_time()` becomes the `time_object` parameter in the method definition (`13` becomes the `hour`, `43` the `minute` and `6` the `second`).
- When the method executes it updates a single object, in this case the object referenced by `a`.
- It updates the object by assigning values to its `hour`, `minute` and `second` attributes.
- We can represent the resulting situation with the following diagram where attributes and (instance) methods are attached to objects:



- Some terminology: the `set_time()` method is called an *instance method* because it acts upon an instance of the class.
- The instance an instance method acts on will always be the first parameter of the method.
- Some more terminology: `time_object.hour`, `time_object.minute` and `time_object.second` are called *instance variables* because they are variables attached to a particular instance of a `Time` object. They are also referred to as an object's *data attributes*.

Multiple objects of the same type

- There is nothing to stop us making multiple objects of type `Time`.
- *Crucially, attached to each object is its own distinct set of instance variables (data attributes).*

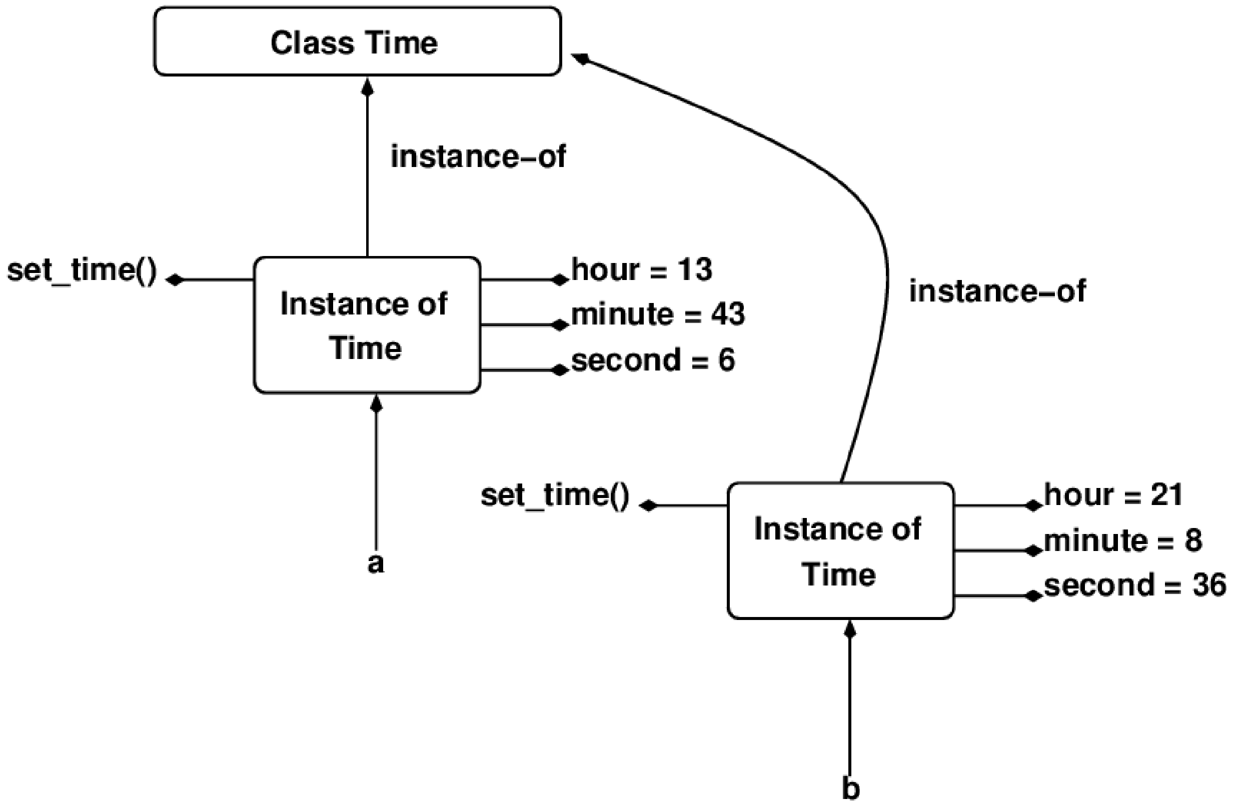
```
a = Time()
Time.set_time(a, 13, 43, 6)
print('{:02d}:{:02d}:{:02d}'.format(a.hour, a.minute, a.second))

b = Time()
Time.set_time(b, 21, 8, 36)
print('{:02d}:{:02d}:{:02d}'.format(b.hour, b.minute, b.second))

c = Time()
Time.set_time(c, 3, 4, 7)
print('{:02d}:{:02d}:{:02d}'.format(c.hour, c.minute, c.second))
```

```
13:43:06
21:08:36
03:04:07
```

- Above we instantiate three objects, `a`, `b` and `c`, of the class `Time`.
- We can create as many instances of a class as we wish.
- As a result a class is sometimes referred to as an *object factory*.
- A class definition serves as a *blueprint* for generating objects.
- As we have seen, a new object is generated whenever we call the class as a function.
- Note again how the object being updated serves as an argument to the `set_time()` method. Thus each time the latter method is invoked above it is setting the data attributes of a *different object*.
- We can represent the situation (for `a` and `b`) as follows:



Adding a method to print the time

- Let's add a function that prints the time.
- Where should we add this function?
- Since the `Time` class encapsulates everything related to processing `Time` objects it makes sense to add it there.
- This is what *object oriented programming* is about.
- Our `Time` class is where we bundle together all `Time`-related data and functions.
- Since functions in a class are called methods, our new function is really a method.
- Here is the resulting expanded class, now boasting two methods.

```
class Time(object):

   def set_time(time_object, hour, minute, second):
      time_object.hour = hour
      time_object.minute = minute
      time_object.second = second

   def show_time(time_object):
      print('The time is {:02d}:{:02d}:{:02d}'.format(
         time_object.hour, time_object.minute, time_object.second))
```

- This method specifies a single parameter i.e. the object's whose time we want to print.

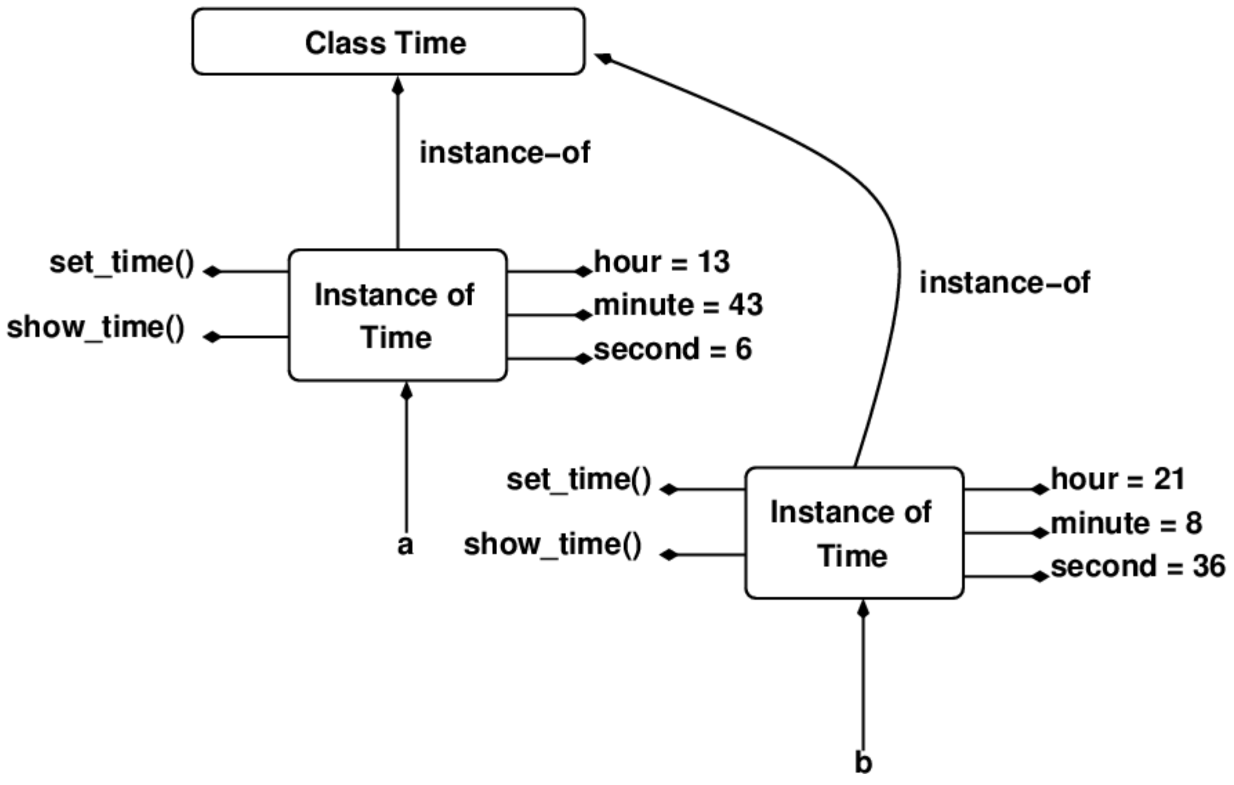
```
a = Time()
Time.set_time(a, 13, 43, 6)
Time.show_time(a)

b = Time()
Time.set_time(b, 21, 8, 36)
Time.show_time(b)

c = Time()
Time.set_time(c, 3, 4, 7)
Time.show_time(c)
```

```
The time is 13:43:06
The time is 21:08:36
The time is 03:04:07
```

- We depict below the change to our objects where a new instance method called `show_time()` is attached to each.



Is there a handier way to call methods on an object?

- The way we are invoking methods on our `Time` objects requires we name both the class (e.g. `Time`) and the object (e.g. `a`).

```
Time.show_time(a)
```

```
The time is 13:43:06
```

- Remember how we earlier invoked methods on string (and other) objects?
- It seemed handier because it did not require us naming the `str` class and, interestingly, the string object `s` did not *appear* to be an argument for the method.

```
s = 'This is a string object, an instance of the string class'
print(s.count('a')) # Invoke the count method on object s
```

```
4
```

- It turns out, however, that `s.count('a')` is really just shorthand for `str.count(s, 'a')`.
- We can adopt the same approach with objects of our `Time` class i.e. rather than calling the `Time` class's methods by explicitly referencing the class name we can instead invoke our methods directly on an object of the `Time` class.

```
a = Time()
a.set_time(13, 43, 6) # Time.set_time(a, 13, 43, 6)
a.show_time()         # Time.show_time(a)

b = Time()
b.set_time(21, 8, 36) # Time.set_time(b, 21, 8, 36)
b.show_time()         # Time.show_time(b)

c = Time()
c.set_time(3, 4, 7)   # Time.set_time(c, 3, 4, 7)
c.show_time()         # Time.show_time(c)
```

```
The time is 13:43:06
The time is 21:08:36
The time is 03:04:07
```

- To understand how to write and call methods it is vital you appreciate that the code above and the corresponding comments are equivalent.
- Note when we call `a.show_time()` or `a.set_time(13, 43, 6)` the `show_time()` and `set_time()` methods still require the object `a` be passed as an argument.
- **Thus when we invoke an instance method on a Python object that object is automatically supplied as the first argument to the method**.
- This means that whenever we invoke an instance method on an object **we supply one fewer arguments than the number of parameters listed in the method definition** inside the class.
- We do so because Python automatically supplies the missing object argument on our behalf.
- What is *an instance method*? An instance method is one that acts upon a particular instance of an object. It is a method whose first parameter is the object operated upon.
- In our `Time` class both methods `set_time()` and `show_time()` are instance methods and the first parameter of each is a `time_object`.
- A class's methods are by default instance methods whose first parameter will always be the instance on which the method has been invoked.
- By convention the first parameter of instance methods is named `self`. Thus our `Time` class should really be implemented as follows.

```
class Time(object):

   def set_time(self, hour, minute, second):
      self.hour = hour
      self.minute = minute
      self.second = second

   def show_time(self):
      print('The time is {:02d}:{:02d}:{:02d}'.format(
         self.hour, self.minute, self.second))

a = Time()
a.set_time(13, 43, 6)
a.show_time()
```

```
The time is 13:43:06
```

- We will from now on write and invoke our instance methods as outlined in this section.