

COM6115: Text Processing

OO Programming: Python basics

Extended presentation

Includes some additional background and motivation for OOP, plus basics of using inheritance in Python

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Let's talk about meaning

The picture shows a (simplified) example of a *semantic network*.

This is a *knowledge representation* used in AI, which has:

- **nodes**: represent *concepts* or *instances*
- **links**: represent relations between concepts:

- ◇ **instance**: indicates class *membership*

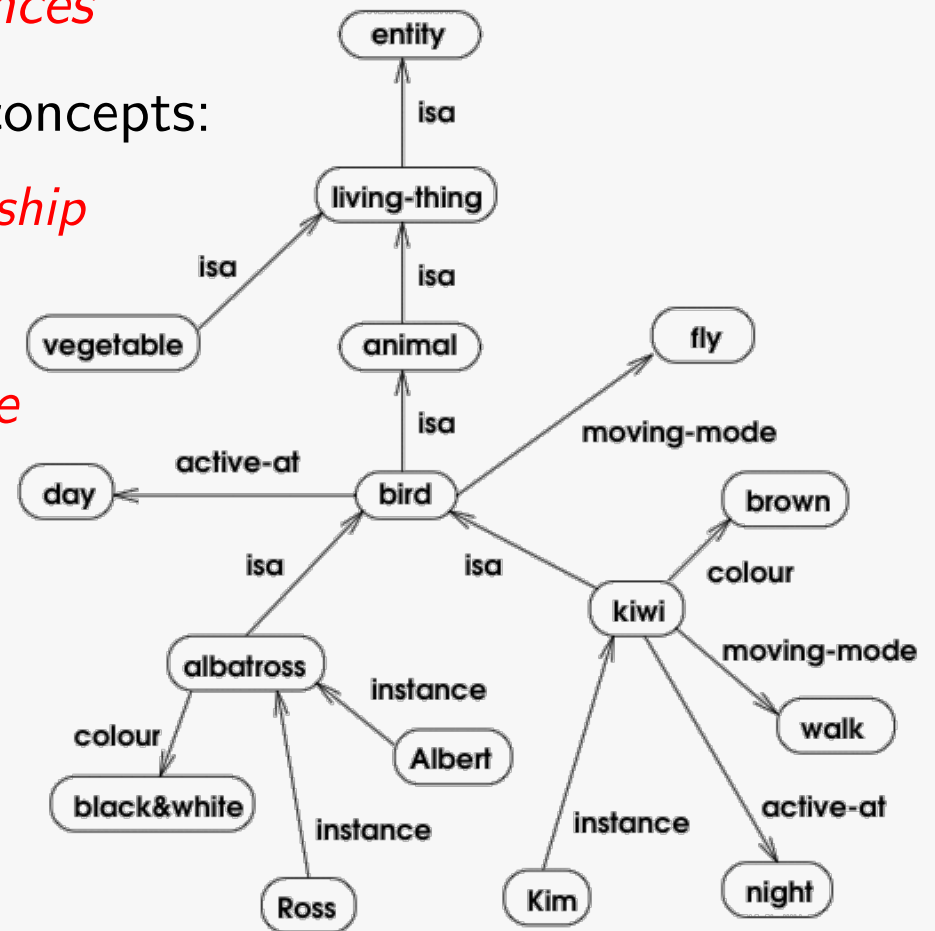
- ◇ **isa**: indicates class *inclusion*

- nodes *inherit* properties from *above*

e.g. know albatrosses fly,
because we know birds do!

- ◇ but can also encode *exceptions*
(Kiwis don't fly!)

- ◇ gives *economy* of representation
i.e. avoids *redundancy*



Let's talk about meaning (ctd)

- Semantic networks also used in:
 - ◇ Psychology: esp. models of human knowledge / memory
 - ◇ Linguistics: models of language meaning
- Related ideas explored in Philosophy
 - ◇ esp. under headings of Taxonomy and Ontology
- The *Semantic Web* relies critically on *ontologies*
 - ◇ ontologies: a form of knowledge representation (related to SNs)
 - ◇ used to associate *semantics* (meaning) with web content
 - ◇ so machines can address this in a more *intelligent* fashion
- Why is he telling he telling us this stuff??
 - ◇ this is supposed to be a programming course, isn't it?!
- ... *because* related ideas adopted in work on programming
 - ◇ giving approach known as *Object Oriented Programming*
 - ◇ now the *dominant paradigm*; includes e.g. Java, C++

Let's talk about meaning (ctd)

- To reiterate the main points ...
- Key notion: *CONCEPT*
 - ◇ general idea of a *class of things* with particular properties in common
e.g. *person, bird, animal, vehicle, chair, gun, etc.*
- A *concept* has *INSTANCES*
 - ◇ actual occurrences in the world
e.g. concept *person* has *instances* such as: *Me! You! Obama!*
- For a given concept, expect certain *attributes*
 - e.g. for *person*, expect: *age, gender, height, etc.*
 - ◇ a specific *actual* person will *instantiate* these attributes
i.e. provide specific *values* for them
- Concept may also have associated *expected behaviours*
 - e.g. for *person* — *walk, talk, read, Hoover, give birth*
 - e.g. for *bird* — *fly, lay eggs*

Object Oriented Programming

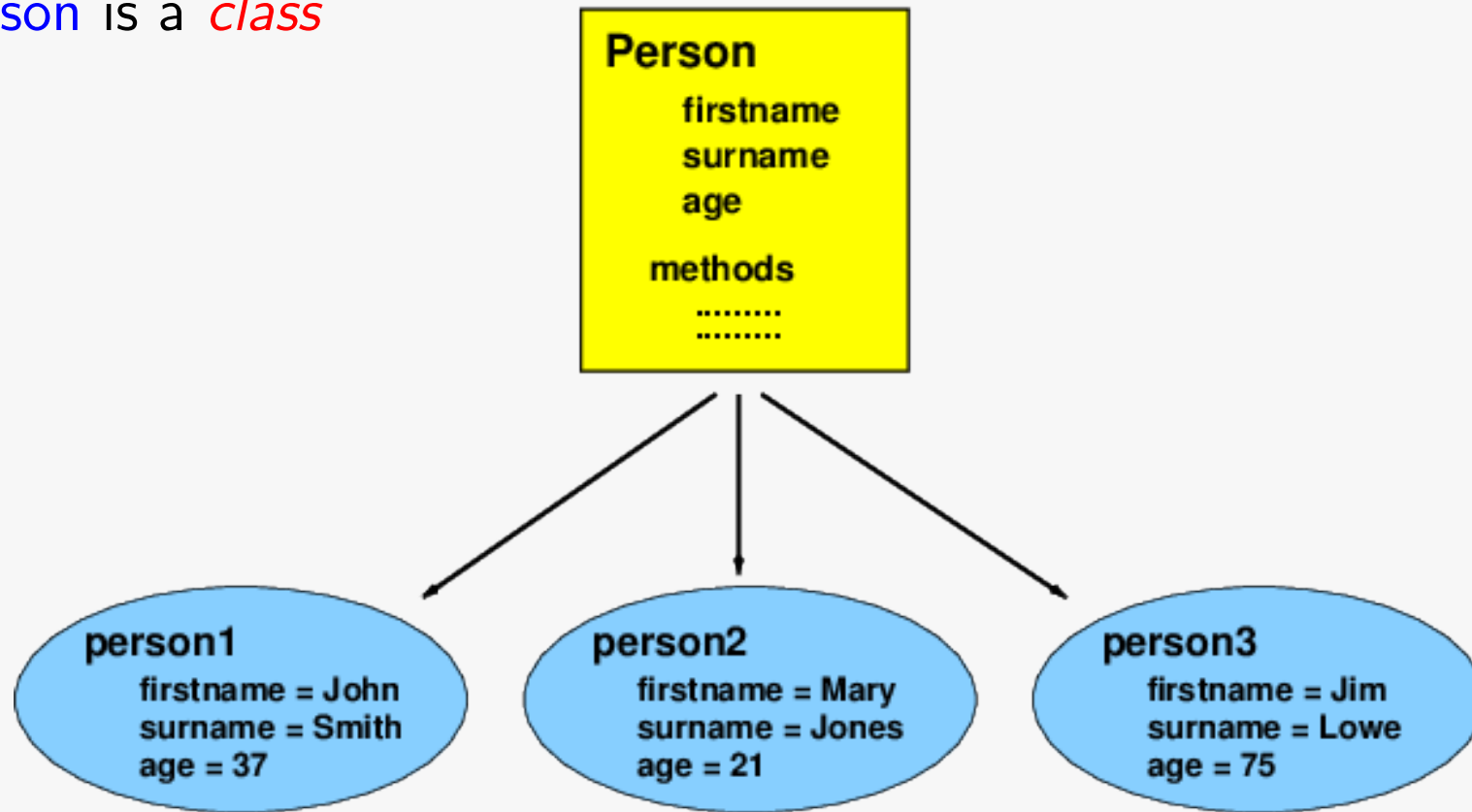
- A *programming paradigm* is a particular *approach to* or '*style*' of programming
- So far, we have used a *procedural programming* paradigm
 - ◇ focus is on writing *functions* or *procedures* to operate on data
- Alternative paradigm: *object oriented programming*
 - ◇ over last 20 years, has become the *dominant* programming paradigm
 - ◇ developed to make it easier to create and/or modify large, complex software systems
- In Object Oriented Programming (OOP):
 - ◇ focus is on creating *objects*
 - ◇ *objects* contain both *data* *and* *functionality*

Objects and Classes — *an example*

- A **Person** class might:
 - ◇ have *attributes* (variables) for:
 - name, age, height, address, tel.no., job, etc
 - ◇ have *methods* (functions) to:
 - update address
 - update job status
 - work out if they are adult or child
 - work out if they pay full fare on the bus
 - *etc.*
- There might be many *objects* of the **Person** class
 - ◇ each representing a *different person*
 - *with different specific data*
 - ◇ but all store *similar information* and *behave similarly*

Objects and Classes — *an example*

- Person is a *class*



- ◇ person1, person2 & person3 are *objects*

Defining Classes in Python

- Definition opens with keyword `class` + class name
- Class needs an *initialisation* method
 - ◇ called when an instance is created
 - ◇ has 'special' name: `__init__`
 - ◇ establishes the *attributes* (i.e. vars) belonging to objects

```
class Person:
    def __init__(self):
        self.firstname = None
        self.surname = None
        self.age = None
        self.species = 'homo sapiens'
```

- ◇ note use of *special variable* `self` here
- ◇ it is the instance's way of *referring to itself*
e.g. `self.species` above means "the `species` attribute of *this instance*"

Defining Classes in Python (ctd)

- `Person` class with its *initialisation* method, again:

```
class Person:
    def __init__(self):
        self.firstname = None
        self.surname = None
        self.age = None
        self.species = 'homo sapiens'
```

- Can create an `object` (i.e. *instance*) of this class as follows:

```
>>> p1 = Person()
>>> p1.species
'homo sapiens'
```

- ◇ here, call to `Person()` creates a new instance of the `Person` class
 - the `__init__` method is called automatically, to initialise the object
 - the object is assigned to `p1`

Defining Classes in Python (ctd)

- Last example again:

```
>>> p1 = Person()  
>>> p1.species  
'homo sapiens'
```

- ◇ statement `p1.species` accesses `p1`'s species *attribute* directly
i.e. that value is accessed in the e.g. above, and printed by the interpreter

- Can think of objects as being like “*bundles of data*”

- ◇ each object is a different *bundle of data*, storing info about a *different instance of the class*
- ◇ Note extra *self* arg in:

```
class Person:  
    def __init__(self):  
        self.firstname = None  
        ...
```

- is object's way of talking about *itself*, i.e. *the bundle that I am*
- info stored with a `self.` attribute becomes *part of the bundle*
— is carried around with it, and is *always available*

Defining Classes in Python (ctd)

- More generally, **initialisation** method can have *parameters*
 - ◇ can be used to set *initial values of attributes*

```
def __init__(self, firstname, surname, age):  
    self.firstname = firstname  
    self.surname = surname  
    self.age = age  
    self.species = 'homo sapiens'
```

- ◇ example of creating an instance:

```
>>> p1 = Person('John', 'Smith', 37)  
>>> p1.firstname  
'John'  
>>> p1.age  
37
```

- ◇ note `__init__` has 4 args, but 3 given when object created – *Why?*
 - first `self` is left *implicit* – stands for *this object* (i.e. *bundle of data*)
 - that object stored as `p1`, can access bundle data directly, e.g. `p1.age`

Defining Classes — *adding functionality*

- Can define (more) functions — in OOP, are known as *methods*

```
class Person:
    def __init__(self):
        ...

    def greeting_informal(self):
        print('Hi', self.firstname)

    def greeting_formal(self):
        print('Welcome, Citizen', self.surname)
```

- ◇ as before, *self* appears as 1st arg of every method
 - shows that this is an *object method*, i.e. will be *called from an object*
- ◇ *self* again refers to *this instance*, allowing access to *its own data*
 - thus, *self.firstname* above *means* value of *my firstname attribute*
 - that value, stored with this bundle of data, is accessed and used

Defining Classes — *adding functionality* (ctd)

- Example: here create two instances:

```
>>> p1 = Person('Harry', 'Potter', 12)
>>> p2 = Person('Hermione', 'Grainger', 12)
```

- Call newly defined methods from instances:

```
>>> p1.greeting_informal()
Hi Harry
>>> p1.greeting_formal()
Welcome, Citizen Potter
>>> p2.greeting_formal()
Welcome, Citizen Grainger
```

- ◇ note that 1st `self` arg from definition again absent – *i.e. is left implicit*
- ◇ when `p1.greeting_informal()` is called, `p1` stores an instance, and `self` aspects of definition are *about that instance*
- ◇ thus, method calls access data (e.g. `surname`) from given instance (`p1` or `p2`), and output depends on that

Defining Classes — *adding functionality* (ctd)

- Another method ...

```
class Person:
    ...

    def greeting_age_based(self):
        if self.age < 18:
            print('Welcome, Young', self.firstname)
        elif self.age > 60:
            print('Welcome - oh Venerable', self.firstname)
        else:
            self.greeting_formal()
```

- ◇ here see behaviour that *uses* instance data (*firstname*) and that *is conditioned on* instance data (*age*)
- ◇ note: 'else' case *calls* another method of the instance
 - does so in form: *self.greeting_formal()*
 - uses *self*, as it is *this object's* method being used
 - but *self* is *prefixed*, not supplied as arg

Defining Classes — *adding functionality* (ctd)

- Example

- ◇ First create three instances:

```
>>> p1 = Person('Harry', 'Potter', 12)
>>> p2 = Person('Sirius', 'Black', 38)
>>> p3 = Person('Minerva', 'McGonagall', 66)
>>>
```

- ◇ Call method – behaviour is conditioned on the person's age:

```
>>> p1.greeting_age_based()
Welcome, Young Harry
>>> p2.greeting_age_based()
Welcome, Citizen Black
>>> p3.greeting_age_based()
Welcome - oh Venerable Minerva
>>>
```

Defining Classes with Inheritance

- Recall the `Person` class:

```
class Person:
    def __init__(self, firstname, surname, age):
        self.firstname = firstname
        self.surname = surname
        self.age = age
        self.species = 'homo sapiens'

    def greeting_informal(self):
        print('Hi', self.firstname)

    def greeting_formal(self):
        print('Welcome, Citizen', self.surname)

    def greeting_age_based(self):
        ...
        ...
```


Defining Classes with Inheritance (ctd)

- Consider that we might want to define a class **Wizard**
 - ◇ **Wizards** have *much in common with Persons*, e.g.:
 - have *firstnames, surnames, ages, etc* that must be stored
 - also *exchange greetings*, etc.
 - ◇ **But** also *differ* from ordinary Persons (muggles) *in various ways*
 - can cast *spells*, etc.
- Could simply define **Wizard** class from scratch
 - e.g. specifying *firstname, surname, age, etc attributes*
 - e.g. methods for *greetings*, etc
 - ◇ **BUT** such code will be *highly redundant* with that for **Person** class
- **ALTERNATIVE:** use *inheritance*
 - ◇ **Wizard** class inherits from **Person** class – provides *basic set up*
 - ◇ this base is then *modified*, e.g. with *new attributes, new methods*

Defining Classes with Inheritance (ctd)

- Following `Wizard` class *inherits* from the `Person` class

```
class Wizard(Person):  
    def __init__(self, firstname, surname, age):  
        self.firstname = firstname  
        self.surname = surname  
        self.age = age  
        self.species = 'homo magicus'
```

- ◇ starts essentially as a *copy* of the `Person` class
 - say `Wizard` *inherits from* the `Person` class
- ◇ can then *overwrite* methods of `Person` class, to modify behaviour
 - above code defines the `__init__` method
 - this definition *overwrites* definition from the `Person` class
- ◇ can add new methods, to add new behaviour
- In above example:
 - ◇ `Person` is the *more general* class — it is the *superclass*
 - ◇ `Wizard` is the *more specific* class — the *subclass*

Defining Classes with Inheritance (ctd)

- Wizard class, again — *inherits* from Person class

```
class Wizard(Person):  
    ...  
    def greeting_formal(self):  
        print('Welcome, Magician', self.surname)
```

- Above code overrides `greeting_formal` method of `Person` class:

e.g. compare:

```
>>> p1 = Person('Harry', 'Potter', 12)  
>>> p1.greeting_formal()  
Welcome, Citizen Potter
```

with:

```
>>> p1 = Wizard('Harry', 'Potter', 12)  
>>> p1.greeting_formal()  
Welcome, Magician Potter
```

Defining Classes with Inheritance — *initialisation*

- By default, *inherit* `__init__` method of *superclass*
 - ◇ so this works exactly as before
- Alternatively, can choose to *redefine* it, as we did above, i.e. in:

```
class Wizard(Person):  
    def __init__(self, firstname, surname, age):  
        self.firstname = firstname  
        self.surname = surname  
        self.age = age  
        self.species = 'homo magicus'
```

- ◇ new definition *overwrites* old definition, in usual way
- ◇ **BUT** some of work done by this `__init__` method is the *same* as work done by the *superclass* `__init__` method
 - i.e. there is some *redundancy*

Defining Classes with Inheritance — *initialisation* (ctd)

- Some *redundancy* between `__init__` methods of the `Wizard` and `Person` classes in preceding example:

```
class Person:
    def __init__(self, firstname, surname, age):
        self.firstname = firstname
        self.surname = surname
        self.age = age
        self.species = 'homo sapiens'
```

```
class Wizard(Person):
    def __init__(self, firstname, surname, age):
        self.firstname = None
        self.surname = None
        self.age = None
        self.species = 'homo magicus'
```

Defining Classes with Inheritance — *initialisation* (ctd)

- It may be that we want to *change only a part* of the *initialisation behaviour* of the *superclass*
 - ◇ in that case, can invoke *superclass* `__init__` method *directly*
 - method performs its usual initialisation of current data bundle
 - ◇ then have additional commands to modify the initialisation
- Example: new `__init__` method definition for *Wizard* class:

```
class Wizard(Person):  
    def __init__(self, firstname, surname, age):  
        Person.__init__(self, firstname, surname, age)  
        self.species = 'homo magicus'
```

- ◇ definition invokes the superclass (*Person*) `__init__` method with call:
`Person.__init__(self, firstname, surname, age)`
- ◇ note how *self* special var is explicitly passed as first argument

Defining Classes with Inheritance — *adding extra methods*

- Can also add completely *new methods*
 - ◇ to add functional behaviour that doesn't exist for superclass

```
class Wizard(Person):  
    ...  
  
    def stun(self):  
        print('Expelliarmus!')
```

- ◇ here, instances of `Wizard` class have a `stun` method
- ◇ instances of `Person` class have no such method

Defining Classes — *FURTHER* inheritance

- Can use inheritance *again*, to build further classes *on top of* the `Wizard` class, e.g.

```
class HogwartsTeacher(Wizard):  
    def __init__(self, firstname, surname, age, subject):  
        Wizard.__init__(self, firstname, surname, age)  
        self.subject = subject  
  
    def greeting_formal(self):  
        print('Welcome, Professor', self.surname)
```

- Some example behaviour:

```
>>> p2 = HogwartsTeacher('Severus', 'Snape', 38, 'potions')  
>>> p2.subject  
'potions'  
>>> p2.greeting_formal()  
Welcome, Professor Snape
```


What problem does OO Programming solve?

- In simpler '*imperative*' (non-OO) programming:
 - ◇ program may be one “long” list of commands
 - ◇ might group smaller sections of statements into *functions* / *subroutines*
 - ◇ common for data to be '*global*'
 - i.e. accessible from any part of the program
 - hence, any statement/function might modify any piece of data
- Found to be very difficult to build large programs
 - ◇ approach allows *bugs* to have *far-reaching consequences*
 - ◇ may be very hard to track down
- Example: large program might require several programmers
 - ◇ work on different parts of code
 - ◇ one programmer's code makes change to data
 - ◇ second programmer does not anticipate this
 - second programmer's code now crashes *or*
 - appears to work but produces incorrect results

What problem does OO Programming solve? (ctd)

- Solution to problem through *modularity*:
 - ◇ break code down into suitably-sized chunks: *modules*
 - ◇ limit interactions between different components
- *Object-Oriented Programming* is most successful approach to achieving *modularity*
 - ◇ modules realised as *Classes*
 - ◇ group functionality / data-handling together
 - ◇ external code should not interfere with 'inner workings' of class
 - ◇ rather, should only access/modify data stored by class via *methods* that the class provides
 - ◇ these methods together constitute an *interface* for external code to use the class
 - ◇ in theory, I should be able to change inner workings of my class, without affecting external code that uses my class
 - i.e. provided interface stays the same, and code delivers same functionality

Inheritance and Real-world Programming Problems

- In lab session, will see interesting case where *inheritance* is useful, i.e.
 - ◇ superclass of `MovingShapes`
 - ◇ specific shapes (e.g. `Triangle`, `Square`, etc), that *inherit* from it
 - but also have *own special behaviour*
 - ◇ that's a very specialised, abstract example
 - ◇ but is *inheritance* needed for real-world programming tasks?
- *EXAMPLE:*
 - ◇ Company wants to keep records of its employees (past and present)
 - ◇ BUT, company has various kinds of employee, e.g.
 - employee (standard, full-time)
 - employee (standard, part-time)
 - employee (executive)
 - employee (retired)
 - employee (zero-hours contract worker)

Inheritance and Real-world Programming Problems (ctd)

- *EXAMPLE (continued) ...*

- ◇ Records of different employee types will have much *in common* — both for *information stored*, and *actions required*
 - e.g. name, D.O.B., address, etc
 - e.g. function to update address, etc
- ◇ But records of different employee types will also have *differences* — again, w.r.t. both *information* and *actions*
 - e.g. executive may need additional fields for “type of company car”, “expenses quota”, etc
 - e.g. different National Insurance contributions calculations may be needed, say, for “zero-hours” vs. “full-time” employees
- ◇ Hence, want:
 - *superclass* for `Employee_Record`, to capture the commonality
 - *subclasses* for different employee types
 - so different characteristics can be handled, without redundancy

Organising your Code via OOP

- Your programming task may not be complicated enough to need **inheritance**
- Even so, **OO Classes** are an excellent way to organise your code
- Without **OOP**, may have large collection of functions
 - ◇ must always check what is the right data to provide as input
 - ◇ must collect and store results of function calls, etc
- Often, much tidier to collect together as a **Class**
 - ◇ **initialisation** method can define (and initialise) all attributes needed to store data to be handled
 - ◇ then just provide as many methods as needed, to operate on data, with results often being stored back into object
 - ◇ conceptually, a much cleaner way to work

Reading

- Recommended source for module is:
 - ◇ *How to Think Like a Computer Scientist: Learning with Python 3.*
By Peter Wentworth, Jeffrey Elkner, Allen B. Downey, & Chris Meyers.
 - ◇ available free, on-line: see module homepage for link
- This week's reading:
 - ◇ Chs. 15, 16