COMP 1531
Software Engineering Fundamentals

Week 03 Wednesday

Domain Modelling using Object Oriented Design Techniques

Domain model

- Also referred to as a conceptual model or domain object model

- Provides a visual representation of the problem domain, through decomposing the domain into key concepts or objects in the real-world and identifying the relationships between these objects

Requirements Analysis vs Domain modelling

- Requirements analysis determines “how users will interact with system-to-be” - (external behavior)

- Domain modelling determines “how elements of system-to-be interact to produce the external behaviour” (internal behavior)

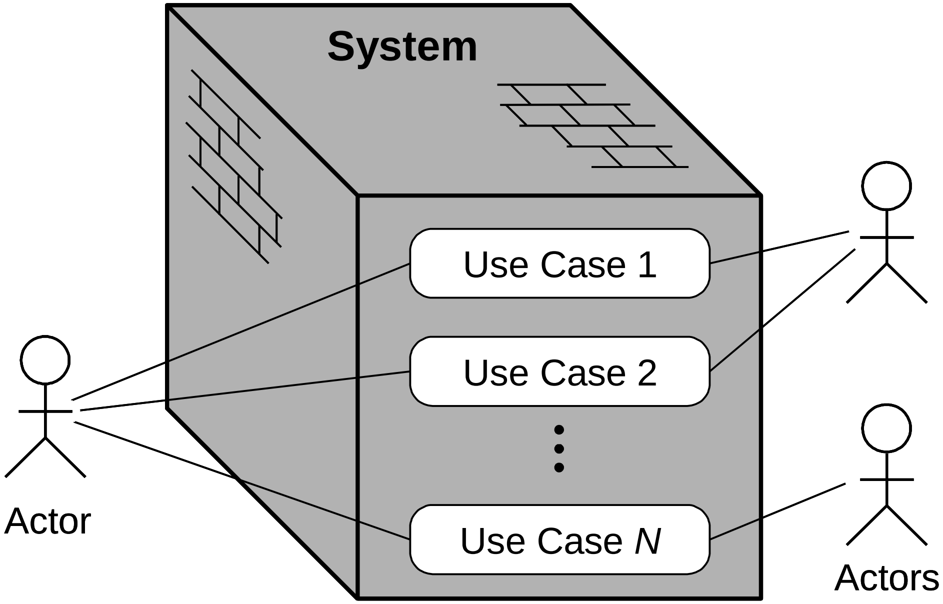
- Requirements analysis and domain modelling are mutually dependent - domain modelling supports clarification of requirements, whereas requirements help building up the model.

Use Cases vs. Domain Model

In **use case analysis**, we consider the system as a “**black box**”

In **domain analysis**, we consider the system as a “**transparent box**”

(a)



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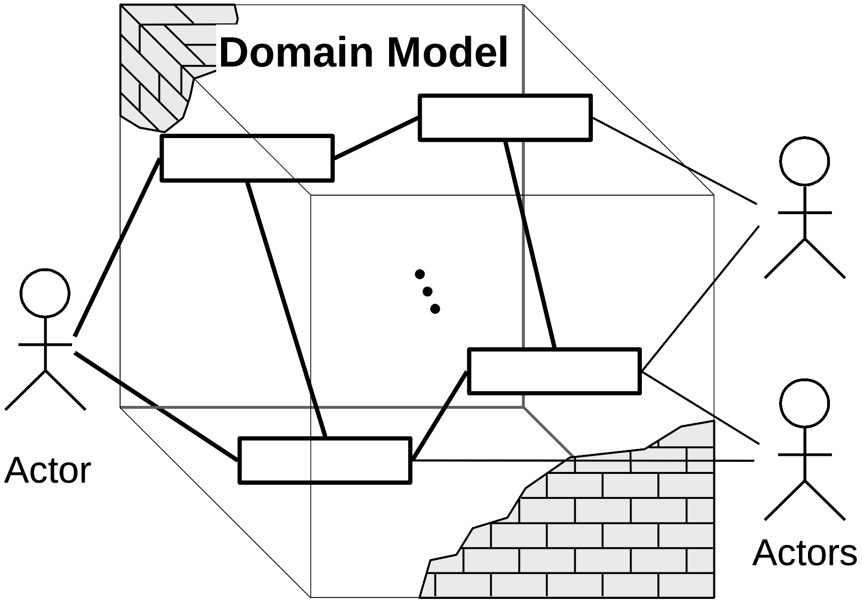
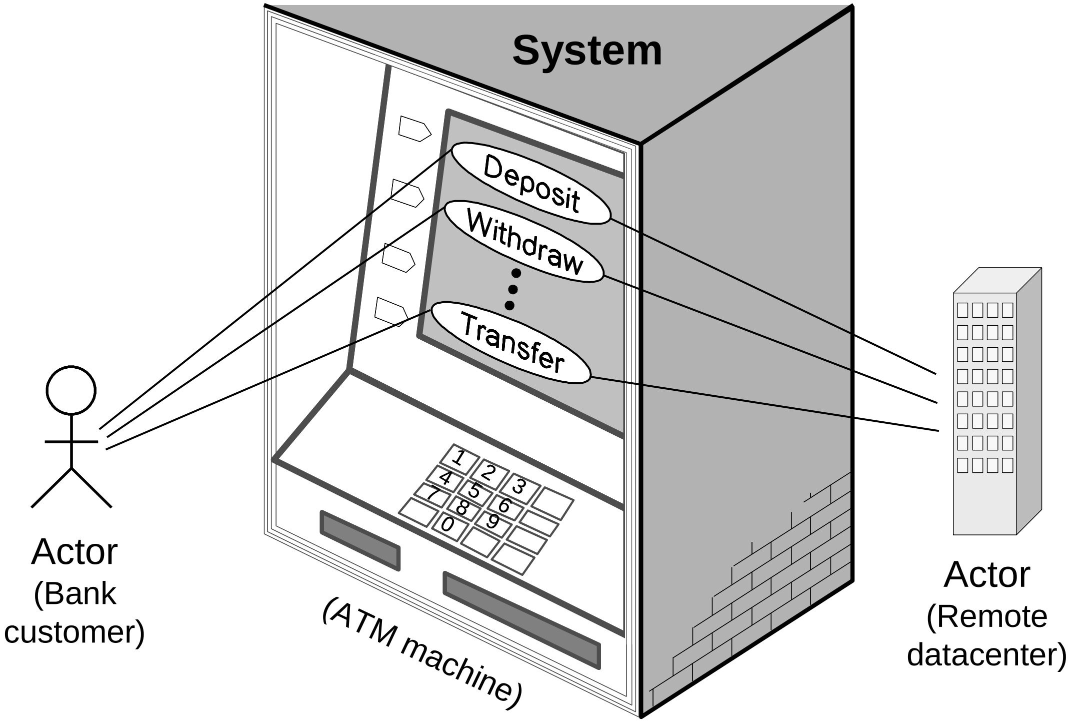
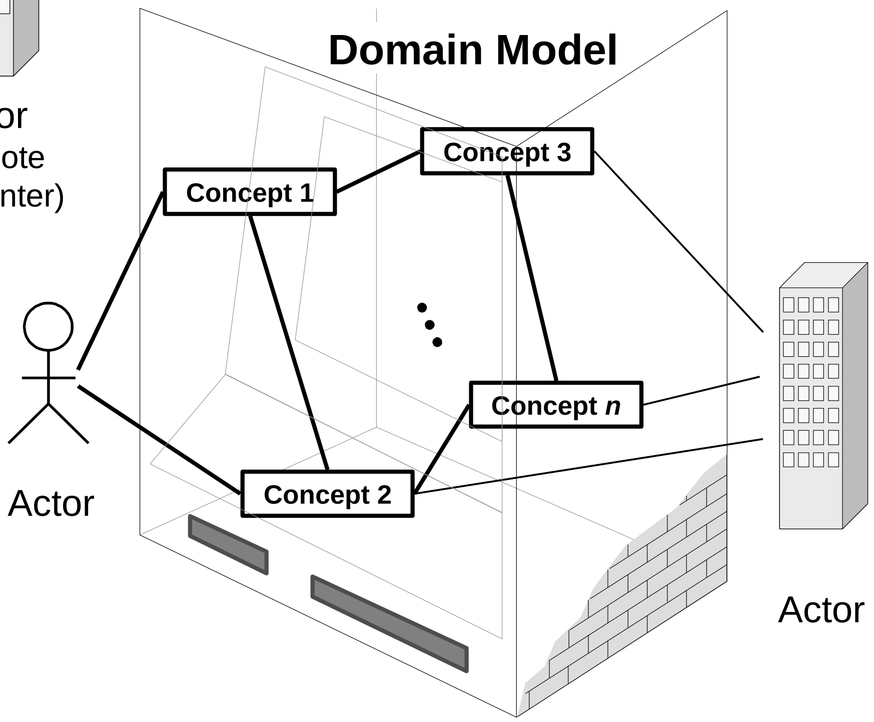


Example: ATM Machine



(a)



(b)

Benefits of a Domain model

- Triggers high-level discussions about what is central to the problem (the core domain) and relationships between sub-parts (sub-domains)

- Ensures that the system-to-be reflects a deep, shared understanding of the problem domain as the objects in the domain model will represent domain concepts

- Importantly, the common language resulting from the domain model, fosters unambiguous shared understanding of the problem domain and requirements among business visionaries, domain experts and developers

How do we create a domain model?

One widely adopted technique is based on the **object-oriented design** paradigm

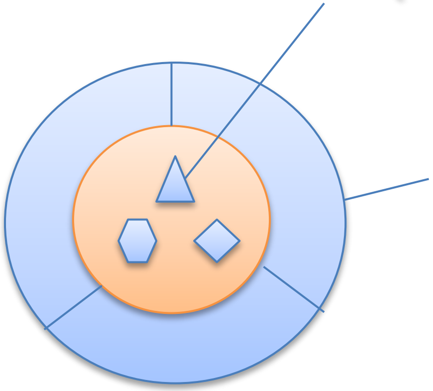
Object Oriented Design

- ***Objects*** are real-world entities and could be
  - Something tangible and visible e.g., your car, phone, apple or pet.
  - Something intangible (you can't touch) e.g., account, time

- Every object has:
  - *attributes:* properties of the object e.g., model number, colour, registration of a car or colour, age, breed of a dog
  - *behaviour* – what the object can do (or methods) e.g., a duck can *fly*, a dog can *bark,* you can *withdraw* or *deposit* into an account
- Each object encapsulates some *state* (the *currently assigned values* for its attributes) ; gives the object its identity *(as state of one object is independent of another)*

Object Oriented Design

- Identify your domain
- Identify objects



attributes { account No, balance, interest }

deposit
(behaviour)

withdraw
(behaviour)

balance
(behaviour)

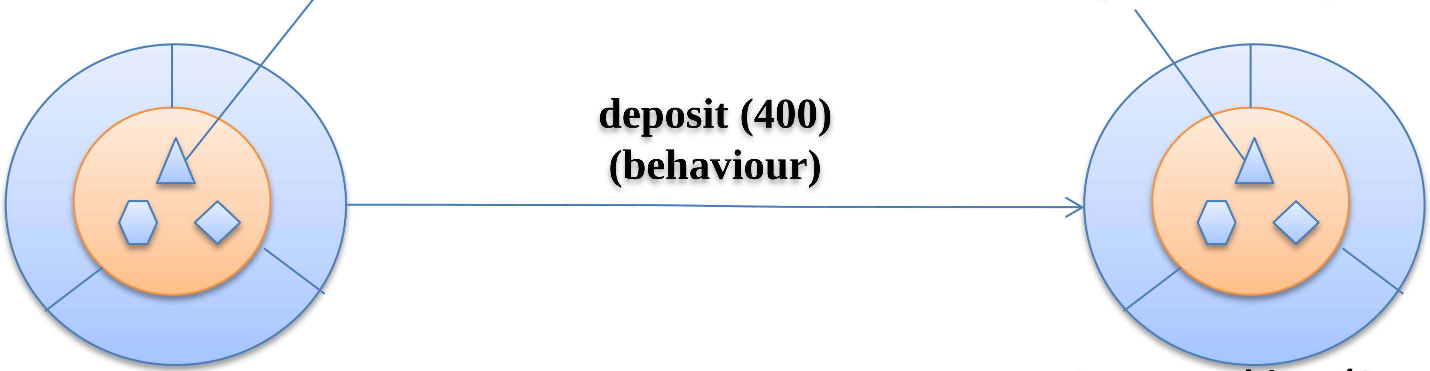
An Account software object

Object collaboration

- Objects communicate by sending *messages* to each other i.e. invoking *methods*
- The message is typically made up of three parts:
  – name of the object to whom the message is addressed (e.g, My “Account” object)
  – name of the method (e.g., deposit())
  – any additional information needed (e.g., cash to be deposited)
- Objects play a *client* and *server* role and could be located in the same memory space or on different computers

attributes { customerName, address }

attributes { account No, balance, interest }

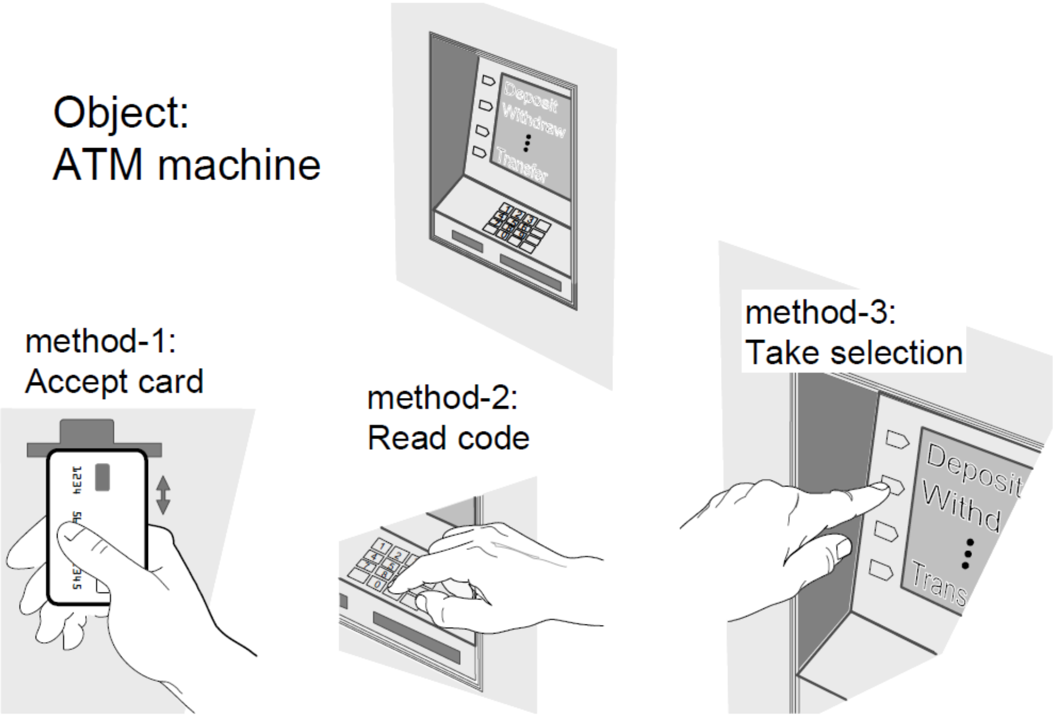


deposit (400)
(behaviour)

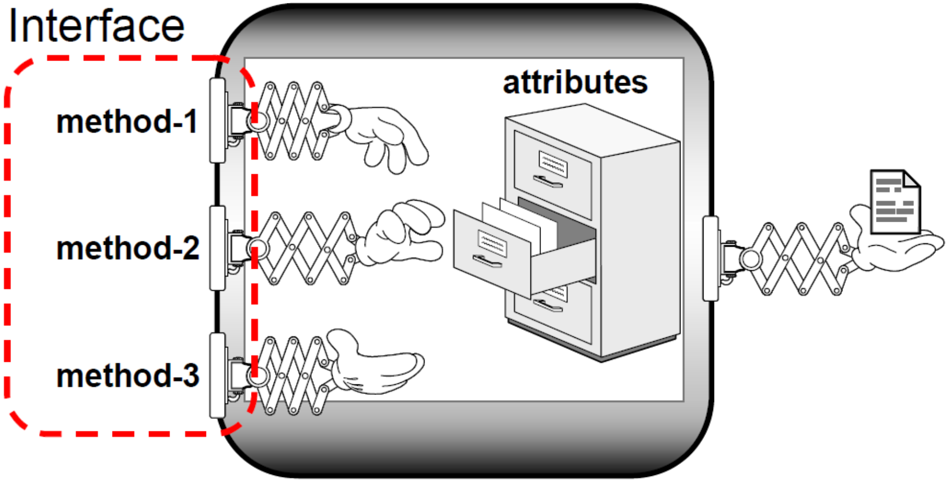
Customer object (Client)

Account object (Server)
(John’s account)

Object's Interface



- An object's *interface* is the set of the object's methods that can be invoked on the object
- The interface is the fundamental means of communication between objects

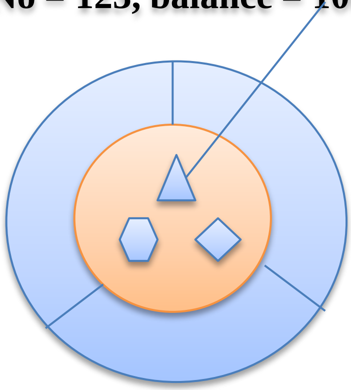


Objects and Classes

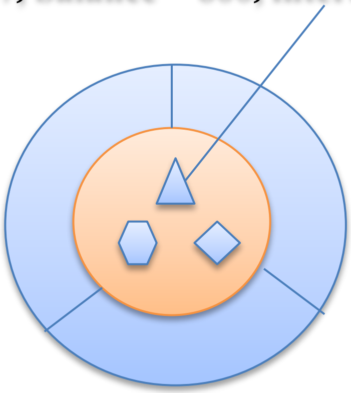
- Many objects are of the same "kind" but have different identity

  e.g., *there are many Account objects belonging to different customers, but they all share the same attributes and methods*

- Identify the commonality among the objects to design a blue-print of the objects or "**class**"



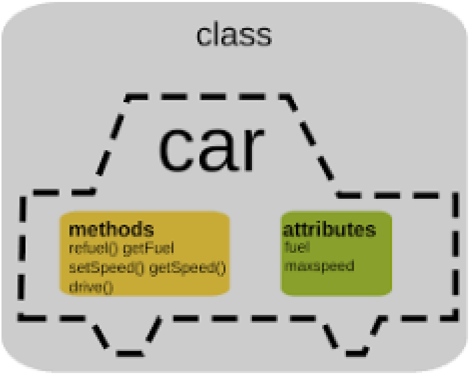
John's account
{ accountNo = 123, balance = 100, interest=5% }

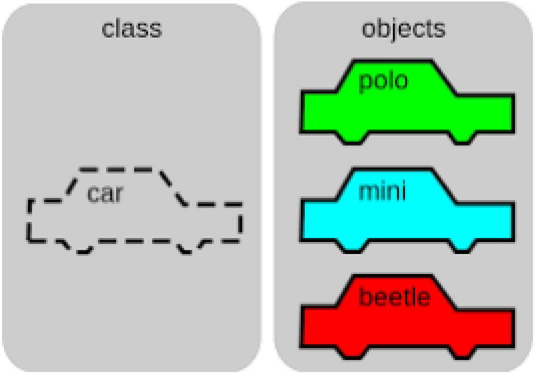


Tom's account
{ accountNo = 567, balance = 600, interest=5.2% }

Objects and Classes

- We tend to "logically group" objects that share some common properties and behaviour. This logical group is called a **class**
- A class serves as a *blue-print* defining the attributes and methods (behaviour) of this logical group of objects
- Two object instances from the same class share the same attributes and methods, but have their own object identity and are independent of each other

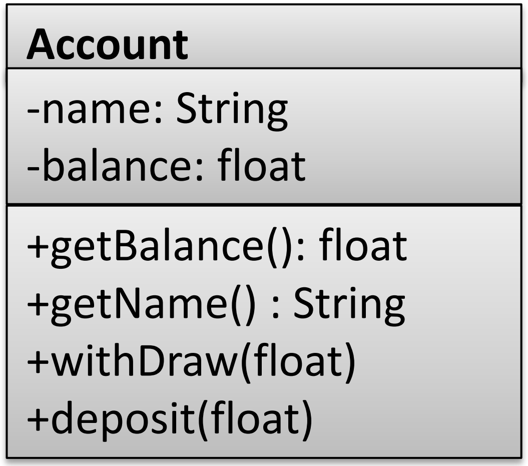




Representing classes in UML

- A class is sometimes referred to as an **object's type**.
- An object is instantiated from a class and the object is said to be an instance of the class)
- An object has state but a class doesn't

class (class diagram)

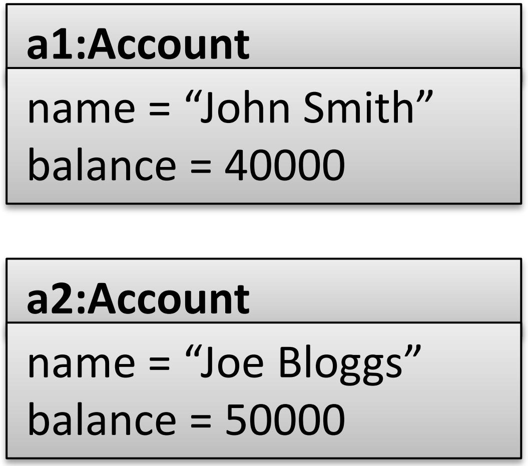


Account

-name: String
-balance: float

+getBalance(): float
+getName() : String
+withDraw(float)
+deposit(float)

object instances (object diagram)



a1:Account

name = "John Smith"
balance = 40000

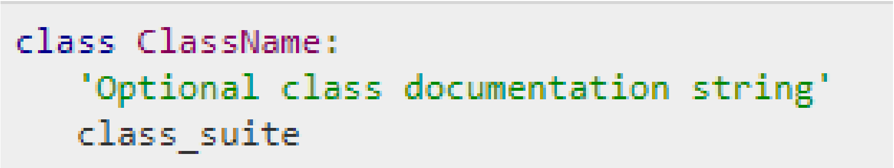
a2:Account

name = "Joe Bloggs"
balance = 50000

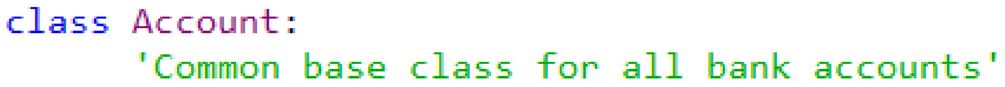
Defining a class in Python

Basic Python Syntax

- To create a class, use the keyword **class** followed by the name of the class e.g., **Account**



```
class ClassName:
   'Optional class documentation string'
   class_suite
```



```
class Account:
      'Common base class for all bank accounts'
```

- An ***object instance*** is a specific realization of the class
  - Defining a class, does not actually create an object
  - Create an instance of the Account class as follows:

Creating object instances

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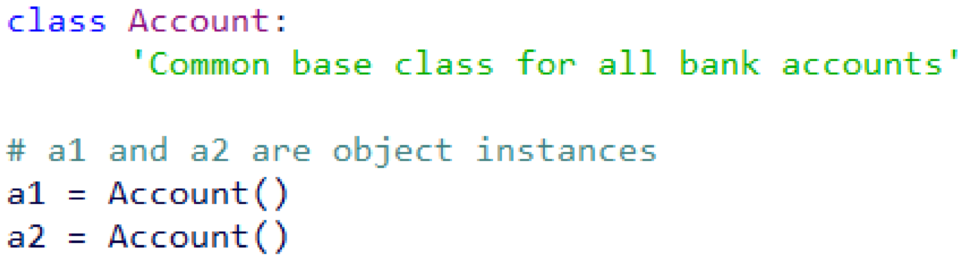
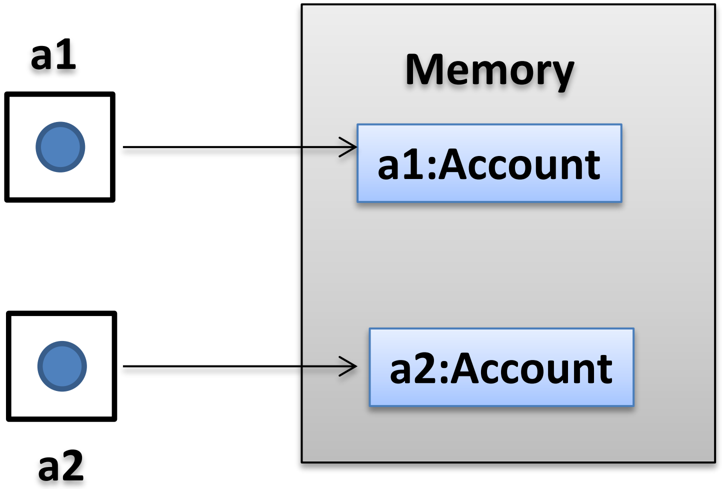


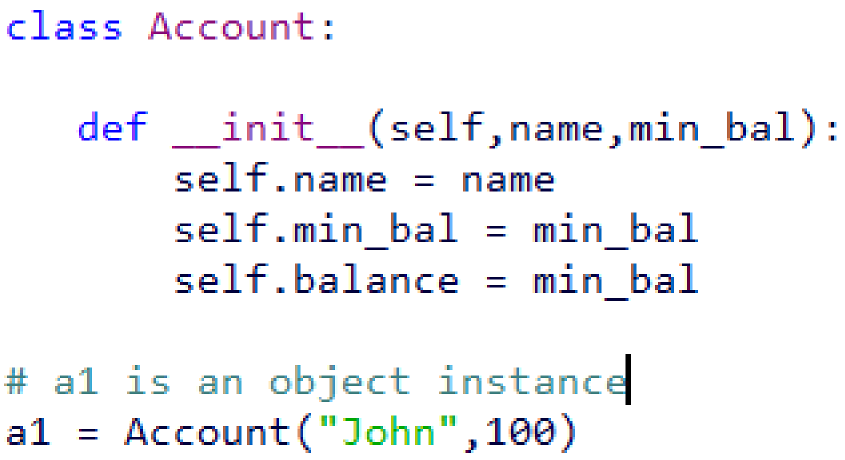
```
class Account:
       'Common base class for all bank accounts'

# a1 and a2 are object instances
a1 = Account()
a2 = Account()
```



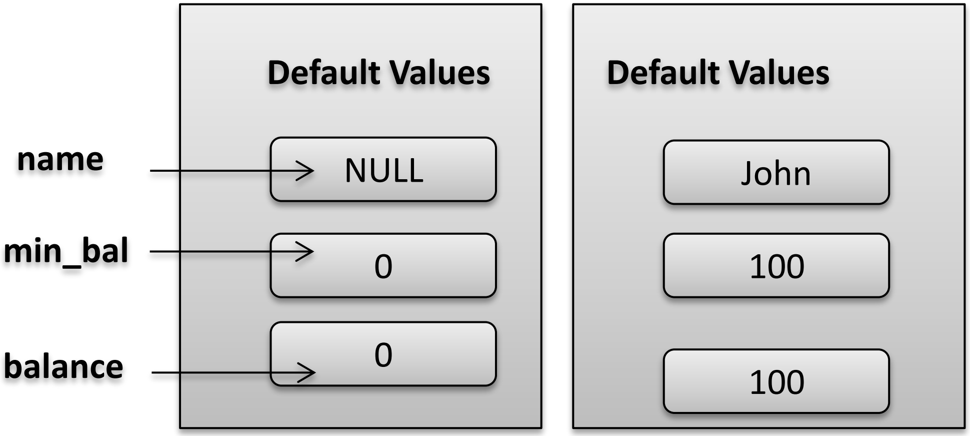
a1 == a2 -----> True or False?

Constructor & Instance Variables

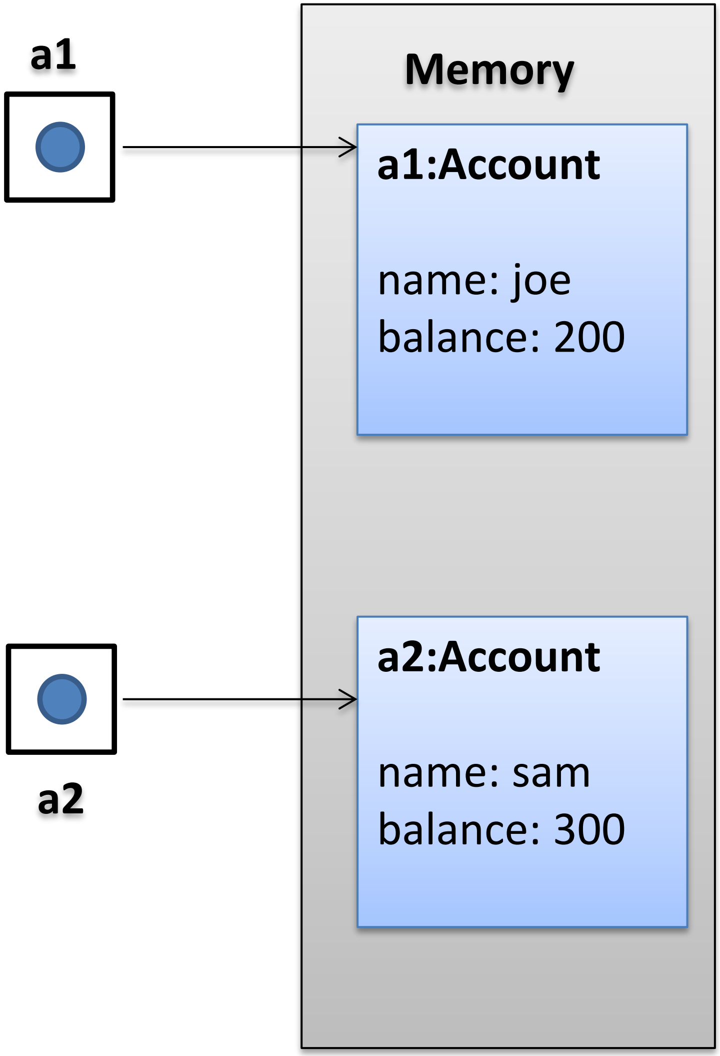
- A special method that creates an object instance and assign values (initialisation) to the attributes (instance variables)
- Constructors eliminate default values
- When you create a class without a constructor, Python automatically creates a default “no-arg” constructor for you



```
class Account:

   def __init__(self,name,min_bal):
       self.name = name
       self.min_bal = min_bal
       self.balance = min_bal

# a1 is an object instance
a1 = Account("John",100)
```



Object References

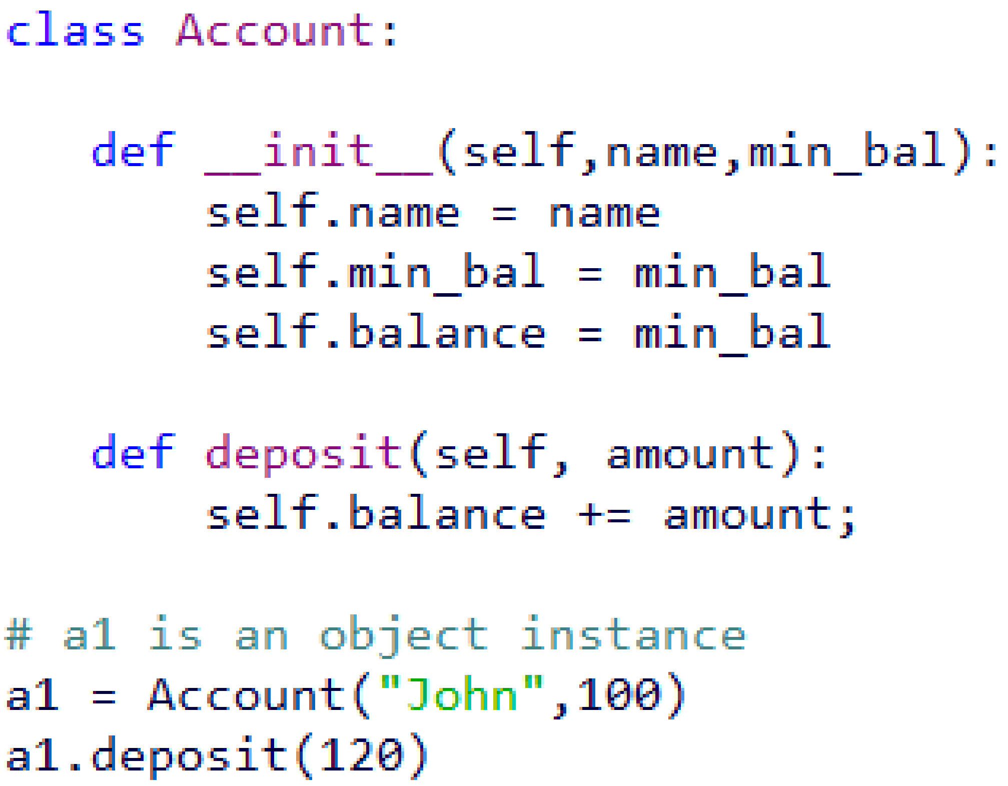


a1 == a2 -----> True or False?

Consider,
a3 = a1
a3 == a1 -----> True or False?

Instance Methods

- Similar to instance variables, methods defined inside a class are known as **instance methods**
- Methods define what an object can do.
- In Python, every instance method, must specify **`self`** (the specific object instance) as an argument to the method including the constructor (`__init__()`)



```
class Account:

    def __init__(self,name,min_bal):
        self.name = name
        self.min_bal = min_bal
        self.balance = min_bal

    def deposit(self, amount):
        self.balance += amount;

# a1 is an object instance
a1 = Account("John",100)
a1.deposit(120)
```

Key principles of OO

- Abstraction
- Encapsulation
- Inheritance

Abstraction

- Helps you to focus on the common properties and behaviours of objects
- Good abstraction help us to accurately represent the knowledge we gather about the problem domain (discard anything unimportant or irrelevant)
- What comes to your mind when we think of a “car” ?

Do you create a class for each brand (BMW, Audi, Chevrolet…) ?

- write ***one*** class called Car

and ***abstract***;

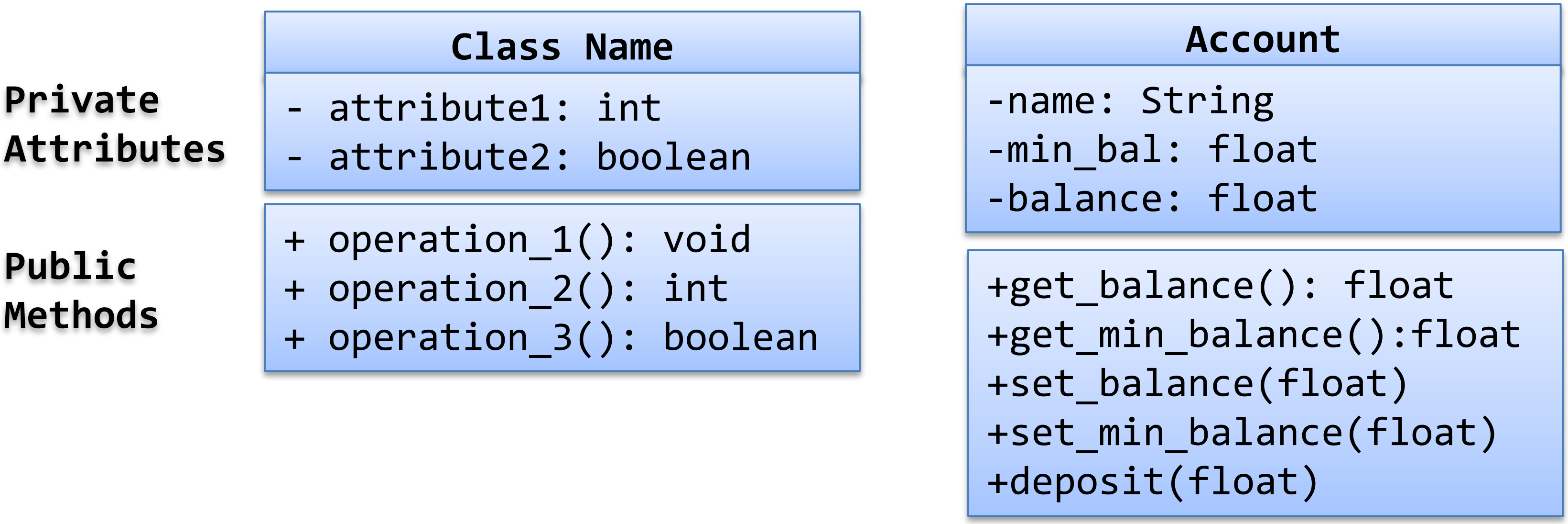
- focus on the common essential qualities of the object
- focus on the current application context

- What if a specific brand had a special property or behaviour? Later on….***inheritance***

Encapsulation

- Encapsulation implies ***hiding*** the object state (attributes)
- An object’s attributes represent its individual characteristics or properties, so access to the object’s data must be restricted
- **Methods** provide explicit access to the object

  e.g. use of *getter* and *setter* methods to access or modify the fields



Private Attributes

Public Methods

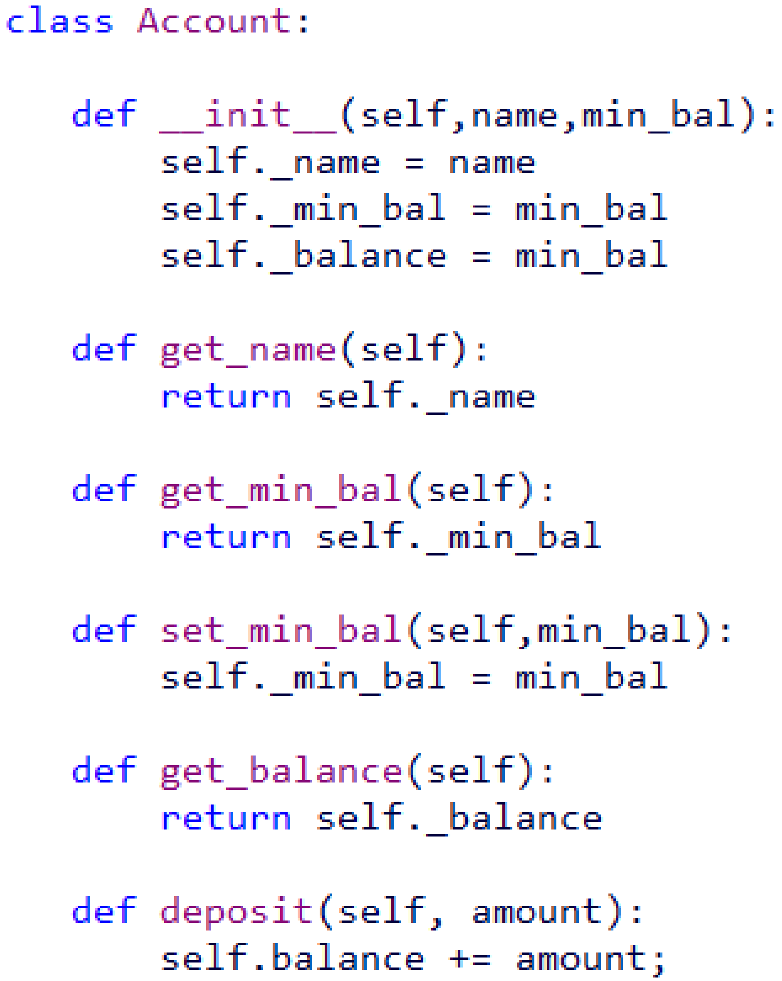
```
Class Name
- attribute1: int
- attribute2: boolean
+ operation_1(): void
+ operation_2(): int
+ operation_3(): boolean
```

```
Account
-name: String
-min_bal: float
-balance: float
+get_balance(): float
+get_min_balance():float
+set_balance(float)
+set_min_balance(float)
+deposit(float)
```

UML notation for a Class

Encapsulation in Python

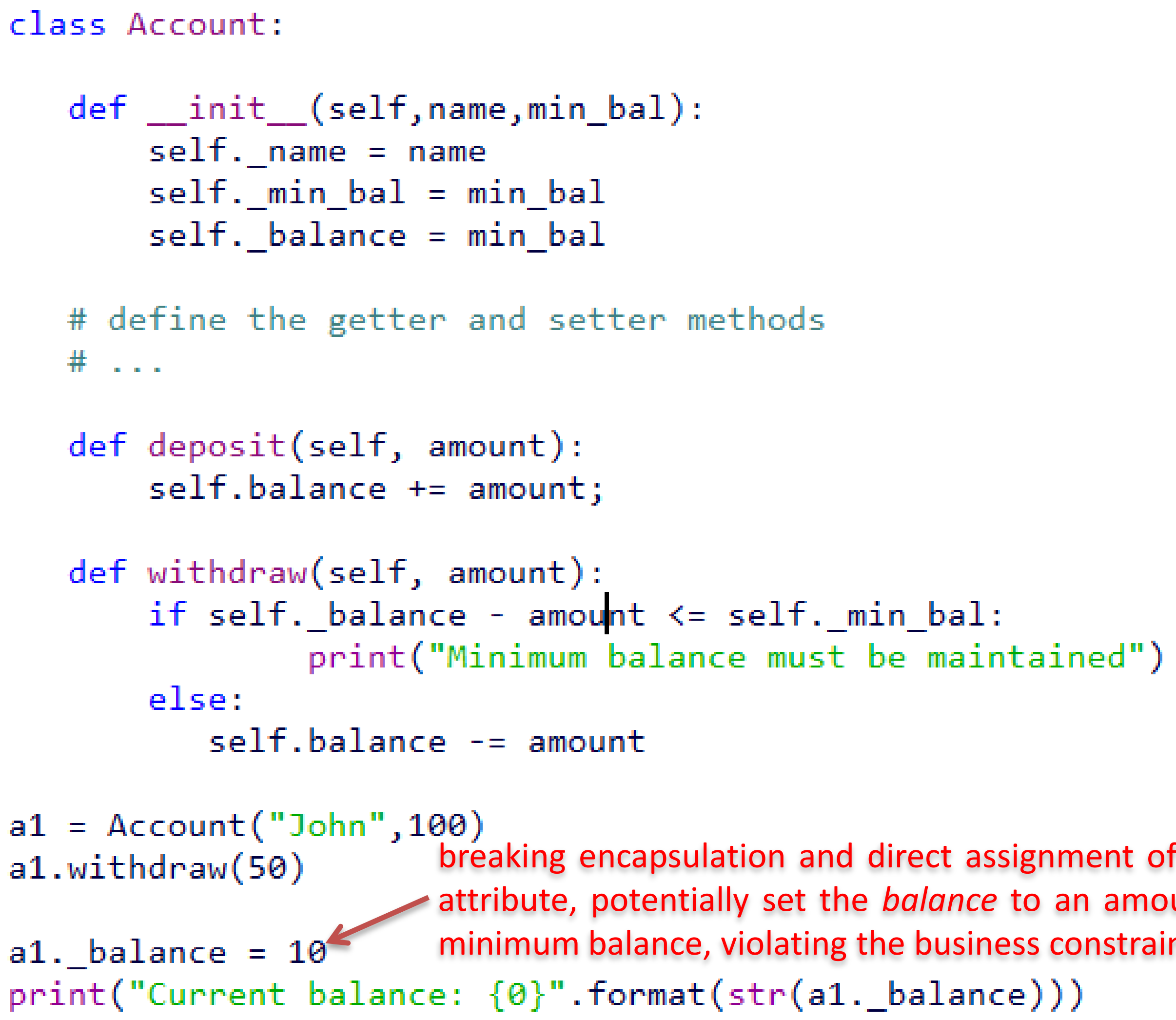
- Python does not support strong encapsulation. Attribute names are simply prefixed with a single underscore e.g., _name to signal that these attributes are **private** and must not be directly accessed by clients



```
class Account:

    def __init__(self,name,min_bal):
        self._name = name
        self._min_bal = min_bal
        self._balance = min_bal

    def get_name(self):
        return self._name

    def get_min_bal(self):
        return self._min_bal

    def set_min_bal(self,min_bal):
        self._min_bal = min_bal

    def get_balance(self):
        return self._balance

    def deposit(self, amount):
        self.balance += amount;
```

Why is encapsulation important (1) ?

1. Encapsulation ensures that an object’s state is in a consistent state



```
class Account:

    def __init__(self,name,min_bal):
        self._name = name
        self._min_bal = min_bal
        self._balance = min_bal

    # define the getter and setter methods
    # ...

    def deposit(self, amount):
        self.balance += amount;

    def withdraw(self, amount):
        if self._balance - amount <= self._min_bal:
                print("Minimum balance must be maintained")
        else:
            self.balance -= amount

a1 = Account("John",100)
a1.withdraw(50)

a1._balance = 10
print("Current balance: {0}".format(str(a1._balance)))
```

breaking encapsulation and direct assignment of the *balance* attribute, potentially set the *balance* to an amount less than minimum balance, violating the business constraint

encapsulation enforces that *balance* is hidden and can only be changed through *deposit* and *withdraw* methods

Why is encapsulation important (2)?

2. Encapsulation increases usability

- Keeping the data private and exposing the object only through its interface (public methods) provides a clear view of the role of the object and increases usability
- Clear contract between the invoker and the provider, where the client agrees to invoke an object's method adhering to the method signature and provider guarantees consistent behaviour of the method invoked (if the client invoked the method correctly)

3. Encapsulation abstracts the implementation, reduces the dependencies so that a change to a class does not cause a rippling effect on the system

Tomorrow

- Relationships between classes (inheritance and association)
- Creating a domain model applying object-oriented design principles…

- So far,
  - we have defined classes and object instances
  - objects have attributes and responsibilities
- let us now look at **relationships between objects** e.g.,
  - a dog **is-a** mammal
  - an instructor **teaches** a student
  - a university **enrols** students
- Relationships between objects can be broadly classified as:
  - Inheritance
  - Association

Relationships (1) – Inheritance

- So far, we have logically grouped objects with common characteristics into a class, but what if these objects had some special features?

  e.g., if we wanted to store that sports car has spoilers

- Answer is inheritance - models a relationship between classes in which one class represents a more general concept (parent or base class) and another a more specialised class (sub-class)

- Inheritance models a "is-a" type of relationship e.g.,

  - a savings account is a type of bank account

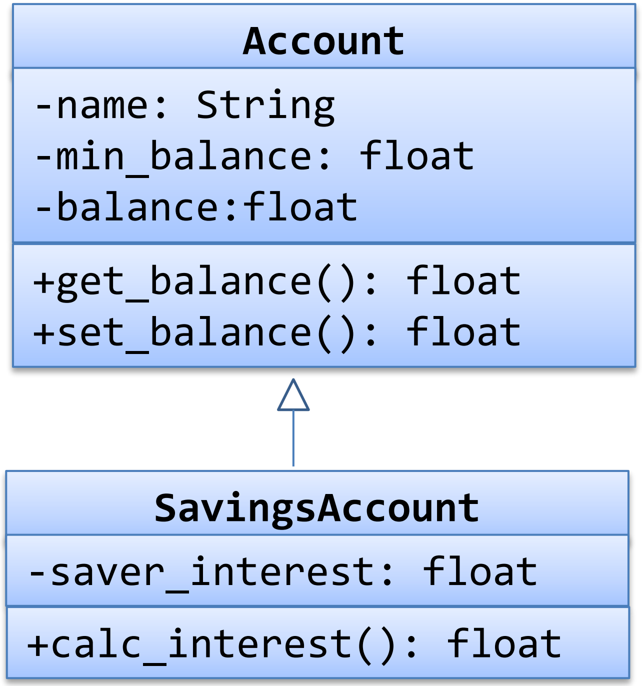
  - a dog **is-a** type of pet

  - a manager **is-a** type of employee

  - a rectangle **is-a** type of 2D shape

Inheritance

- To implement inheritance, we
  - create a new class (sub-class) , that inherits common properties and behaviour from a base class (parent-class or super-class)
    - We say the child class *inherits/ is-derived from* the parent class
  - sub-class can *extend* the parent class by defining additional properties and behaviour specific to the inherited group of objects
  - sub-class can *override* methods in the parent class with their own specialised behaviour



Account

-name: String
-min_balance: float
-balance:float

+get_balance(): float
+set_balance(): float

SavingsAccount

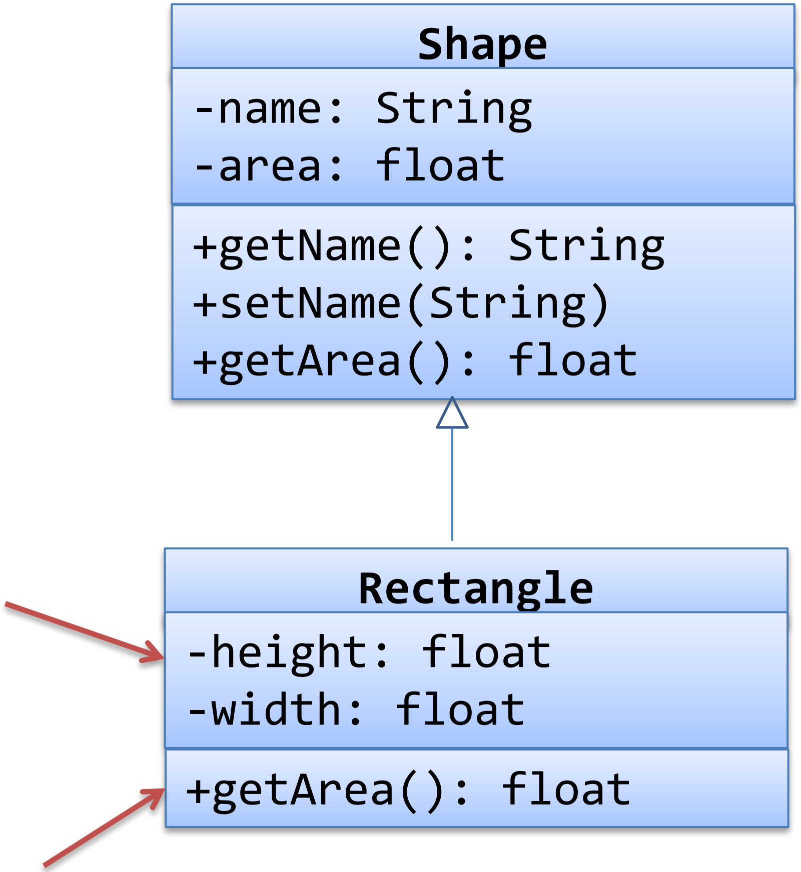
-saver_interest: float

+calc_interest(): float

Parent class - Account
class Account defines *name*, *min_bal*, *balance*

Child class – SavingsAccount
extends Account class adding its own attributes and methods e.g., *saver_interest* & *calc_interest()*

Inheritance – another example



Shape

-name: String
-area: float

+getName(): String
+setName(String)
+getArea(): float

Rectangle

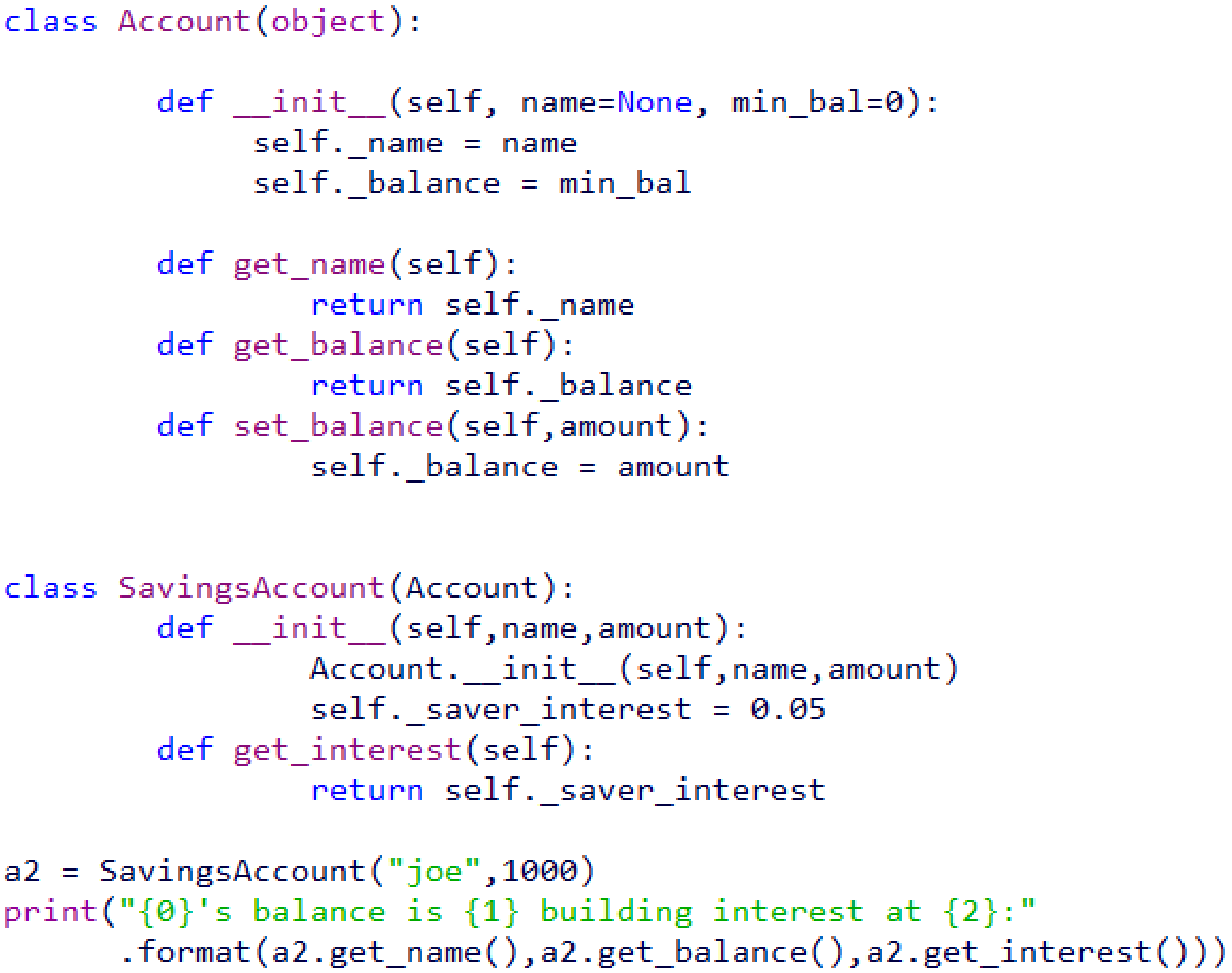
-height: float
-width: float

+getArea(): float

class Rectangle *extends* Shape adding attributes *height* , *width*

class Rectangle *overrides* method *getArea()* to provide its own implementation

Implementing Inheritance in Python



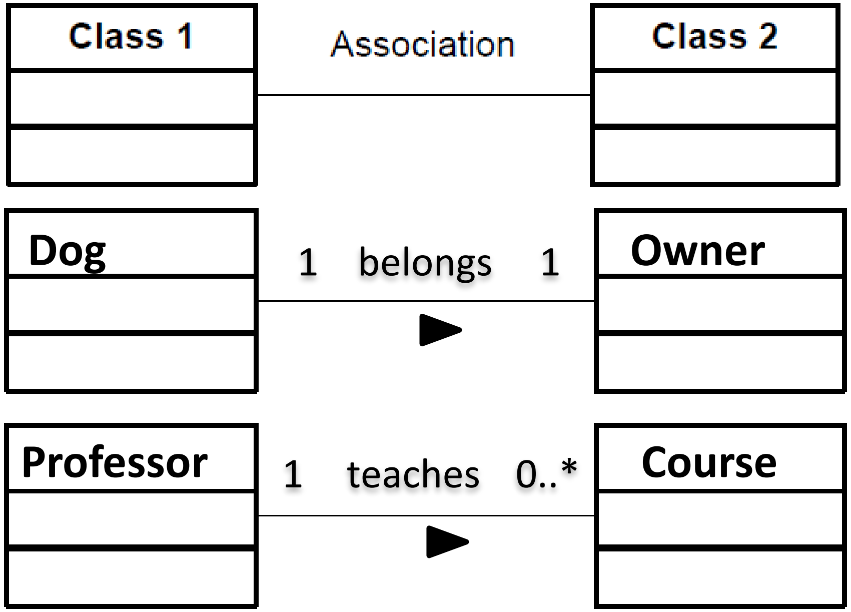
```python
class Account(object):

        def __init__(self, name=None, min_bal=0):
             self._name = name
             self._balance = min_bal

        def get_name(self):
                return self._name
        def get_balance(self):
                return self._balance
        def set_balance(self,amount):
                self._balance = amount


class SavingsAccount(Account):
        def __init__(self,name,amount):
                Account.__init__(self,name,amount)
                self._saver_interest = 0.05
        def get_interest(self):
                return self._saver_interest

a2 = SavingsAccount("joe",1000)
print("{0}'s balance is {1} building interest at {2}:"
      .format(a2.get_name(),a2.get_balance(),a2.get_interest()))
```

Relationships (2) – Association

- Association is a special type of relationship between two classes, that shows that the two classes are:
  - linked to each other

    e.g., a lecturer *teaches* a course-offering
  - or combined into some kind of *"has-a"* relationship, where one class "contains" another class

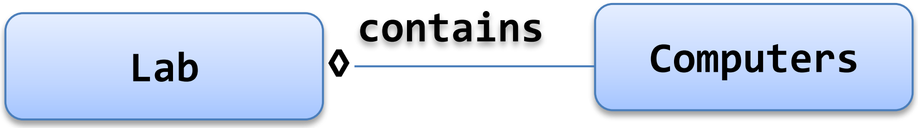
  e.g., a course-offering *has* students
- Modelled in UML as a line between two classes



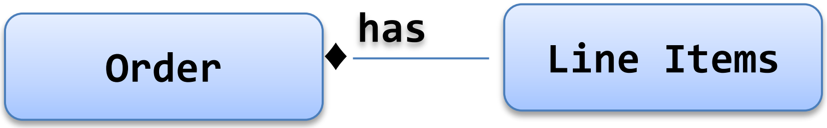
Relationships – Association

- Associations can model a ***"has-a"*** relationship where one class "contains" another class
- Associations can further be refined as:

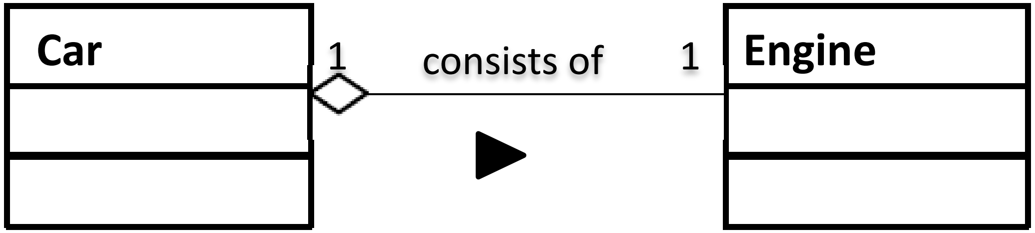
Aggregation relationship (hollow diamond symbol ◊): The contained item is an element of a collection but it can also exist on its own, e.g., a lecturer in a university or a student at a university



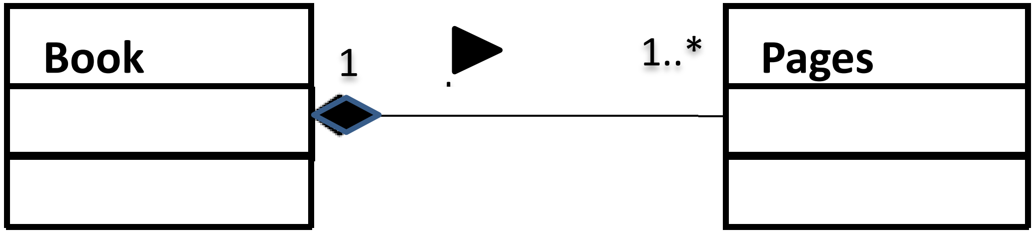
Composition relationship (filled diamond symbol ♦ in UML diagrams): The contained item is an integral part of the containing item, such as a leg in a desk, or engine in a car



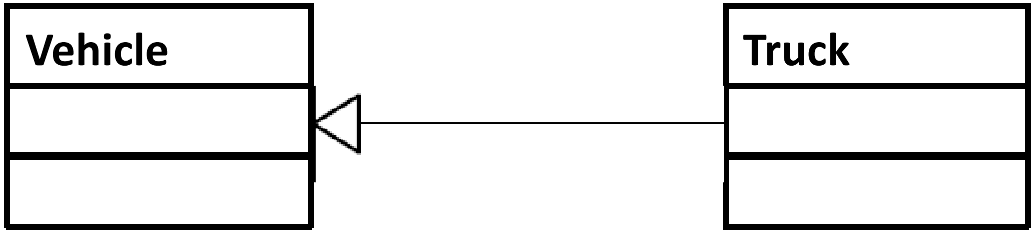
More examples of associations



- Aggregation - “has-a” relationship where the part can exist without container



- Composition – “is-composed-of” relationship where part cannot live without container



- Inheritance – “is-a-kind-of” relationship

Re-visiting our earlier question:

How to create a domain model?

So far, requirements engineering helped us to

- Understand the problem domain
- Establish knowledge of how system-to-be is supposed to behave (from requirements analysis, e.g., use cases and sequence diagrams)
- We now apply OO design principles to build a domain model

Next,

- Noun/Verb analysis
- CRC cards
- Domain model

Noun/Verb Verb Phrase Analysis

- Analyze textual description of the domain to identify **noun** phrases
- Caveats: Textual descriptions in natural languages are ambiguous (different nouns can refer to the same thing and the same noun can mean multiple things

Consider this text about an ATM machine:

A customer arrives at an ATM machine to withdraw money. The customer enters the card into the ATM machine. Customer enters the PIN. The ATM verifies whether the customer's card number and PIN are correct. Customer withdraws money from the account. The ATM machine records and updates the transaction.

Candidate conceptual classes: ATM, Customer, Account, Card

Domain Modelling Techniques (2) – Using CRC cards

- CRC stands for:
  - ***Class*** : Represents a collection of similar objects
  - ***Responsibility*** : Something that the class *knows* or *does*
  - ***Collaborator*** : Another class that a class must interact with to fulfil its responsibilities
- Written in 4 by 6 index cards, an individual CRC card use to represent a domain object
- Featured prominently as a design technique in XP programming

Student	
Enrols in a Course-Offering *Knows* Name *Knows* Address *Knows* Phone Number	Course-Offering

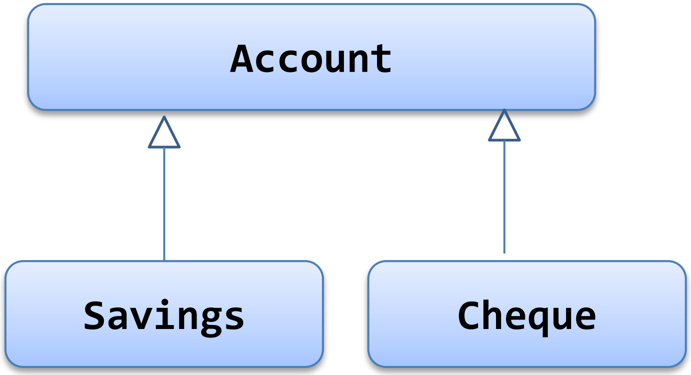
Techniques for Domain Modelling (2)

Evolve CRC domain models into UML class diagrams where:

- Concepts are represented as classes
- Collaborations between the classes established as relationships
- Depending on the kind of relationship, we can use the different notations that we’ve used for associations – non-hierarchical, part-of (aggregation), is-a (inheritance),

Abstract Classes in Inheritance

- In the example below
  - Savings and Cheque both inherit from the base class Account
    - But Account is really not a real-world object
    - Account is a *concept* that represents some real-world objects like a Savings Account), so Account is said to be an abstract class
    - It does not make sense to create an instance of an abstract class



Abstract class – Vehicle
Defines common attributes e.g., *make, model, year, miles, wheels*