School of Electrical Engineering and Computing

SENG2200/6220 PROGRAMMING LANGUAGES & PARADIGMS

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Inheritance

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Outline

- Introduction to Inheritance
  - *Building and accessing objects under inheritance structures*
  - *Abstract classes*
  - *Interfaces*
  - *C++ multiple inheritance*
- Composition and Aggregation Revisited
  - *Java References*
  - *C++ Pointers, C++ Object*

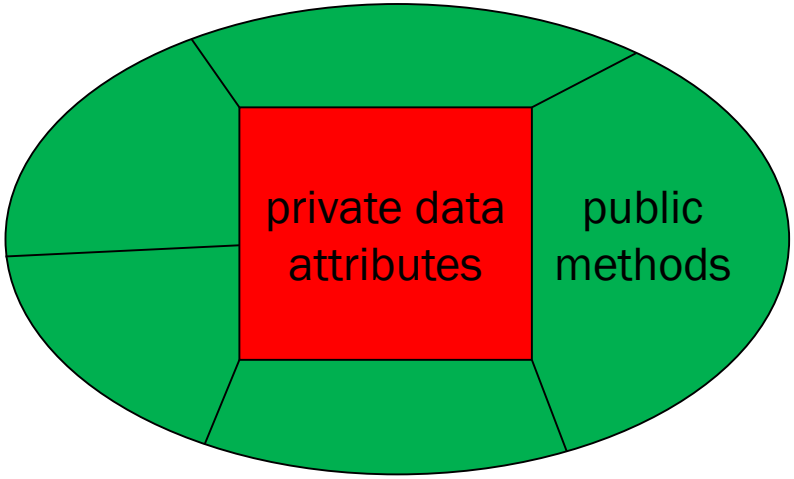
Part 1 - Inheritance

Encapsulation

- Hiding implementation details from outside of a class.
  - *Instance or attribute data*
  - *Functionality via methods*
- Enforces abstraction
  - *Different views between external and internal*
  - *Protect the integrity of an object's data*

Information Hiding

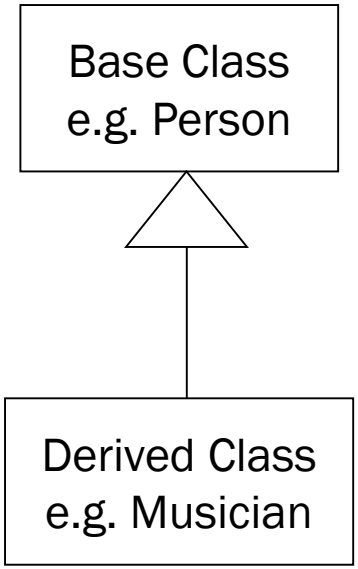
- Restrict unwanted access to the object component(s) from the outside.
- Hide private attribute data and present a functionality interface of public methods
- Private data cannot be accessed outside the class, being hidden behind the public methods
- The public methods are the only feature of the class that can be accessed from outside, ie they are a public interface to the class



Introduction to Inheritance

- A major way of gaining *software re-use*
- Allows a class to be developed directly from another class *without altering or copying the original*
- Basic relationship between the classes is the "IS A" relationship
- E.g. A Musician IS A Person
- When a musician object is created:
  - *A musician IS A person, so any musician object will have all the attributes of a person object*
  - *The person-style methods also remain.*
  - *Extra musician-style attributes are added in.*
  - *Extra musician-style methods are also added.*
  - *Scoping rules allow for person-style methods to have a new musician-style implementation added if required.*

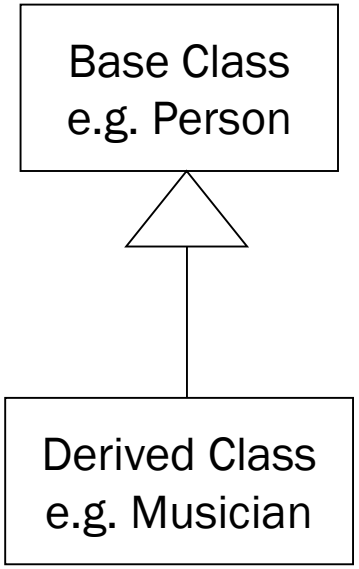
Inheritance
In UML



Deriving A Subclass

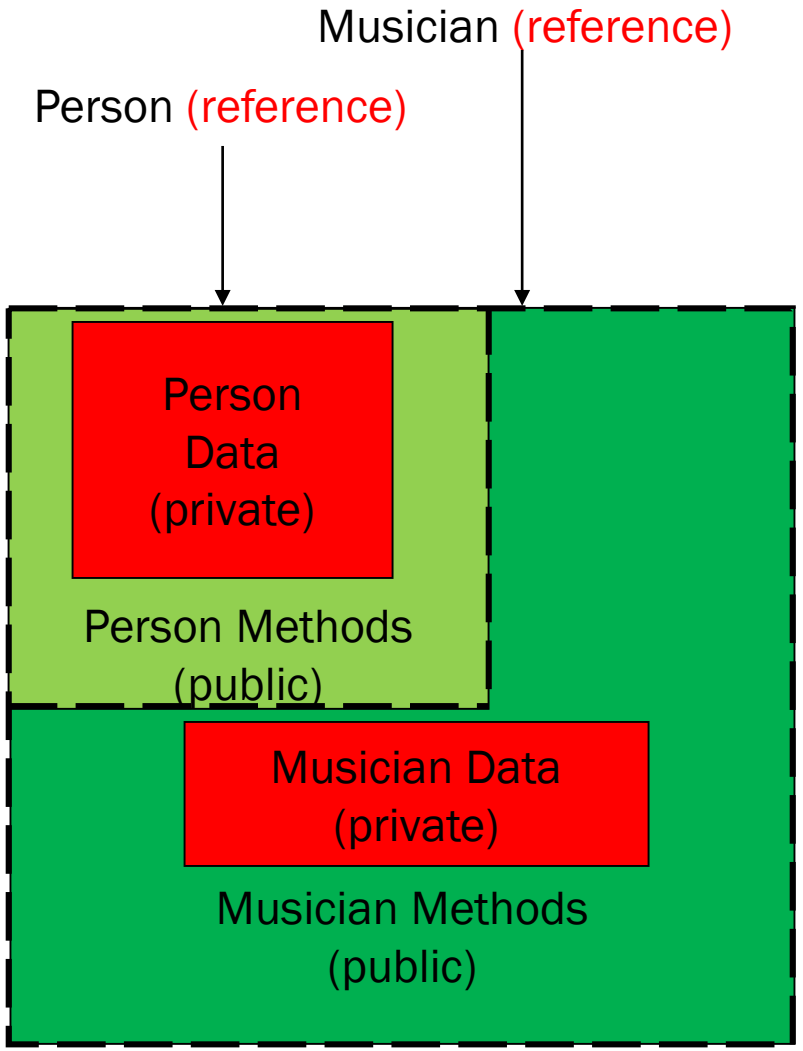
- In Java, we use the keyword extends to implement inheritance relationship.

```
class Musician extends Person {
    // class contents
}
```



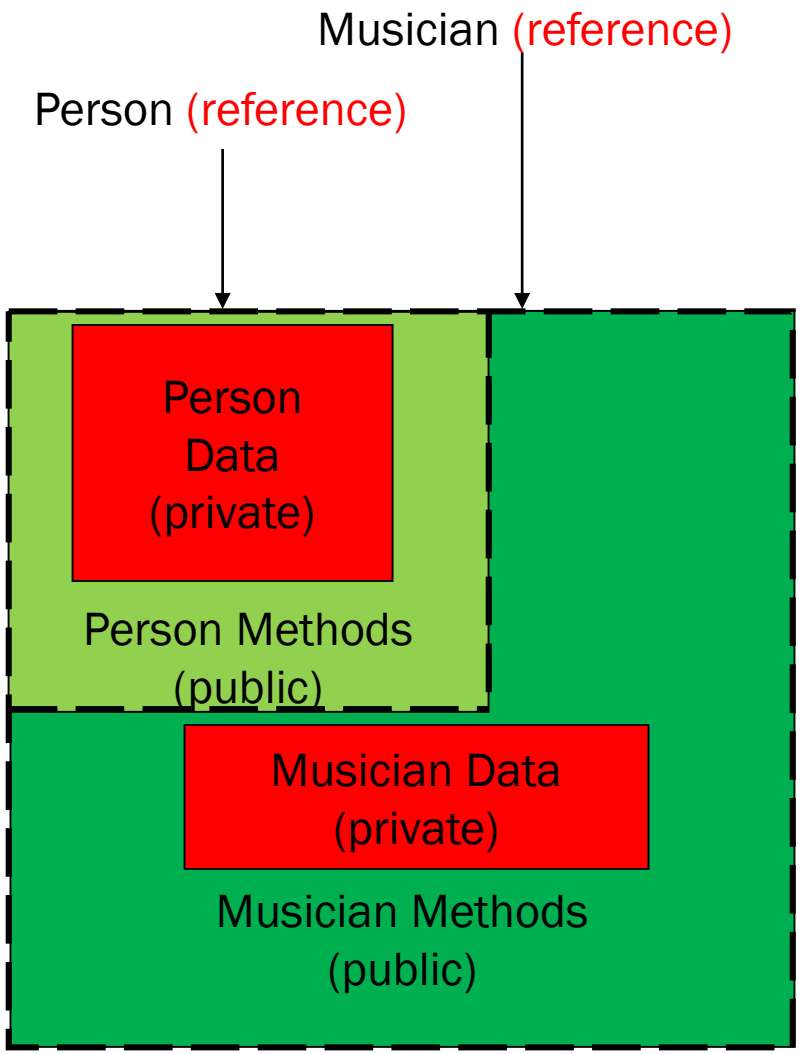
Attributes and Methods

- Person data remains private within the Person class and so is only accessible to the Musician methods via the Person methods
- Musician data is private.
- Scoping still allows methods to be redefined.
- This is a very low level schematic view – normally you don't need to think about derived objects at this level.



Attributes and Methods

- What is available? (What can be seen?)
- Outside the Derived (Musician) class:
  - *Public methods of both the Base and Derived Classes.*
  - *We can ask for BOTH Musician operations and Person operations.*
- Inside the Derived (Musician) class:
  - *Base class public methods*
  - *Anything that is public or private in the derived class (i.e. ANYTHING)*
- What about the Base class private data?
  - *Only valid operations can be done (information hiding) and so the Base class public methods must be used to alter or access the Base class attribute data.*

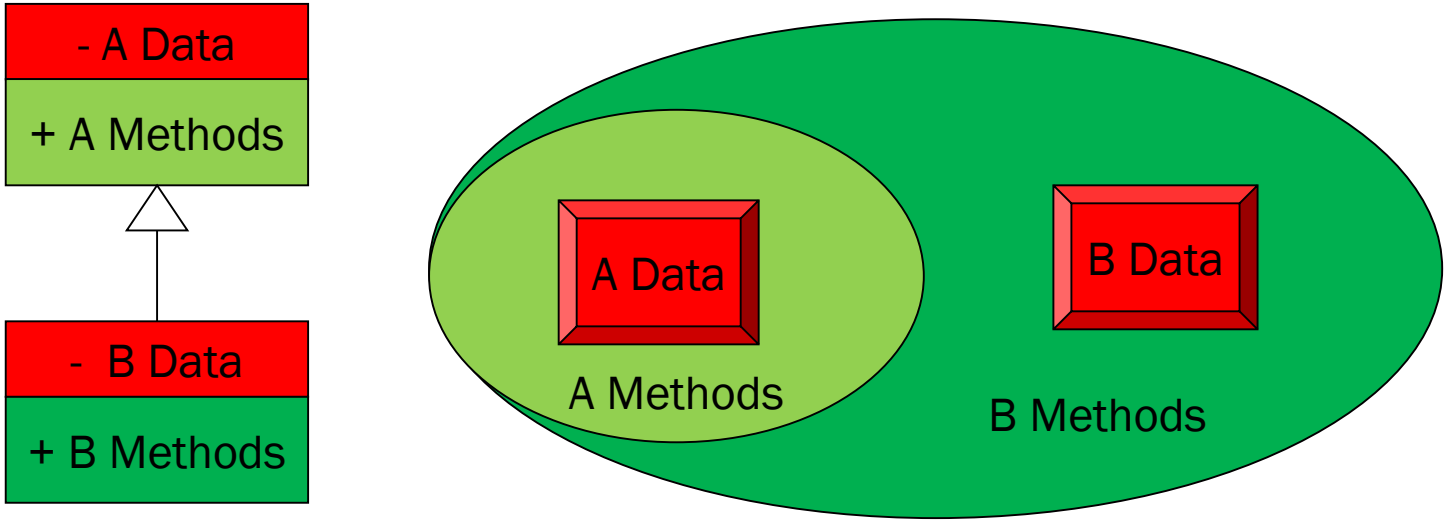


Attributes and Methods

```
public class Person  {
        private String name;
        private String addr;
        ……
        public String getName() {…}
        public String getAddr() {…}
        ……
}
```

```
public class Musician extends Person {
        private boolean onTour;
        private String addrOnTour;
        ……
        public String getAddrLabel()  {…}
}
```

Inheritance Hierarchies and Finding Item Names



- Calling a public method - Start at the derived class and search up the inheritance hierarchy for a method implementation.
- Within derived class – directly accessing data – Look at derived class private data, then look up the inheritance hierarchy looking for a protected data item in one of the super classes.

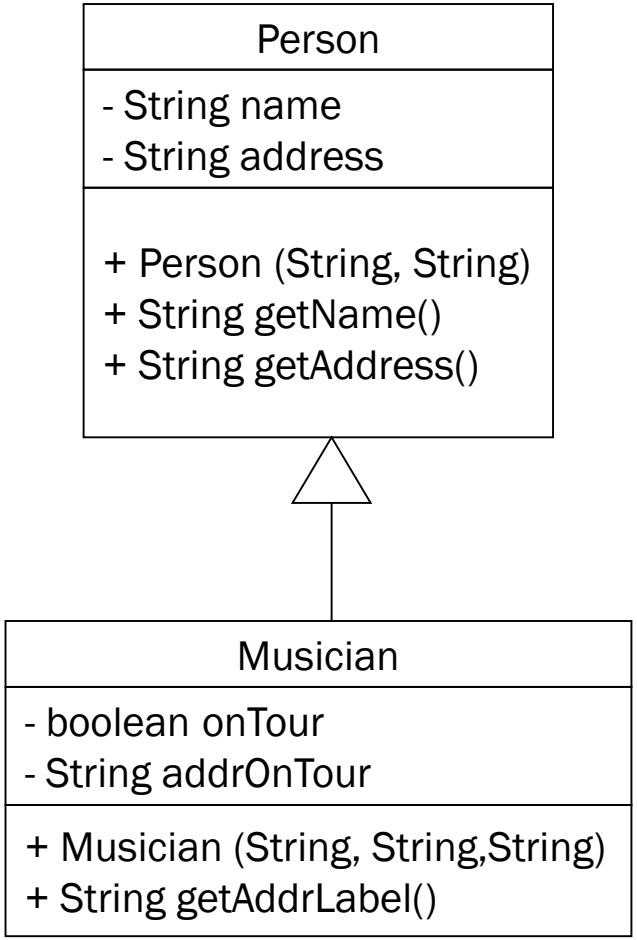
Protected Data

- This is attribute data in the base (ie parent) class that is labelled as protected rather than private.
- The UML designation for protected data is #.
- Protected data can be directly accessed within its own class in the same way that private data can.
- However, it can ALSO be directly accessed (ie without using base class methods) from within any class that inherits from this class.
- It is a breach of Information Hiding principles – however it does have a place in O-O design.
- It is NOT simply a shortcut that allows a bad designer or bad programmer to be lazy.

Protected Data vs Private Data

- This is a breach of Information Hiding principles to provide (shortcut) direct access to data that would otherwise be private data in the parent class.
- It is providing a shortcut to the programmer to remove the need for get and set methods that then need to be called every time the sub-class wants to fetch or alter the data item(s) in the super-class.

Musician and Person



Musician extends Person

Private data in Person becomes inaccessible in Musician

getAddrLabel method for Person

return name + address

getAddrLabel for Musician

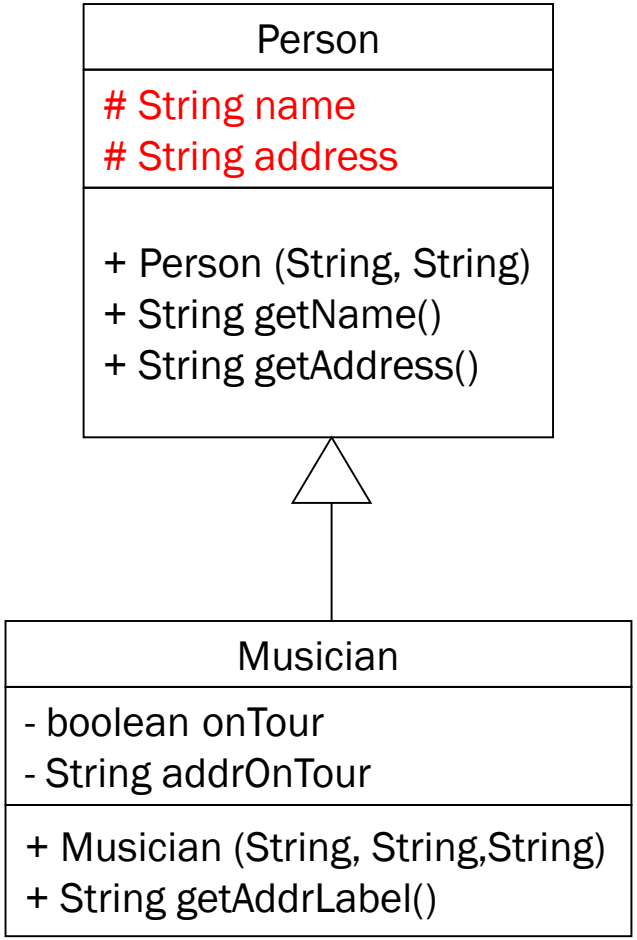
if (onTour)

return getName() + addrOnTour

else

return getName() + getAddress()

Musician and Person



Musician extends Person

Protected Data in Person class remains visible in Musician

getAddrLabel method for Person

return name + address

getAddrLabel for Musician

if (onTour)

return name + addrOnTour

else

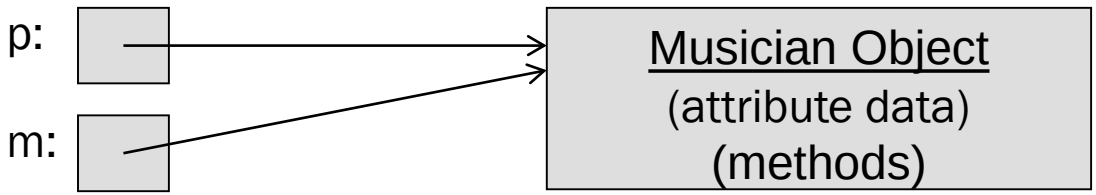
return name + address

Pointers and References under Inheritance

- A Musician IS A Person, and therefore reference/pointer of type Person is able to refer to a Musician object.
- Allowing a derived class object to be referred to as a base class object is integral to implementing the IS A relationship and so is basic to understanding inheritance.
- It is also the first step in allowing polymorphism.

E.g. A Musician Object IS A Person, so:

```
Person p;          // in Java –> in C++, Person *p
Musician m = new Musician(… constr params …);
p = m;             // This assignment is legal
```



Inheritance in Java

- The basic mechanism for inheritance in Java is the keyword extends and this provides basic public inheritance.
  - *It is only possible to extend a single class*
  - *Public items (mainly methods) remain public in the derived class*
  - *Private items (data attributes and supporting functions) become inaccessible within the derived class*
  - *Protected items remain protected in the derived class*

Inheritance in C++

class B : public A ; // Public inheritance is the only IS A construct

- *Public items remain public*
- *Protected items remain protected*
- *Private items become inaccessible*
  - except via the public methods

class H : protected G ; // this is not part of SENG2200

- *Public items become protected*
- *Protected items remain protected*
- *Private items become inaccessible*

class K : private J ; // Often referred to as Implementation Inheritance

- *Public and protected items become private*
- *Private items become inaccessible*

Inheritance in Java and C++

- Inheritance in Java is simpler and more straight forward than in C++.
- Java classes may extend a single class and implement as many interfaces as you like.
- C++ classes may inherit from any number of classes, so multiple inheritance is allowed.
- C++ allows the implementation of public, protected, and private inheritance.
- Java inheritance can be viewed as a refinement of C++ inheritance structures, making useful features easier to use, and leaving less useful features out of the language.

Building an Object under Inheritance

- The object is built from the inside first.
- class B extends A in Java (or class B : public A in C++) means that
  - *The class A part of the object is built first by way of the class A constructor*
  - *Then the class B extensions are added by way of the class B constructor*
  - *In C++ this may involve aggregated sections being implicitly instantiated and initialized by their default constructor.*
  - *In Java, any first class objects aggregated within the object must be explicitly instantiated. This is also the case for C++ if explicit pointers are used, whereupon an explicit destructor is usually required.*

Chaining Constructor Calls

- Java: There can be only one parent class called the super class
- Java is therefore able to use the keyword call super to explicitly call the constructor of its parent class
- Parameters may be passed via the call as in

  super(… , … , …);

- If no reference is made to super then an implicit call is made to super( ); (default constructor).

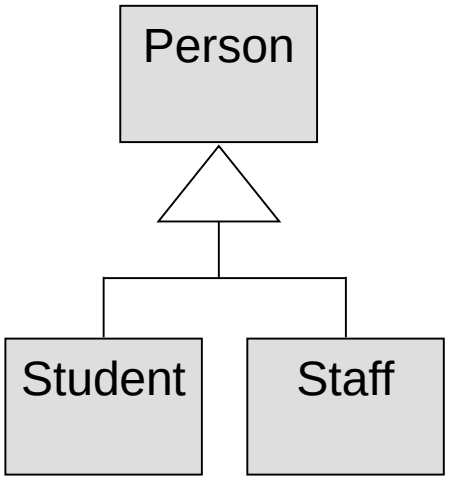
- C++: The possibility of multiple inheritance in C++ means that explicit calls to a parent class constructor must explicitly give the name of the constructor (the particular class), e.g.,

  Person(… , …);

- Under multiple inheritance base class sections of the object can be made in a specific order.

Inheritance – When and Where?

- We know how to implement inheritance in Java and C++
- When and where do we use it?
  - *This is a major part of O-O Analysis and Design*
- Mostly we do not think about having a Person object and then deriving a Student object from it.
- A Uni-based problem will have a whole lot of different people that our problem statement will initially talk about as Student(s) and Staff (as a simple example).
  - *We set up specs (a class) for a set of Students*
  - *We set up specs (a class) for a set of Staff members*
  - *THEN, we realise that there are attributes and methods in common*
  - *We extract (factor out) these common specs into a base class and decide that Person is a good name for it.*
  - *Later we might decide that a Contractor can also inherit from Person*



Overriding Methods

- A derived (child) class can *override* the definition of an inherited method in favor of its own.
- The new method must have the same signature as the method of the base class, but can have a different body.
- The type of the object executing the method determines which version of the method is invoked.
- A base class method can be invoked explicitly using the `super` reference
- If a method is declared with the `final` modifier, it cannot be overridden

Example

```
class Shape {
    public void draw() {
        System.out.println("Draw a shape.");
    }
}

class Square extends Shape {
    // This method overrides draw() of Shape
    @Override
    public void draw() {
        System.out.println("Draw a square.");
    }
}
```

The Java Class Called Object

- Unlike C++, Java is a pure O-O language
  - *Remember that C++ is C with O-O extensions*
- A benefit Java has from this is that it defines a standard base class called Object from which all other classes, including programmer defined classes are derived.
- If you write a class in Java, and do not specify any inheritance-style derivation for it, then it is implicitly taken to be derived from class Object.
- This allows certain standard features, required by all objects (no matter what their class) to be defined in their most basic form.
- Object is an abstract class (see later)

The Object Class

- toString() is a method defined in the Object class.
  - *It returns the name of the class and other information.*
- We override toString() every time we have defined it in a class.
- It guarantees:
  - *All classes have toString() methods.*
  - *println() method can print any class object passed to it.*

Abstract Methods and Classes

- Abstract method

  Knowing that a particular operation (method) is needed but not knowing exactly how to perform it, results in the abstract specification of that method – you will know how to call the method, and what answer it will give you, you just won't know how it is to be done.

- An abstract class may contain zero or more abstract methods.
- Any class that contains one (or more) method (s) of this type, is an abstract class.
- Such abstract classes only exist for the purpose of having other more specialized classes (perhaps non-abstract classes) derived from them.
- Once you have implementations of all methods you have a concrete class that can be instantiated – i.e. an abstract class cannot be instantiated.

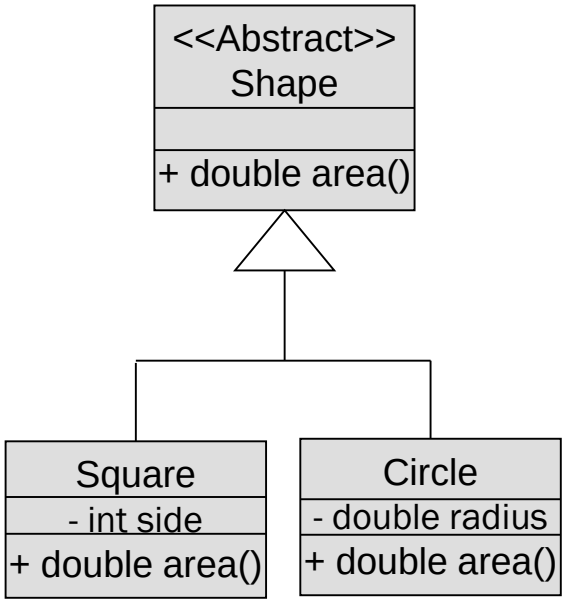
Example

```
abstract class Shape {
    abstract public void draw();
}

class Square extends Shape {
    // This method implements draw() of Shape
    public void draw() {
        System.out.println("Draw a square.");
    }
}
```

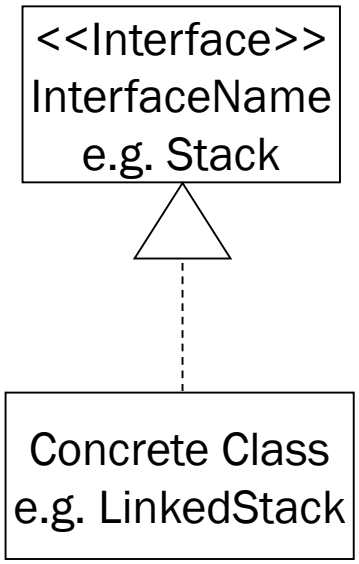
Abstract Classes & References

- The special thing about a Shape is that a shape may not know how to calculate its area until it knows that it is a circle or a square or a triangle, but it can still be looked at (or referred to) in terms of it being a basic shape.
- Consequently, even though it is not possible to have an object instantiated as a member of an abstract class, once a concrete object has been created, it can be referred to in terms of any of its derivation ancestors, even if they are abstract classes.
- So a Square object and a Circle object can both be referred to as Shape(s), and this is the key to making polymorphism work in practice.



Interfaces

- A class which contains nothing other than a set of abstract method specifications and no implementations of any of them, and no associated attribute data, is a special type of abstract class called an Interface.
- The special thing about interfaces is that they (unlike a base class) do not bring any implementation at all to the concrete class (neither attributes, nor actual methods) and so they play a different role in the inheritance structures outlined earlier
- The Java keyword implements allows any number of interfaces to be added into a derived class as interfaces only add specification, not implementation.
  - *All methods of the interface MUST be implemented*



UML diagram for Interface implementation

Interfaces

- Inheritance can be applied to interfaces as well as classes.
- One interface can be derived from another interface.
- The child interface inherits all abstract methods of the parent.
- A class implementing the derived (child) interface must define all methods from both the ancestor and child interfaces.
- All members of an interface are public.

Example

```
interface Shape {
    void draw();
}

class Square implements Shape {
    // This method implements draw() of Shape
    public void draw() {
        System.out.println("Draw a square.");
    }
}
```

Abstract Classes and Interfaces

Abstract classes

- extends
- Attributes
  - *Can be non-static or non-final*
- Single Inheritance
- May contain implementations

Interfaces

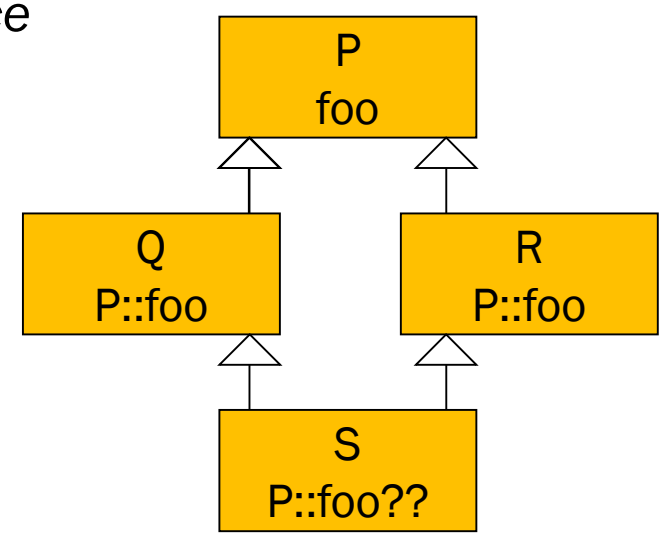
- implements
- Attributes
  - *public static final.*
- Multiple inheritance
- All methods are *public abstract*
- All methods must be implemented.

Interfaces in C++

- There is no specific interface structure in C++, but …
- The same thing can be obtained by using pure virtual classes (this is basically what an interface is), coupled with multiple (public) inheritance
- Extra flexibility is possible as a class, so derived, can remain abstract until a derivation of it finally has all method specifications implemented.

Multiple Inheritance in C++

- class S : public Q, R { , ... } ;
  - *Problems arise when both Q and R are derived from a common class (say class P)*
  - *Do you have two copies of the attribute data?*
  - *This is the so-called diamond inheritance problem*
  - *Solution: virtual inheritance*

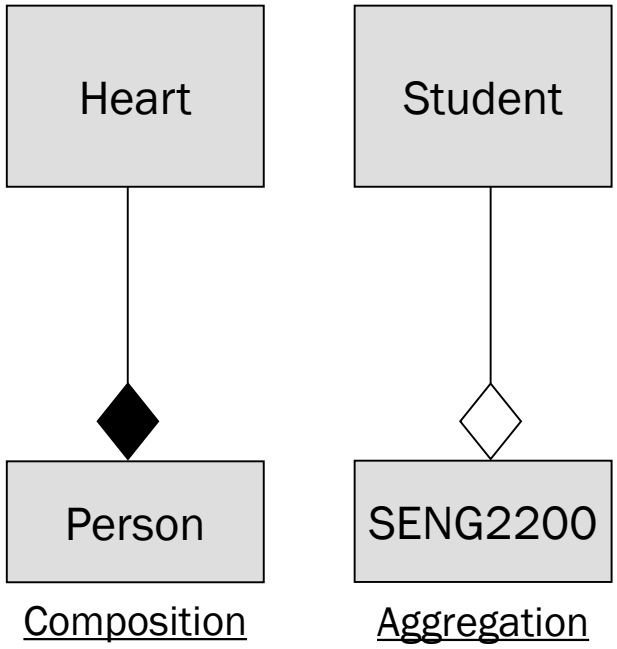


Part 2 – Composition & Aggregation

Composition vs Aggregation

- Objects created (modelled) by joining other objects together
- Composition - Eg a person is composed of: a head, a heart, etc.
- Aggregation - Eg a student is an aggregation of personal details, academic record, and currently enrolled courses.
- The main difference is in the relative lifetimes of the component parts – composition implies an equality of lifetimes for the components, aggregation implies a possibility that component lifetimes do not match.
- The level at which the object is modelled is important in deciding which of the component descriptions is used.

In UML

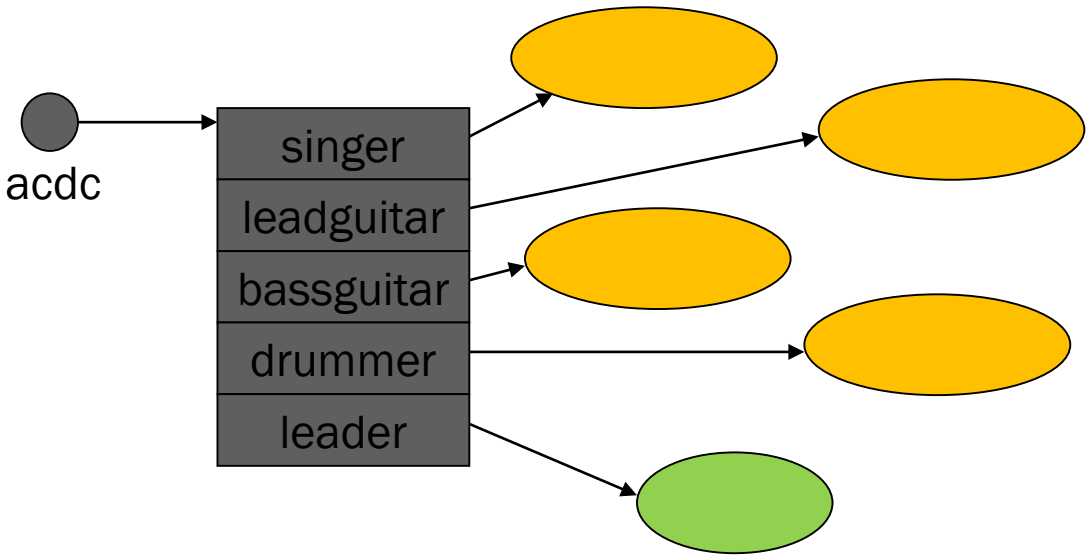


Composition – Java

Group
- Musician singer - Musician leadguitar - Musician bassguitar - Musician drummer - Manager leader
<methods go here>

- Components are references
- Need to be separately instantiated

Exercise: Write Java to create what is below

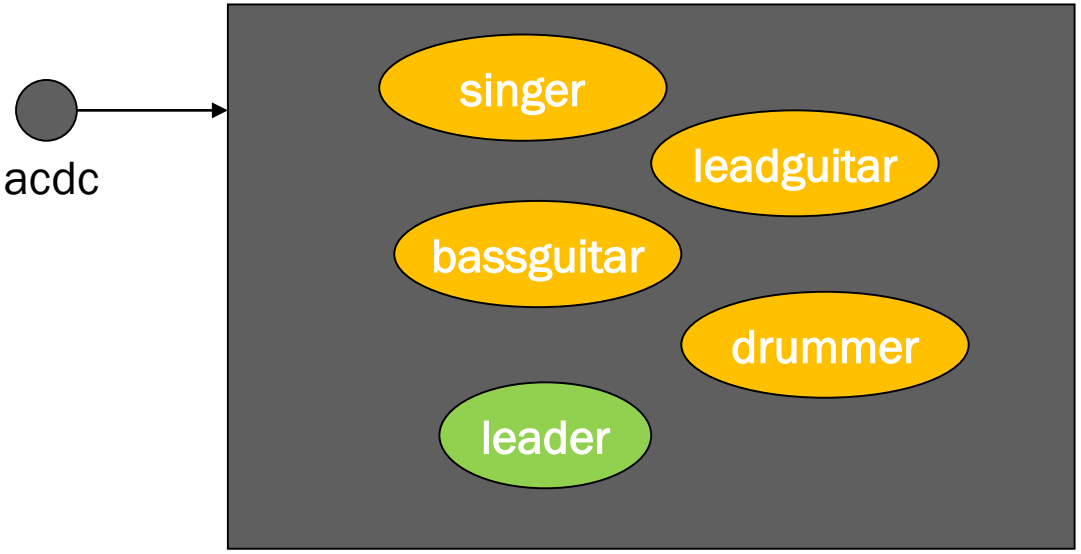


Composition – C++

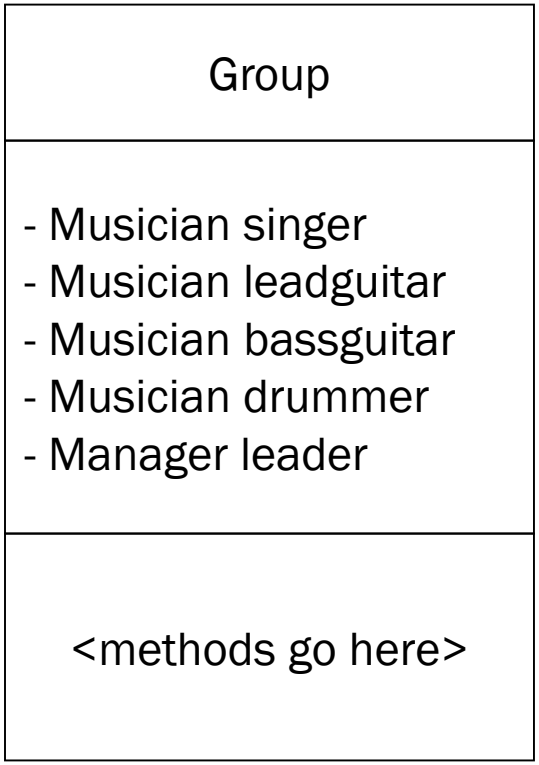
Group
- Musician singer - Musician leadguitar - Musician bassguitar - Musician drummer - Manager leader
<methods go here>

- Components are objects
- Instantiated and initialized using the default constructor (or could receive parameters)

Exercise: Write C++ to create what is below



Composition Comparisons



Java

- Components are references
- Need to be separately instantiated
- Relies on the garbage collector to recognize when each of the composite parts needs to be deallocated

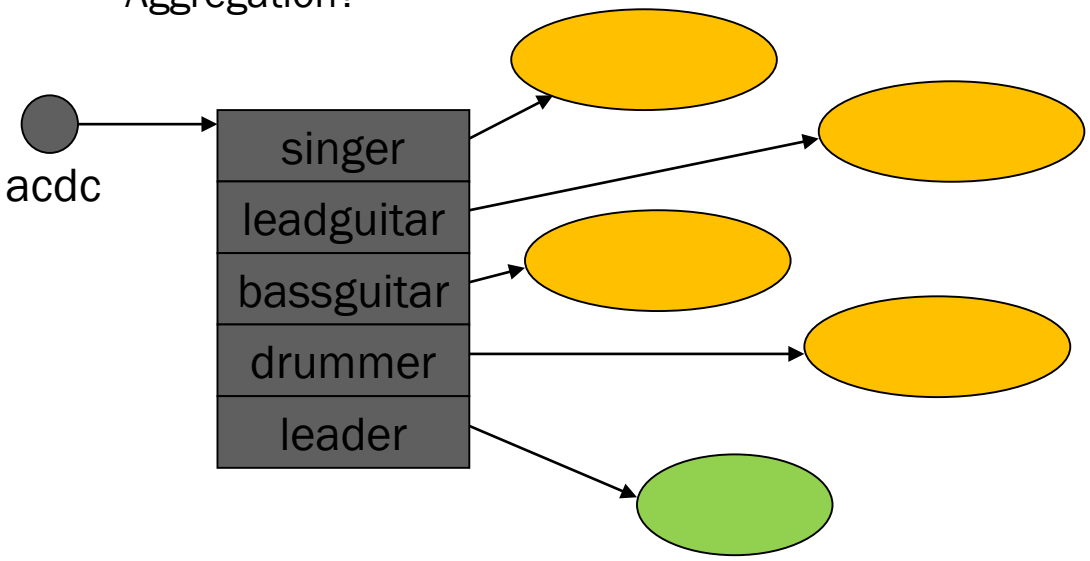
C++

- Components are objects
- Instantiated and initialized using the default constructor
- When the outer object is destroyed the composite parts are deallocated as well

Aggregation – Java

Group
- Musician singer - Musician leadguitar - Musician bassguitar - Musician drummer - Manager leader
<methods go here>

- How would aggregation be different from composition?
  - It is exactly the same as the layout for composition – the programmer decides on the relative lifetimes (GC enforces lifetimes)
- Does this mean that if you use Java you don't have to worry about whether you have Composition or Aggregation?



Aggregation – C++

Group
- Musician singer - Musician leadguitar - Musician bassguitar - Musician drummer - Manager leader
<methods go here>

- Components are pointers
- Need to be separately instantiated

Exercise: Write C++ to create what is below

- How would composition (using pointers) be different?
  - *Destructor*