STRUCTURE OF AN OBJECT

Structure of an Object

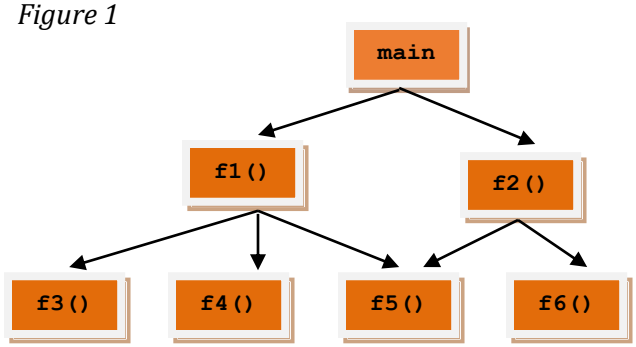
The "class" forms the foundation of object-oriented programming. A class can be viewed as an abstract data type that has been enhanced by the addition of object-oriented functionality. It should be noted that software reuse was one of the intended benefits of this type of programming. It was argued that the reuse of software components was necessary for software engineering to become a true engineering discipline. However, this has been found to be more difficult to achieve than originally anticipated.

Procedural versus Object-Oriented Programming

As a general rule, programming involves the manipulation of some form of data. The data is represented by a construct that captures the attributes or features of the data in question. For example, employee ID, type of car, etc. The manipulation of the data is provided via a set of primitive operations. These operations are in fact functions that can be represented in a variety of ways. For example, `+` can represent the addition function or `copy()` can represent the copy function. The way the data and the functions are represented by a programming language defines its methodology as well as the category in which the language can be placed.

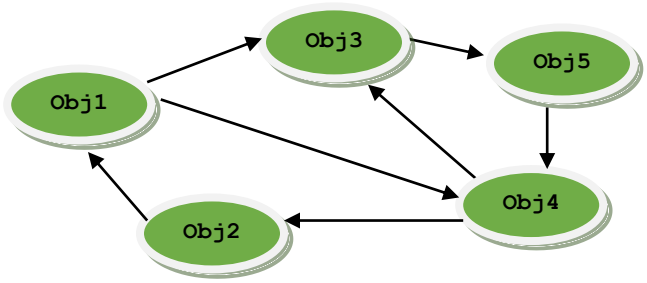
Procedural programming consists of data and a set of functions that operate on that data. The functions and the data are kept **separate** where the data is either global or passed to the functions (as actual parameters). Functions can call other functions, which results in a hierarchical type of structure, as shown in figure 1.

Figure 1



Object-oriented programming also consists of data and relevant functions, however, the data and the functions that act on it are **encapsulated** in a package called an **object**. As a result, an object carries both its data and its functions, making it an independent entity with loose coupling between it and other objects. In order for an object to utilize the functionality of other objects, **messages** are used. Thus, objects communicate with each other via messages. This results in a program that resembles a loosely connected network, as shown in figure 2.

Figure 2



The major benefit of object-oriented programming is that object modeling matches more closely to that of the real world. Also, it encourages and can simplify software reuse but there is no guarantee that one will achieve successful reuse. Error tracking, software modification and upgrades are also somewhat simplified (but again this is not guaranteed).

Finally, it should be remembered that procedural programming and object-oriented programming are very different in terms of design style and require entirely different ways of thinking. Consequently, you should not apply procedural design techniques to object-oriented programming.

It should be noted that it is possible to achieve the benefits of object-oriented programming within procedural programming but the programming process becomes more complex.

Classes versus Objects

Classes are the smallest units of design while objects are essentially the smallest units of execution. The objects interact with each other to provide the required functionality while the classes define the state and behaviour of those objects. In other words, an object is an **instance** of a class or a class defines an object's **type**.

To summarize, a class is a type. This is similar to the types, `int` and `char`. However, these are **primitive** types since they are built into the programming language and so cannot be changed. For example, a variable defined as type `int`, inherits the integer behaviour of the Java language. Therefore, integer operations, such as addition, `+` and subtraction, `-`, can be applied. Also, being integers, no decimal values are stored i.e. the data structure. However, the behaviour and data structure are predefined within the syntax and semantics of the Java programming language.

With classes, a programmer can define the behaviour and the structure of the data used, making them more advanced than primitive types. In order to use a class, you must declare a variable of the type of class in question, just as you would declare one of type `int`. Variables of a particular class type are called **objects**. Syntactically, in order to create and use a Java object, you must declare its **type** or class.

This is accomplished in two steps:

- Declare the object and
- Use the `new` operator to create the instance.

Note that unlike C++, the declaration of an object **does not** create a usable instance of the class. Instead you must use the `new` operator in order to access the functionality of the class. This feature is necessary so that many of the advanced Java object-oriented design techniques can be achieved (these features will be discussed in later handouts).

Consider the following example where an agent class, `Agent`, is created. For now, `Agent` will be an empty class. The `SimulationMain` class will be used to test the class.

```
public class Agent
{
} // Agent

// Actual execution begins in the function main of this class.
public class SimulationMain
{
      public static void main( String args[] )
      {
⇨           Agent a1, a2;            // declare these objects as type Agent

⇨           a1 = new Agent();        // create an instance of Agent
      }
} // SimulationcMain
```

Both objects, `a1` and `a2`, have been initially declared as class type `Agent`. In order to use `a1`, an instance of `Agent` was created via the **`new`** operator (see figure 3). Note that `a2` will remain inaccessible until an instance of `Agent` is created i.e. `a2 = new Agent()`.

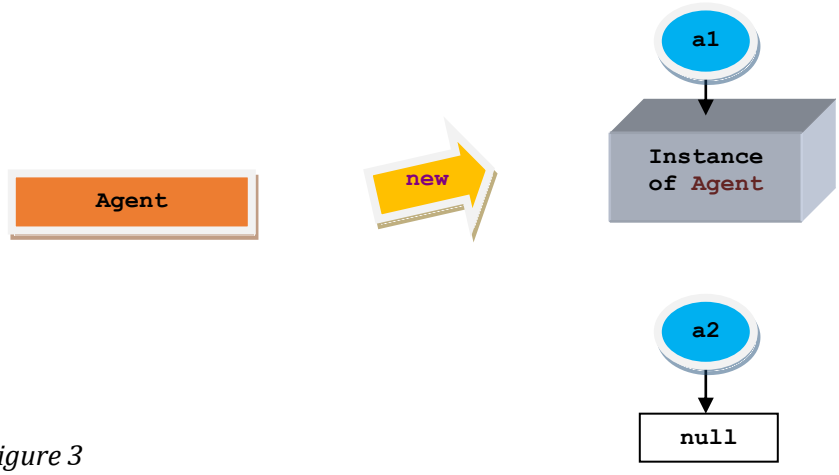


Figure 3

The **`main`** function is the starting point of all Java programs and so when a Java program is executed, the Java Virtual Machine (the Java interpreter) begins execution of the program at this point. As a result, the function prototype has been standardized as follows.

```
public static void main( String args[] )
{

} // main
```

The method declaration above must be followed when used in any Java class.

The Structure of a Class

A class defines the possible **state and behaviour** of any object that adopts that class as its type. In other words, the class defines the behaviour while the object is the actual use of that behaviour. As a result of this separation of definition and use, a program can have more than one object of a particular class type. For example, a car has four wheel objects i.e. each wheel object belongs to the class of wheels.

A class has two main sections: **fields** and **methods**

Fields

Fields define the possible states. The class defines the type and number of fields that an instance of it will contain. The fields hold the data for instance of the class created.

Methods

Methods describe the possible behaviour. They state the actions that an instance of the class can perform. This is also known as the *protocol* of the class. Like the fields, specific methods can be hidden within the class while others are exposed (see *Encapsulation* handout). Some texts use the term functions as opposed to methods.

The Structure of an Object

As stated previously, an object is an instance of a class i.e. the object belongs to a class of objects. Again, this separation is necessary so that more than one object can belong to a specific class. A newly created object is made up of the following four main sections: **id**, **type**, **fields** and **methods**.

The Id

The Id is the unique name assigned to an object, such as `a1` and `a2` in the previous example. It is a compulsory attribute since it is needed to distinguish one object from another.

 Objects within the same scope cannot have the same Id.

The Type

When declared, each object is assigned its class type, for example `Agent`. This attribute is also compulsory since it is required to ensure type safety and correct interface usage. When a programming language uses type safety it ensures:

- The class contains the named methods.
- The correct parameter types are passed to methods (functions).
- The types used in assignments are compatible. For example, an integer value can be assigned to a variable of type **`int`** but not one of type **`char`**.

Fields

Fields define the state of an object. Each instance of the class (each object) will receive its own copy of the fields, providing each object with its own unique state. These are also referred to as instance variables since a copy is created for each instance of a class. Consider the following example:

```
public class Agent
{
	// Fields
	int age, height; // fields or instance variables
} // Agent

public class SimulationMain
{
	public static void main( String args[] )
	{
		Agent a1, a2;

		a1 = new Agent();
		a2 = new Agent();
		a1.age = 35;
		a1.height = 150;
		a2.age = 25;
		a2.height = 200;
	}
} // SimulationMain
```

The class `Agent` defines 2 fields, `age` and `height`. Any instance of `Agent` will be given its own copy of the fields. In the previous example, both objects are of type `Agent` but each contains its own values for `age` and `height` i.e. `a1(35,150)` and `a2(25,200)` (see figure 4).

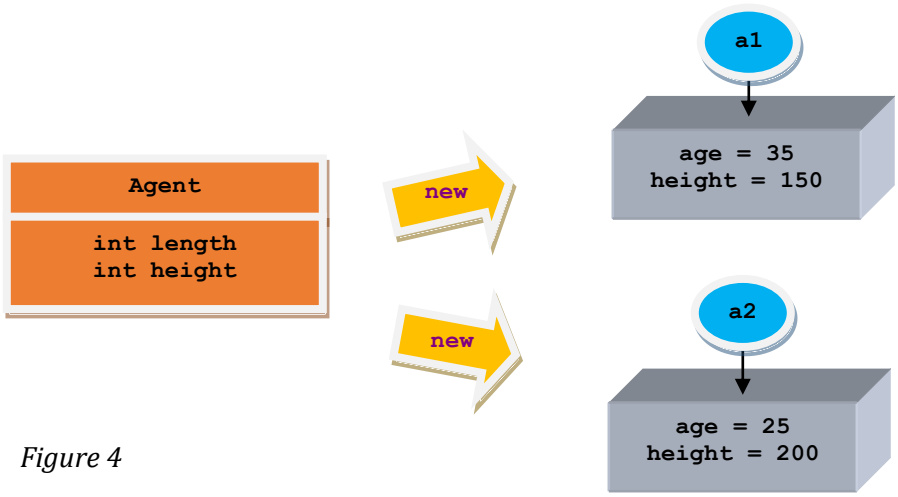


Figure 4

Fields are generally not exposed to the outside world (as in the previous example) and are hidden within the object. This will be discussed further in the *Encapsulation* handout.

Methods

Methods describe the behaviour of an object. All instances of a class share the same copy of the methods since they have the same behaviour. In our previous example, the fields for both `a1` and `a2` were accessed directly. By adding a method to set the field values, this direct access is no longer necessary. Consider the following example.

```
public class Agent
{
      int age, height;                          // Fields

      void set( int newAge, int newHeight )     // Methods
      {
            age = newAge;
            height = newHeight;
      } // set
} // Agent

public class SimulationMain
{
      public static void main( String args[] )
      {
            Agent a1, a2;

            a1 = new Agent();
            a2 = new Agent();
            a1.set( 35, 150 );                  // Method call
            a2.set( 25, 200 );                  // Method call
      }
} // SimulationMain
```

A method `set` has now been added to the class `Agent`. In this example, `a1` and `a2` use the same copy of the method `set` (see figure 5). This makes sense since there is no need to store more than one copy of the methods.

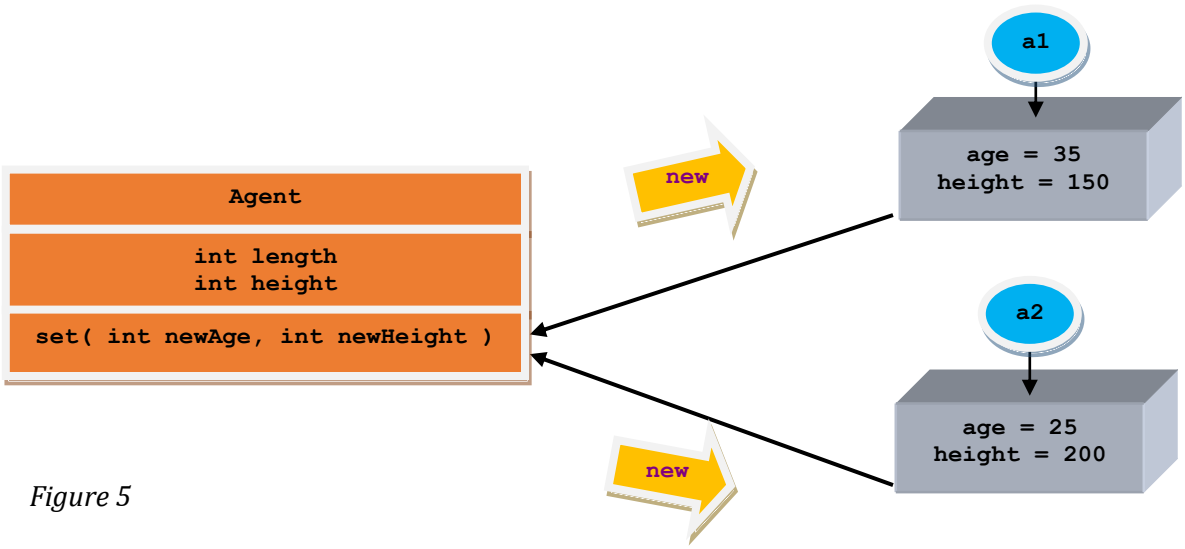


Figure 5

The `new` Operator

As stated previously, the **`new`** operator is used to create a usable instance of a class. In reality, when this operator is used, the **J**ava **V**irtual **M**achine (JVM) allocates enough memory to hold all of the object's data. This raises the question of what happens to the memory when the object is no longer in scope. In C/C++, the user would have to manually de-allocate the memory using the **`delete`** operator. In Java this is performed automatically and is called *Garbage Collection*. Garbage Collection has the following advantages and disadvantages.

Advantages

- Reduces the possibility of memory leaks since memory is freed/recovered as soon as it is no longer in use. A memory leak occurs when unused memory is not released, resulting in the eventual consumption of all of the available memory.
- An object that is being referenced cannot be deleted. This occurs mainly with pointers where it is possible to delete an object that is still being referenced by other pointers, resulting in some form of memory corruption.

Disadvantages

- Garbage collection can be one of the greatest bottlenecks in the speed of execution of a program, if not implemented correctly. Each time the garbage collector is activated, some aspects of the interpreter activity may be suspended. For example, if a call to the **`new`** operator is made and there is not enough memory, the execution of the code may be suspended until the garbage collector frees enough memory.
- Makes the low-level aspect of systems programming very difficult since the level of control of the memory allocation/de-allocation process has been reduced.

The `instanceof` Keyword

Java provides the `instanceof` keyword for **testing the type of an object**. Consider the following code.

```
public class TypeTest
{
      public static void main( String args[] )
      {
            Agent a = new Agent();

            if( a instanceof Agent )
            {
                  System.out.println( "This is an instance of Agent." );
            }
            else
            {
                  System.out.println( "This is NOT an instance of Agent." );
            }
      } // main
} // TypeTest
```

The output of this program will be:

This is an instance of Agent.

Since `a` is of type `Agent` then the test will return `true`.

Pointers

Java has no pointers but instead uses *references*. A reference is created when an object is declared. It provides access only to the functionality of the object and so the programmer does not have direct access to the memory, removing the dangers of pointer manipulation. For example:

- Pointers remove the concept of private data since they can provide direct access to that data.
- In some cases, integer values can be converted to pointer addresses which can result in incorrect addresses being formed and hence memory corruption.
- Arrays can be accessed directly by pointers. This can result in the program writing past the end of the array.

Interestingly, the lack of pointers can be a hindrance in specific cases. For example, imagine trying to create a memory manager for an operating system without pointers.

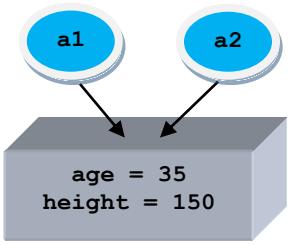
By using references, an assignment operation between two object-references in Java does not result in a copy of the values from one object to the other. Instead, both object-references now **refer to the same object**. Consider the following example.

```
public class SimulationMain
{
      public static void main( String args[] )
      {
            Agent a1, a2;      // declare these objects as type
                               // Agent i.e. the references

            a1 = new Agent();

            a1.set( 35, 150 );

⇨           a2 = a1;
      }
} // SimulationMain
```



The references `a1` and `a2`, both refer to the same object.

For each object created, Java keeps a **reference count**. This is an integer value that states how many references are currently referring to the object. When this count becomes 0, the object can be removed from memory by the Java Garbage Collector.

Global Variables

In Java, the global name space is the class hierarchy and so one cannot create a variable outside of a class. This removes the possibility of side effects occurring on a system-wide basis due to some change in the state of a global variable. For example, it is impossible to ensure that a global variable is changed in a consistent and controlled manner. Java does allow a modified form of the global variable called **static variables**, which is discussed in the *Encapsulation* handout.