Introduction To Java

What Is Java?

- New object-oriented programming (OOP) language developed by SUN Microsystems
- Similar to C and C++, except without some of the confusing, poorly understood features of C++
- Extensive networking facilities
- Extensive set of APIs for GUIs, distributed computing, 2D/3D graphics, mail, and others
- Portable: Write Once, Run Anywhere
- Multithreading support built into the language

Java Features

- Automatic garbage collection
  - ⇨ No manual memory allocation and deallocation
  - ⇨ Never have to worry about memory leaks
- No pointers or pointer arithmetic
  - ⇨ No off-by-one bugs
- Arrays are first-class objects
  - ⇨ Array bounds are always checked
- Multiple inheritance replaced by interfaces
  - ⇨ Eliminates complexities of multiple inheritance

Improves software reliability

Increases programmer productivity

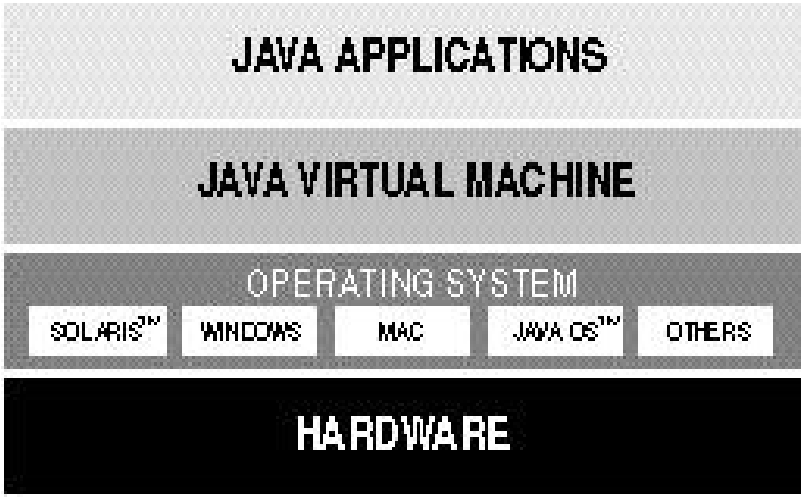
Features Removed From C/C++

- No typedefs, defines or preprocessor
- No header files
- No structures or unions
- No enums
- No functions - only methods in classes
- No multiple inheritance
- No goto
- No operator overloading (except “+” for string concatenation)
- No automatic type conversions (except for primitive types)
- No pointers

Java Virtual Machine

- Java is compiled into bytecodes
- Bytecodes are high-level, machine-independent instructions for a hypothetical machine, the Java Virtual Machine (JVM)
- The Java run-time system provides the JVM
- The JVM interprets the bytecodes during program execution
- Since the bytecodes are interpreted, the performance of Java programs slower than comparable C/C++ programs
- But the JVM is continually being improved and new techniques are achieving speeds comparable to native C++ code

Java Virtual Machine



- All Java programs run on top of the JVM
- The JVM was first implemented inside Web browsers, but is now available on a wide variety of platforms
- The JVM interprets the bytecodes defined in a machine-independent binary file format called a *class* file

Types Of Java Programs

- Application
  - ⇨ Standalone Java program that can run independent of any Web browser
- Applet
  - ⇨ Java program that runs within a Java-enabled Web browser
- Servlet
  - ⇨ Java software that is loaded into a Web server to provide additional server functionality ala CGI programs

The Hello World Program

- Create source file: Hello.java

```
public class Hello {
  public static void main (String args[]) {
    System.out.println("Hello World!");
  }
}
```

- Note that the name of the file is the name of the public class with a .java extension added
- Compile: javac Hello.java
  - ⇨ Produces the class file Hello.class
- Run: java Hello
  - ⇨ Starts up the JVM
  - ⇨ Note that the .class extension is *not* specified

Basic Java Language Elements

- Primitive Types
  - byte (1 byte) -128 to +127
  - short (2 bytes) -32,768 to 32,767
  - int (4 bytes) -2.15E+9 to +2.15E+9
  - long (8 bytes) -4.61E+18 to +4.61E+18
  - float (4 bytes) 1.0E-38 to 1.0E+38
  - double (8 bytes) -1.0E-308 to 1.0E+308
  - char (2 bytes) 0 to 0xffff (Unicode)
  - boolean (1 byte) *true* and *false*
  - All numeric types are sign extended

Basic Java Language Elements

- Operators
  - Similar to C++
  - Differences between C++ and Java Operators:
    - + is used to concatenate strings
    - instanceof returns true or false depending on whether the left side object is an instance of the right side object
    - >>> shifts bits right, filling with zeros
- Decision Constructs
  - if-else (test expression must resolve into a boolean)
  - switch (switch expression must resolve to an int, short, byte or char)
- Loops
  - Same as C/C++
  - while, do-while
  - for

Some Java OO Terminology

- *Class* - collection of data (attributes) and methods that operate on that data
- *Member* - either an attribute or a method of a class
- *Public Member* - member which is accessible by any method in any class
- *Private Member* - member which is accessible only by methods defined within the class
- *Public Class* - class that is visible everywhere and can be used by any method in any class
- *Object* - instance of a class
- *Object Instantiation* - the creation of a new object

Some Java OO Terminology

- *Constructor* - method which performs object initialization (*not* creation!)
- *Object Reference* - variable that holds a reference to (really the memory address of) an object
- *Instance Variable* - attribute for which each object (instance) has its own copy
- *Class Variable* - attribute for which there is only one copy for the class. Each object (instance) shares this copy. Also called a *static variable*

Some Java OO Terminology

- *Instance Method* - method which operates on the attributes of an object (instance)
- *Class Method* - method which does not operate on a particular object, but performs some utility function or operates on static variables. Also called a *static method*.
- *Method Signature* - the number, type and order of arguments of a method
- *Method Overloading* - defining a method with the same name but different signature as another method in the same class

Simple Java Example: Point

```
/**
 * Class Point implements a geometric point.
 * @author Bob Tarr
 */
public class Point {

  private int x;  // X Coordinate
  private int y;  // Y Coordinate

  /**
   * Creates a new Point with coordinates 0,0.
   */
  public Point() {
    x = 0;
    y = 0;
    System.out.println("Point() constructor: " + this);
  }
```

Simple Java Example: Point (Continued)

```
/**
 * Creates a new Point with the specified coordinates.
 * @param x The x coordinate.
 * @param y The y coordinate.
 */
public Point(int x, int y) {
  this.x = x;
  this.y = y;
  System.out.println("Point(int,int) constructor: " + this);
}

/**
 * Returns the x coordinate.
 * @return The x coordinate.
 */
public int getX() {return x;}
```

Simple Java Example: Point (Continued)

```
/**
 * Returns the y coordinate.
 * @return The y coordinate.
 */
public int getY() {return y;}

/**
 * Sets the x coordinate.
 * @param x The x coordinate.
 */
public void setX(int x) {this.x = x;}

/**
 * Sets the y coordinate.
 * @param y The y coordinate.
 */
public void setY(int y) {this.y = y;}
```

Simple Java Example: Point (Continued)

```
  /**
   * Converts a Point to a String.
   * @return The Point as a String.
   */
  public String toString() {
    return ("[" + x + "," + y + "]");
  }

}
```

Test Program For Point

- Test program for the Point class:

```
// Test program for the Point class.
public class TestPoint {
  public static void main(String  args[]) {
    // Create some Point objects.
    Point p1 = new Point();
    Point p2 = null;
    p2 = new Point(5,10);

    // Test the accessors and mutators.
    p1.setX(22);
    System.out.println("P1 is now: " +   p1);
    p2.setY(13);
    System.out.println("P2 is now: " +  p2);
  }
}
```

Test Program For Point (Continued)

- Test program output:

```
Point() constructor: [0,0]
Point(int,int) constructor: [5,10]
P1 is now: [22,0]
P2 is now: [5,13]
```

Arrays

- Arrays are objects in Java
- Creating an array involves three steps: declaration, creation and initialization
- Declaration:

```
Point data[];  // The variable data can hold a reference
               // to an array of Points
Point[] data;  // Same thing!
```

- Creation:

```
data = new Point[10]; // Now the variable data refers to the
                      // array of 10 elements that can refer
                      // to a Point object.  All the references
                      // in the array are null.
```

Arrays

- Initialization:

```
data[0] = new Point(4, 5);  // First array element initialized.
                            // It is now referring to the new
                            // Point object.
```

- Declaration, creation and initialization can be combined:

```
int[] values = {1,7,5,8,9};
Point[] points = {new Point(4,5), new Point(1,-3)};
```

Exceptions

- *Exception* - a signal that an error or special condition has occurred
- *Throw an exception* - to signal the error or special condition
- *Catch an exception* - to handle the error or special condition
- Exceptions propagate up the lexical block structure of the Java program until they are caught and handled
- If an exception is not handled, the Java interpreter will print an error message and stack trace and then exit

Exceptions

- Exceptions handling is done within a try/catch block:

```
try {
            // Try this code.  If it generates an exception,
            // we'll handle it in a catch block.
    }
catch (Exception1 e1) {
            // Handle exception type Exception1.
}
catch (Exception2 e2) {
            // Handle exception type Exception2.
}
finally {
            // Always execute this code.
}
```

Exceptions

- All exceptions in Java are objects derived from the Exception class
- Exceptions are of two types:
  - ⇨ Unchecked exceptions: These are exceptions that commonly occur, such as divide by zero. (They are instances of RuntimeException, a subclass of Exception).
  - ⇨ Checked exceptions: These are less common exceptions, such as an I/O error.
- Checked exceptions must either be caught or specified, else a compiler error will result
- A throws clause is used to indicate that the method may throw an exception up the call stack:

```
public void someMethod() throws IOException { ... }
```

Inheritance

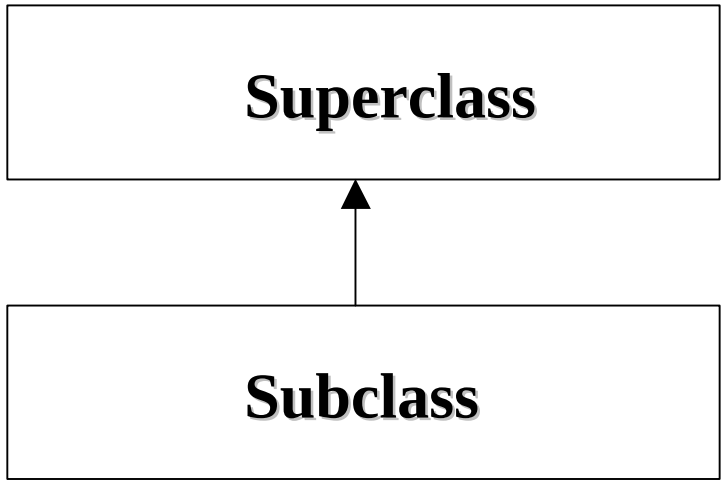
- Java supports single inheritance using the *extends* keyword:

```
public class B extends A
```

- The extended class is called a *subclass* of the class it extends
- The class that is extended is called its *superclass* or base class
- All classes implicitly extend the Object class
- A subclass can *override* a method in its superclass by providing a new definition for a method with the same name, return type and signature
- All method invocations in Java are *polymorphic*. The method called depends on the type of the object referred to by its object reference and not on the type of the object reference itself.

Inheritance

- A *protected member* of a class can be accessed by any method in the same class or a subclass. (It can also be access by any method in a class in the same package which will be described later.)
- UML Notation:



Inheritance Example

- Here's the superclass:

```
public class A {

  protected int aData;

  public A(int aData) {this.aData = aData;}

  public A() {aData = 0;}

  protected void f() {
    System.out.println("This is A's f");
  }

}
```

Inheritance Example (Continued)

- Here's the subclass:

```
public class B extends A {

  protected int bData;

  public B(int bData) {this.bData = bData;}

  public B() {this(0);}

  protected void f() {
    System.out.println("This is B's f");
  }

  protected void g() {
    System.out.println("This is B's g");
  }
}
```

Inheritance Example (Continued)

- Here's the test program:

```
public class ABTest {

  public static void main(String[] argv)  {

    //Polymorphism
    A a = new A();
    B b = new B();
    a.f();              // Invokes A's f()
    b.f();              // Invokes B's f()
    A a1 = b;
    a1.f();             // Invokes B's f()

    // Up Casting
    A a2 = (A) b;       // Ok
```

Inheritance Example (Continued

```
    // Down Casting
    //B b1 = a;          // Illegal at compile time,
                         //   explicit cast needed
    //B b2 = (B) a;      // Ok at compile time,
                         //   exception at run time

    // Other stuff
    int i = a.aData;     // Ok, same package
    //i = a.bData;       // Illegal at compile time,
                         //   bData not defined in A
    //a.g();             // Illegal at compile time,
                         //   g() not found in A
  }

}
```

Constructor Chaining

- Java always invokes a superclass constructor when a subclass object is created (since the superclass object is “part of” the subclass object)
- You can explicitly call a superclass constructor using a call to super(…) as the first line of a subclass constructor:

```
public B(int bData) {
  super();  // Explicitly call our superclass constructor
  this.bData = bData;
}
```

- If you do not explicitly invoke a superclass constructor, then the no-arg superclass constructor is implicitly called for you. That is, Java inserts the call to "super()" for you automatically.

Constructor Chaining

- What? You don't have a no-arg superclass constructor? That's ok, provided you have *no* superclass constructors, in which case the default no-arg constructor for a class is supplied for you. (But if you have superclass constructors defined, and do not have a no-arg one, you'll get a compiler error when Java tries to insert the call to "super()" in the subclass constructor.)
- The default no-arg constructor supplied by Java does just one thing - it makes a call to the no-arg superclass constructor!
- One exception: If the first line of a constructor uses the "this(…)" syntax to invoke another constructor of the class, then Java does not automatically insert the call to "super()" in the constructor:

```
public B() {
  this(0);  // Call to super() not automatically inserted here.
}
```

Abstract Methods And Classes

- An *abstract method* has no body
- It is like a pure virtual function in C++.
- The abstract method is expected to be overridden in a subclass with an actual implementation
- Any class with an abstract method is an *abstract class* and must be declared abstract
- An abstract class can not be instantiated
- If a subclass of an abstract class does not provide implementations for all of the abstract methods of its superclass, then the subclass itself is abstract

Abstract Class Example

```
// Class Shape is an abstract base class for a geometric shape.
public abstract class Shape {
  public abstract double area();
}

// Class Rectangle is a concrete implementation of a Shape.
public class Rectangle extends Shape {

  protected double w;
  protected double h;

  public Rectangle(double w, double h) {
    this.w = w;
    this.h = h;
  }

  public double area() { return (w * h); }
}
```

Interfaces

- In OO terminology, an *interface* is some subset of the public methods of a class. The *implementation* of a class is the code that makes up those methods.
- In Java an *interface* is just a specification of a set of abstract methods
- A class that implements the interface must provide an implementation for all of the abstract methods in the interface
- A class can implement many interfaces, but a class can only extend one class
- So a Java interface expressly separates the idea of an OO interface from its implementation

Interface Example

```
// Interface Drawable provides the specification for a drawable
// graphics object.
public interface Drawable {
  public void Draw();
}

// Class DrawableRectangle implements the Drawable interface.
public class DrawableRectangle
  extends Rectangle
  implements Drawable {

  // Other code here.

  public void Draw()  {
    // Body of Draw()
  }
}
```

Differences Between Interfaces and Abstract Classes

- A class can implement more than one interface, but an abstract class can only subclass one class
- An abstract class can have non-abstract methods. All methods of an interface are implicitly (or explicitly) abstract.
- An abstract class can declare instance variables; an interface can not
- An abstract class can have a user-defined constructor; an interface has no constructors
- Every method of an interface is implicitly (or explicitly) public. An abstract class can have non-public methods.

Why Are Interfaces Important?

- An object's type essentially refers to the OO interface of its class
- So, in Java, an object of a class that implements several interfaces has many types
- And objects from many different classes can have the same type
- This allows us to write methods that can work on objects from many different classes which *can even be in different inheritance hierarchies:*

```
public void renderScreen(Drawable d) {
  // Render this Drawable on the screen.
  // It does not matter whether this is DrawableRectangle,
  // DrawableCircle, etc. Since the object is a Drawable, it
  // MUST implement the Draw method.
  d.Draw();
}
```

Packages

- Java classes can be grouped together into a *package*
- Packages have several advantages:
  - ⇨ related classes can be grouped together
  - ⇨ class names and member names need not be unique across the entire program
  - ⇨ members can be accessible only to methods of classes in the same package
- The package statement must appear as the first statement of the Java source file:

```
package BT.Tools.Graphics;
```

- If no package statement is present, the code is made part of the unnamed default package

Packages

- A fully qualified Java name for a class is:
  - ⇨ <Package Name>.<Class Name>
  - ⇨ For example, BT.Tools.Graphics.Point
- Class files must be stored in a directory that has the same components of the package name for the class
  - ⇨ For example, the class BT.Tools.Graphics.Point must be in the BT/Tools/Graphics/Point.class file
  - ⇨ This filename is interpreted relative to one of the directories specified in the CLASSPATH environment variable

Packages

- The CLASSPATH environment variable tells the Java interpreter where to look for user-defined classes. CLASSPATH is a colon-separated list of directories to search or the names of "zip" or "jar" files that contain the classes:
  - ⇨ For example, setenv CLASSPATH .:/home/bt/java:/usr/local/comms/classes.zip
  - ⇨ Given the above CLASSPATH, if the Point.class file is in /home/bt/java/BT/Tools/Graphics, it will be successfully found by the Java run-time system

The Import Statement

- The import statement allows the use of abbreviated class names in a Java source file
- Classes are always available via their fully-qualified names:

```
BT.Tools.Graphics.Point p = new BT.Tools.Graphics.Point();
```

- The import statement does not "read in" the class or "include" it; it just saves typing:

```
import BT.Tools.Graphics.Point;
Point p = new Point();
```

- All of the classes of a package can be imported at one time using this form of the import statement:

```
import java.util.*;
```

This imports all of the classes in the java.util package.

Visibility Modifiers

- We've already seen that a class member can be modified with the public, private or protected keywords
- If none of these modifiers are used, the member has the default visibility or "package" visibility
- A *package member* is only accessible from within the class that defines it or a class in the same package
- Here's the definitive chart!

ACCESSIBLE TO:	MEMBER VISIBILITY			
	public	**protected**	**package**	**private**
Same class	Yes	Yes	Yes	Yes
Class in same package	Yes	Yes	Yes	No
Subclass in different package	Yes	Yes	No	No
Non-subclass in different package	Yes	No	No	No

Table from *Java In A Nutshell, 2nd Edition* by David Flanagan

Inner Classes

- Inner classes were added to the Java language in Java 1.1
- There are now five different types of Java classes and two different types of Java interfaces
- Top-level classes and interfaces
  - *Package member class (or interface)*
    - Ordinary class (or interface) that is a direct member of a package
    - The original, familiar Java 1.0 class (or interface)
  - *Nested top-level class (or interface)*
    - A class (or interface) declared static within another top-level class (or interface)
    - Can only access the static members of its containing class
    - Useful for helper classes (and interfaces) and provide a convenient way to group related classes (or interfaces)

Inner Classes (Continued)

- Inner classes
  - *Member class*
    - A class defined as a member of another class
    - Can not be declared static
    - Can not have any static members
    - Can access all members (even private) of its containing class
    - Also useful for helper classes
  - *Local class*
    - Class defined inside a block of code
    - Is visible only within the enclosing block
    - Analogous to a local variable
    - Can access all members (even private) of its enclosing class
    - Similar in use to a member class, but can be put close to the location in the code where it is actually used, thus improving readability

Inner Classes (Continued)

- Inner classes
  - *Anonymous class*
    - A local class which is defined and instantiated in one statement
    - Does not have a name!
- Inner classes are frequently used to implement the event listener objects required by the Abstract Window Toolkit (AWT) or Swing Java Foundation Classes GUI components

Member Class Example

```
// Member Class example.
public class ButtonDemo {
  public ButtonDemo() {
    // Create a button.
    Button button = new Button("Press me");
    // Register an ActionListener for the button.
    button.addActionListener(new ButtonActionHandler());
    ...
  }
  ...
  // Somewhere later in the file we have this member class which
  //   defines the required ActionListener.
  class ButtonActionHandler implements ActionListener {
    public void actionPerformed(ActionEvent e) {
      System.out.println("You pressed me, you pressed me!");
    }
  }
}
```

Local Class Example

```
// Local Class example.
public class ButtonDemo {
  public ButtonDemo() {
    // Create a button.
    Button button = new Button("Press me");
    // Register an ActionListener for the button.
    button.addActionListener(new ButtonActionHandler());

    // Let's put the definition of the required ActionListener right
    //   here as a local class.  That way, it is much closer in the
    //   source file to its actual use.
    class ButtonActionHandler implements ActionListener {
      public void actionPerformed(ActionEvent e) {
        System.out.println("You pressed me, you pressed me!");
      }
    }
  }
}
```

Anonymous Class Example

```
// Anonymous Class example.
public class ButtonDemo {
  public ButtonDemo() {
    // Create a button.
    Button button = new Button("Press me");

    // Instantiate an anonymous inner class that acts as the
    //   ActionListener for the button.
    button.addActionListener(new ActionListener() {
      public void actionPerformed(ActionEvent e) {
         System.out.println("You pressed me, you pressed me!");
      }
    } );
    ...
  }
  ...
}
```

Anonymous vs Local

- Which one should you use? An anonymous class or a local class?
- It's a matter of your own personal style
- But….
- Prefer an anonymous class if
  - ⇨ The class is very small
  - ⇨ Only one instance of the class is needed
  - ⇨ The class is to be used right after it is defined
  - ⇨ Naming the class does not make your code any easier to read
- Prefer a local class if
  - ⇨ More than one instance of the class is required