# The

# language



The Java language:

- was originally called Oak;
- was developed as a small, clean, OO language for programming consumer devices;
- was built into the Webrunner browser;
- matured into Java and HotJava;
- is now supported by many browsers, allowing Java programs to be embedded in WWW pages;
- is also used by web servers, even if the client user is not running Java; and
- is the implementation language for several large applications.



Basic compilation (`.java` → `.class`):

- Java programs are developed as source code for a collection of Java classes;
- each class is compiled into Java Virtual Machine (JVM) bytecode;
- bytecode is interpreted or JIT-compiled using some implementation of the JVM;
- Java supports a GUI; and
- many browsers have Java plugins for executing JVM bytecode.



Major benefits of Java:

- it's object-oriented;
- it's a "cleaner" OO language than C++;
- it's portable (except for native code);
- it's distributed and multithreaded;
- it's secure;
- it supports windowing and applets;
- it's semantics is completely standardized;
- it has a huge class library; and
- it's finally finally finally officially open source.

Java security has many sources:

- programs are strongly type-checked at compile-time;
- array bounds are checked at run-time;
- `null` pointers are checked at run-time;
- there are no explicit pointers;
- dynamic linking is checked at run-time; and
- class files are verified at load-time.



Major drawbacks of Java:

- it misses some language features, e.g. genericity (until 1.5), multiple inheritance, operator overloading;
- it does not have one *single* standard (`JDK 1.0.2` vs. `JDK 1.1.*` vs. ...) and probably never will;
- it can be slower than C++ for expensive numeric computations due to dynamic array-bounds checks; $Z^{Z^{Z^{ZZ}}}$ and
- it's not JOOS.



Goals in the design of JOOS:

- extract the object-oriented essence of Java;
- make the language small enough for course work, yet large enough to be interesting;
- provide a mechanism to link to existing Java code; and
- ensure that every JOOS program is a valid Java program, such that JOOS is a strict subset of Java.



Programming in JOOS:

- each JOOS program is a collection of classes;
- there are ordinary classes which are used to develop JOOS code; and
- there are external classes which are used to interface to Java libraries.

An ordinary class consists of:

- protected fields;
- constructors; and
- public methods.

```
$ cat Cons.java
public class Cons {
  protected Object first;
  protected Cons rest;

  public Cons(Object f, Cons r)
  { super(); first = f; rest = r; }

  public void setFirst(Object newfirst)
  { first = newfirst; }

  public Object getFirst()
  { return first; }

  public Cons getRest()
  { return rest; }

  public boolean member(Object item)
  { if (first.equals(item))
       return true;
    else if (rest==null)
       return false;
    else
       return rest.member(item);
  }

  public String toString()
  { if (rest==null)
       return first.toString();
    else
       return first + " " + rest;
  }
}
```



Notes on the `Cons` example:

- fields in JOOS must be *protected*: they can only be accessed via objects of the class or its subclasses;
- constructors in JOOS must start by invoking a constructor of the superclass, i.e. by calling `super(...)` where the argument types determine the constructor called;
- methods in JOOS must be *public*: they can be invoked by any object; and
- only constructors in JOOS can be overloaded, other methods cannot.

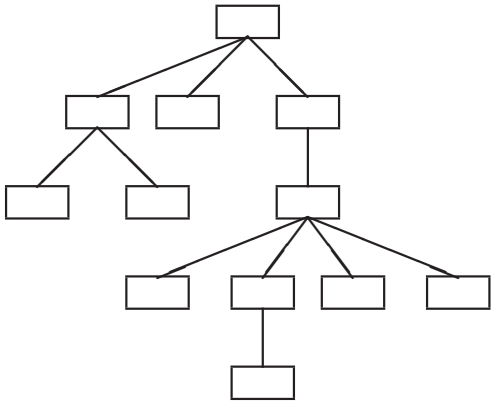


Other important things to note about JOOS:

- subclassing must not change the signature of a method;
- local declarations must come at the beginning of the statement sequence in a block; and
- every path through a non-void method must return a value. (In Java such methods can also throw exceptions.)



The class hierarchies in JOOS and Java are both single inheritance, i.e. each class has exactly one superclass, except for the root class:

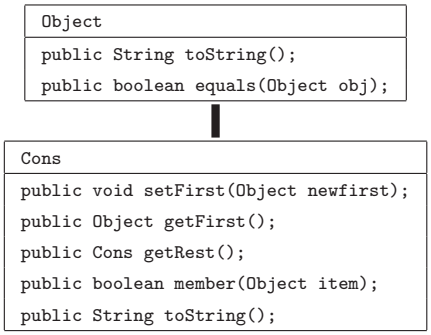


The root class is called `Object`, and any class without an explicit `extends` clause is a subclass of `Object`.

The definition of `Cons` is equivalent to:

```
public class Cons extends Object
{ ... }
```

which gives the tiny hierarchy:






The class `Object` has two methods:

- `toString()` returns a string encoding the type and object id; and
- `equals()` returns true if the object reference denotes the current object.

These methods are often overridden in subclasses:

- `toString()` encodes the value as a string; and
- `equals()` decides a more abstract equality.

When overriding a method, the argument types and return types must remain the same.

When overriding `equals()`, `hashcode()` must also be overridden: equal objects *must* produce the same hashcode.

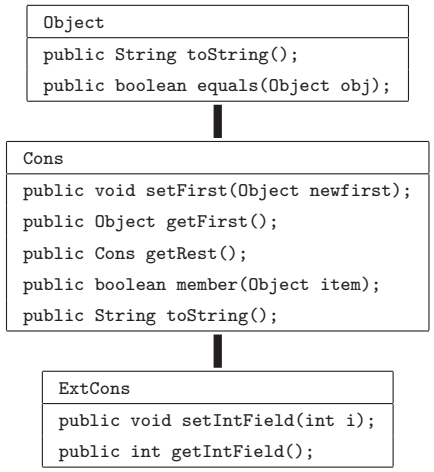


Extending the `Cons` class:

```
$ cat ExtCons.java
public class ExtCons extends Cons {
  protected int intField;

  public ExtCons(Object f, Cons r, int i)
  { super(f,r);
    intField = i;
  }

  public void setIntField(int i)
  { intField = i; }

  public int getIntField()
  { return(intField); }
}
```



The extended hierarchy:



Using the `Cons` class:

```
$ cat UseCons.java
import joos.lib.*;

public class UseCons {

  public UseCons() { super(); }

  public static void main(String argv[])
    { Cons l;
      JoosIO f;

      l = new Cons("a",new Cons("b",new Cons("c",null)));
      f = new JoosIO();
      f.println(l.toString());
      f.println("first is " + l.getFirst());
      f.println("second is " + l.getRest().getFirst());
      f.println("a member? " + l.member("a"));
      f.println("z member? " + l.member("z"));
    }
}
```

A Java program (not an applet) requires a `main()` method.

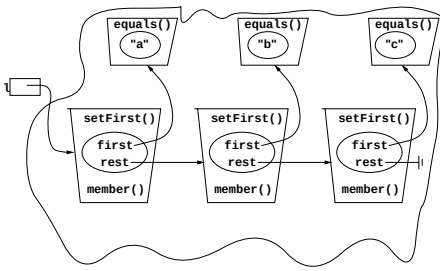
It is necessary to `import` library functions such as `println()`.



Compile and run the `UseCons` program:

```
$ javac joos/lib/*.java
$ joosc UseCons.java Cons.java
$ java UseCons
```

The `UseCons` program builds these objects:




The output of the `UseCons` program is:

```
a b c
first is a
second is b
a member? true
z member? false
```



Types in JOOS are either primitive types:

- `boolean`: `true` and `false`;
- `int`: $-\mathbf{2^{31}} \ldots \mathbf{2^{31} - 1}$;
- `char`: the ASCII characters;

or user-defined class types;

or externally defined class types:

- `Object`;
- `Boolean`;
- `Integer`;
- `Character`;
- `String`;
- `BitSet`;
- `Vector`;
- `Date`.

Note that `boolean` and `Boolean` are different.



Types in Java and JOOS:

- Java is strongly-typed;
- Java uses the name of a class as its type;
- given a type of class `C`, any instance of class `C` or a subclass of `C` is a permitted value;
- there is "down-casting" which is automatically checked at run-time:

  ```
  SubObject subobj = (SubObject) obj;
  ```

- there is an explicit `instanceof` check:

  ```
  if (subobj instanceof Object)
    return true;
  else
    return false;
  ```

- and finally some type-checking must be done at run-time.

Statements in JOOS:

- expression statements:

```
x = y + z;
x = y = z;
a.toString(1);
new Cons("abc",null);
```

- block statements:

```
{ int x;
  x = 3;
}
```

- control structures:

```
if (l.member("z")) {
   // do something
}

while (l != null) {
   // do something
   l = l.getRest();
}
```

- return statements:

```
return;

return true;
```



Expressions in JOOS:

- constant expressions:

```
true, 13, '\n', "abc", null
```

- variable expressions:

```
i, first, rest
```

- binary operators:

```
||
&&
!= ==
< > <= >= instanceof
+ -
* / %
```

- unary operators:

```
-
!
```



Expressions in JOOS:

- class instance creation:

```
new Cons("abc",null)
```

- cast expressions:

```
(String) getFirst(list)
(char) 119
```

- method invocation:

```
l.getFirst()
super.getFirst();
l.getFirst().getFirst();
this.getFirst();
```



Abstract methods and classes:

- a method may be `abstract`, where no implementation is given;
- if a class contains one or more `abstract` methods, it must be defined as an `abstract` class;
- the constructor of an `abstract` class cannot be invoked;
- `abstract` classes are used to define "frameworks".

```
$ cat Benchmark.java
import joos.lib.*;

public abstract class Benchmark {

  protected JoosSystem s;  // JOOS interface to
                           // the Java System Class

  public Benchmark()
  { super();
    s = new JoosSystem();
  }

  // Hook for actual benchmark
  public abstract void benchmark();

  // driver to time repeated executions
  public int myrepeat(int count)
  { int start;
    int i;

    start = s.currentTimeMillis();
    i = 0;
    while (i < count) {
      this.benchmark();
      i = i+1;
    }
    return s.currentTimeMillis()-start;
  }
}
```



```
$ cat ExtBenchmark.java
public class ExtBenchmark extends Benchmark {
  public ExtBenchmark() {
    super();
  }

  public void benchmark() {}   // timing an empty method
}

$ cat UseBenchmark.java
import joos.lib.*;

public class UseBenchmark {

  public UseBenchmark() { super(); }

  public static void main(String argv[])
  { ExtBenchmark b;
    JoosIO f;
    int reps;
    int time;

    b = new ExtBenchmark();
    f = new JoosIO();

    f.print("Enter number of repetitions: ");
    reps = f.readInt();
    time = b.myrepeat(reps);
    f.println("time is " + time + " millisecs");
  }
}
```



Final methods and classes:

- the `final` keyword is used when no modifications to functionality are allowed;
- a `final` method cannot be overridden by subclasses;
- a `final` class cannot be extended;
- `final` classes typically belong to libraries: `Boolean`, `Integer`, and `String` (for security purposes).

Note that JOOS does not provide `final` *fields* like Java does.



Synchronized methods:

- Java and JOOS programs can start multiple threads;
- sometimes access to a shared resource must be protected, such that only one thread is in a *critical section* at a time;
- each object has an associated lock; and
- JOOS provides `synchronized` methods, such that when a thread invokes a `synchronized` method on an object, the thread does not enter the method until it has successfully acquired the target object's lock and it holds on to the lock until the method execution completes.

Note that JOOS does not provide `synchronized` blocks like Java does.

```
$ cat SyncBox.java
public class SyncBox {
  protected Object boxContents;

  public SyncBox() { super(); }

  // return contents of the box, set contents to null
  public synchronized Object get()
  {
    Object contents;
    contents = boxContents;
    boxContents = null;
    return contents;
  }

  // put something in the box,
  // if the box already has something in it, return false
  // else fill the box, return true
  public synchronized boolean put (Object contents)
  {
    if (boxContents != null) return false;
    boxContents = contents;
    return true;
  }
}
```



External classes in Java:

- Java compiles programs with respect to a set of libraries of precompiled class files; and
- when a Java compiler encounters an unknown method, it searches the precompiled bytecode for an implementation.

External classes in JOOS:

- JOOS compiles programs with respect to a set of libraries of precompiled class files; but
- external classes must be explicitly presented to the JOOS compiler.



```
$ cat joos/extern/javalib.joos

[...]

// java.lang.String
extern public final class String in "java.lang" {
  public String();
  public String(String value);
  public String(StringBuffer buffer);
  public String vlaueOf(boolean b);
  public char charAt(int index);
  public int compareTo(String anotherString);
  public boolean endsWith(String suffix);
  public boolean equals(Object obj);
  public boolean equalsIgnoreCase(String anotherString);
  public int indexOf(String str, int fromIndex);
  public int lastIndexOf(String str, int fromIndex);
  public int length();
  public boolean regionMatches(boolean ignoreCase,
      int toffset, String other, int ooffset, int len);
  public boolean startsWith(String prefix, int toffset);
  public String substring(int beginIndex, int endIndex);
  public String concat(String str);
  public String toLowerCase();
  public String toUpperCase();
  public String toString();
  public String trim();
}

[...]
```



External declarations for Java libraries:

- `javalib.joos`
- `appletlib.joos`
- `awtlib.joos`
- `netlib.joos`
- `BigDecimal.joos`

External declarations for JOOS libraries:

- `jooslib.joos`

Example JOOS programs:

- `AppletGraphics`: simple graphics programs to be displayed via a browser;
- `AwtDemos`: examples of using the Abstract Windows Toolkit;
- `ImageDemos`: two techniques for displaying an animation;
- `Network`: simple examples of interacting over the network;
- `Simple`: a relatively large collection of simple programs;
- `Threads`: simple multithreaded programs; and
- `WIGapplets`: examples of WIG applets.

All examples should work, please email your TA if they do not.

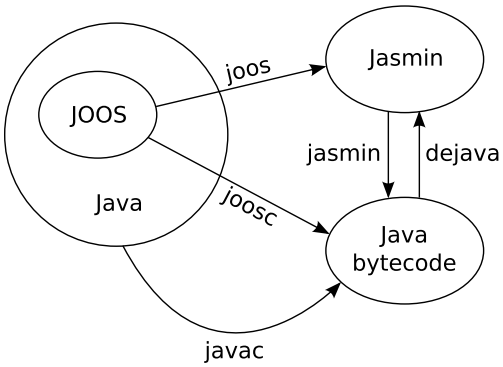


When compared to Java, JOOS:

- does not support packages, interfaces, exceptions, some control structures, mixed statements and declarations;
- has only `protected` fields and `public` methods;
- does not allow overloading of methods;
- does not support arrays;
- does not allow static methods;
- supports only `int`, `boolean`, and `char` as primitive types; and
- uses external class declarations.



Converting between JOOS & Java source code (`*.java`, `*.joos`), Jasmin assembler (`*.j`) and Java bytecode (`*.class`):




`joosc` simply calls `joos` and then `jasmin`.