MJ: A Rational Module System for Java and its Applications

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What is in JAVA?

- Class
  - OO encapsulation
- Package
  - Static Namespace
- Classloader
  - Dynamic Namespace

Review:Package in Java

- Package groups related classes and interfaces and provides access protection and namespace management statically
- package offers an access level between class and subclass,world.
- "world" can only access public classes declared in a package

Review: Java Classloader

- Classloader is responsible for converting Java bytecode into Java class files
- Classloaders are organized in a hierarchy. The root of all class loaders is called the system classloader.
- Policies are defined for each classloader regarding whether a class is allowed to load, access or not.
  - Dynamic Namespace
- The child classloader has to consult the parent to load a class.
- Help manage unknown code,specifically designed for security reason

What is missing in JAVA?

- What they need
  - Flexible component interface
- Class
  - Too fine-grained to define a component
- Package
  - No nested component
  - Expose same interface to outside world
- Classloader
  - Policy hard-coded in the program
  - No static checking

What they do and how?

- Motivation: remove classloader from codes (efficiency?)
- MJ module system
  - Add-on to java
  - Module enabled Javac
  - Static checking
- How?
  - Classloader

Problem:Abstract Datatype

- Need: an object with implementation class C, providing only an abstract interface A to some clients, while providing a more extensive interface to others.
  - e.g. There is no safe backdoor for java.lang.String

```
public class String{
  private char value[];
  public void   getChars (int srcBegin, int srcEnd,
                                  char[] dst, int dstBegin)
}
```

  - Whenever you need the character array of a string, you have to copy it out first

Problem: Multiple Versions of the Same Class

- XML parser, XSL processor
  - XML APIs are changing very rapidly
- Different ORBs
  - IONA Orbix, Visibroker
- But same class name, each ORB has its own different ORB will have its own name space (classloader)

More Problems:

- Classpath management for programmers
- Missed optimization opportunities
- All mentioned problems are not related to security

A Module System For Java: A Programmer's View

- A module's metadata consists of the following information:
  - Which classes this module provides, and where these classes are archived
  - Which other modules does this module depend on, and which classes do we require from each of these modules
  - Access Control for this module's provided classes
  - Initialization Code

Sample Module Definition (.jm file)

```
provides "catalina.jar";
import * from xerces;
import * from bootstrap;
import com.sun.tools.* from tools;

hide * in *;
export org.apache.catalina.* to
  webapp;
export org.apache.catalina.servlets
  to servlets;

forbid org.apache.catalina.* in *;

module catalina {
  public static void load() { …. }
  public static void main(String[]
  args) { … }
}
```

Sample Module Definition: Module Name

```
provides “catalina.jar”;
import * from xerces;
import * from bootstrap;
import com.sun.tools.* from tools;

hide * in *;
export org.apache.catalina.* to
  webapp;
export org.apache.catalina.servlets
  to servlets;

forbid org.apache.catalina.* in *;

module catalina {
  public static void load() { …. }
  public static void main(String[]
  args) { … }
}
```

Sample Module Definition: Java Resources

```
provides "catalina.jar";
import * from xerces;
import * from bootstrap;
import com.sun.tools.* from tools;

hide * in *;
export org.apache.catalina.* to
  webapp;
export org.apache.catalina.servlets
  to servlets;

forbid org.apache.catalina.* in *;

module catalina {
  public static void load() { …. }
  public static void main(String[]
  args) { … }
}
```

- `provides` statements declare that this module provides a particular class or declares a .jar file or directory to this module's list of locations to search for classes

  `provides "catalina.jar";`

Sample Module Definition: Import

```
provides "catalina.jar";
import * from xerces;
import * from bootstrap;
import com.sun.tools.* from tools;

hide * in *;
export org.apache.catalina.* to
  webapp;
export org.apache.catalina.servlets
  to servlets;

forbid org.apache.catalina.* in *;

module catalina {
  public static void load() { …. }
  public static void main(String[]
  args) { … }
}
```

- The `import` clauses specify which modules are prerequisites for this module

Sample Module Definition: Export

```
provides "catalina.jar";
import * from xerces;
import * from bootstrap;
import com.sun.tools.* from tools;

hide * in *;
export org.apache.catalina.* to
  webapp;
export org.apache.catalina.servlets
  to servlets;

forbid org.apache.catalina.* in *;

module catalina {
  public static void load() { …. }
  public static void main(String[]
  args) { … }
}
```

- `hide` statements restrict class visibility
- `export` statements declare a set of classes to be visible to other modules
- The later Statement overrides the previous ones

Sample Module Definition: Forbid

```
provides "catalina.jar";
import * from xerces;
import * from bootstrap;
import com.sun.tools.* from tools;

hide * in *;
export org.apache.catalina.* to
  webapp;
export org.apache.catalina.servlets
  to servlets;

forbid org.apache.catalina.* in *;

module catalina {
  public static void load() { …. }
  public static void main(String[]
  args) { … }
}
```

- `forbid` statements prohibit any importer from implementing a set of classes and from importing such classes from any other module
- Classloader has the corresponding concept

Sample Module Definition: load/unload/main

```
provides "catalina.jar";
import * from xerces;
import * from bootstrap;
import com.sun.tools.* from tools;

hide * in *;
export org.apache.catalina.* to
  webapp;
export org.apache.catalina.servlets
  to servlets;

forbid org.apache.catalina.* in *;

module catalina {
  public static void load() { …. }
  public static void main(String[]
  args) { … }
}
```

- `load` is called once per module, when the module is first loaded
- `unload` is called when the module is unloaded, similar to a `finalize()` method
- The `main` method, which takes a string array as an argument, is called when the module is invoked as a main program

Other Module Declarations

- `seal` and `unseal` declarations to control ability to subclass
- `dynamic export` and `hide`

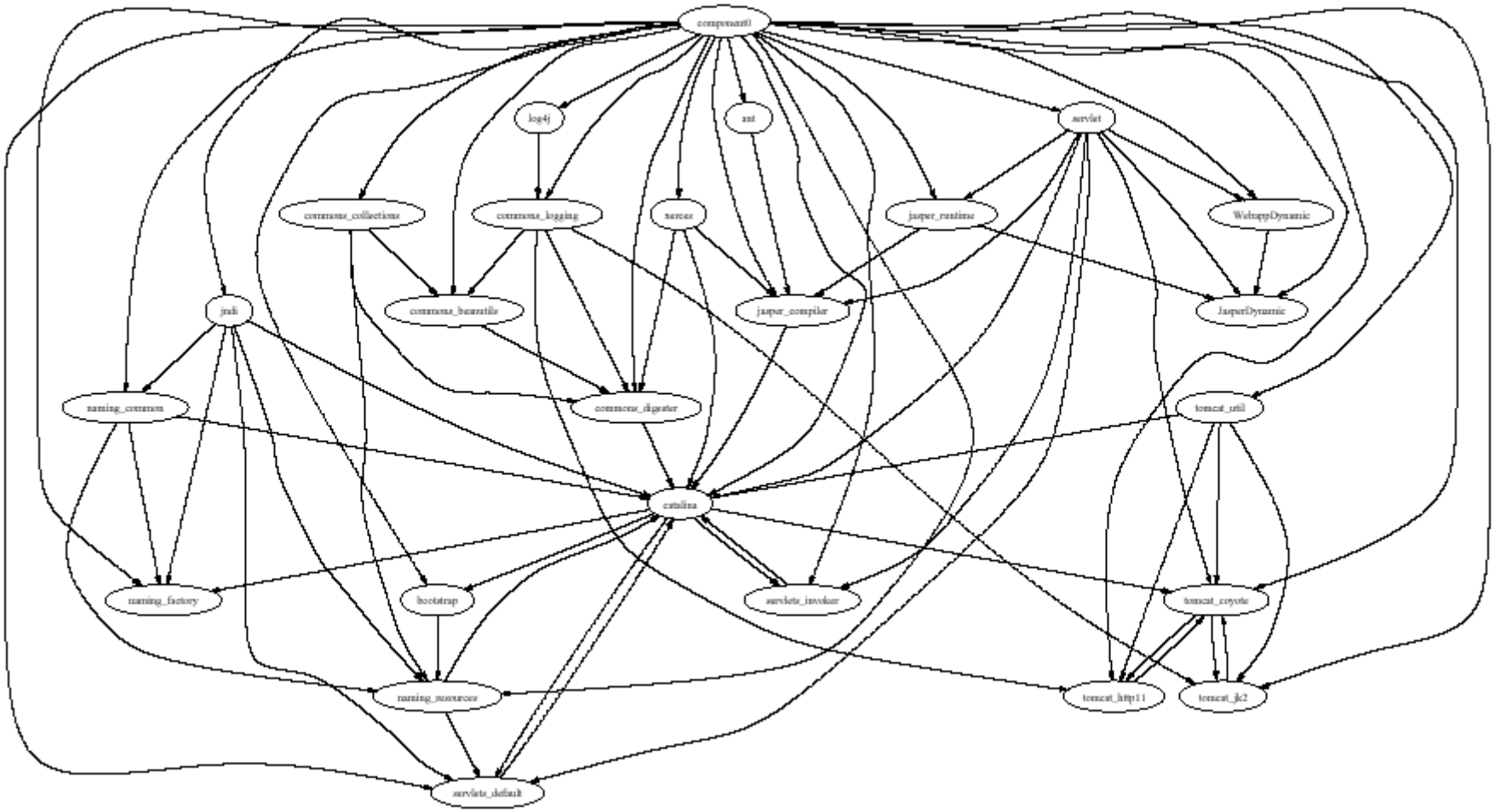
Modularized Apache Tomcat

- No module division, just use libraries and jars as modules
- Basically it is to remove classloader from the code

Classloaders in Tomcat

- Thread Context Classloader
  - The request to the parent classloader breaks down
- Ad-hoc modularity
- Dynamic loading of servlets and JSPs
  - Dynamic loading is necessary
- Some unnecessary ones

Module relationships in Apache Tomcat



Servlet Microbenchmark

- Implemented java.lang.StringInternals class

```
public class StringInternals {
   public static final char[] getValue(String s) {
    return s.value;
   }
}
```

- MJ makes StringInternals available only to trusted code
- Modified java.io.OutputStreamWriter to exploit StringInternals
- Achieved 30% speedup in Servlet microbenchmark on JDK 1.3.1
  - Run on modularized tomcat
  - Servlet generates an HTML multiplication table

Related Work

- Component Systems
  - Microsoft COM object model
  - OSGi bundles; Eclipse plugins
  - Access control is new?
- Module Systems
  - Units [Findler & Flatt]; ML functors [MacQueen]
  - Ada, Modula-2, Modula-3, Haskell

- Java Extensions
  - Jiazzi [McDirmid et al]; Component J [Seco & Caires]; [Bauer et al]
  - JavaMod [Ancona & Zucca]; Multi-Java [Clifton et al]