Security

Security

Security Mechanisms in Java

Virtual machine

- erroneous array accesses
- forbidden casts
- …

Class loader

- loading of code
- Byte-code verification

Security manager

- allowed and forbidden operations

Encryption technologies

- code signing
- authentication

Security

Introduction

Class Loader

Security Manager and Permissions

Summary

Class Loading

In Java code is loaded incrementally on demand

Process of loading class code
(illustrated by execution of program `MyProgram`):

- Loading of class file **`MyProgram.class`**
- Loading of all super classes and classes of variables of class **`MyProgram`**
- Execution on **`main`** in class **`MyProgram`**
- Loading of all classes used when executing **`main`**
  - classes of variables and instances
  - classes of methods

Class Loader

Loading of classes done by `ClassLoader` objects

- Accessing **`ClassLoader`** objects

```
Class clazz = Class.forName("MyProgram");
ClassLoader loader = clazz.getClassLoader();
```

```
ClassLoader loader = ClassLoader.getSystemClassLoader();
```

Standard ClassLoader!

- Class loaders support
  - Loading classes explicitly

```
Class myClass = loader.loadClass("mypack.MyClass");
```

  - and defining new classes

```
byte[] classCode = ...;
loader.defineClass("MyDefinedClass", classCode, 0, classCode.length);
```

- Class loaders can be set
  - for thread one can define a **`ContextClassLoader`**

```
Thread thread = Thread.currentThread();
thread.setContextClassLoader(loader);
```

Then all classes loaded in this thread are loaded by this class loader!

Kinds of Class Loaders

Java uses a hierarchy of class loaders

- Bootstrap class loader:
  - loads all system classes from **rt.jar**

which contains standard library!

- Extension class loader:
  - loads all extensions from directory **jre/lib/ext**

Better name would be "application class loader"

- `SystemClassLoader`:
  - loads classes in class path (CLASSPATH)

- Special class loader:
  - Application-specific class loader as extension of **`SystemClassLoader`**

Hierarchy of Class Loaders

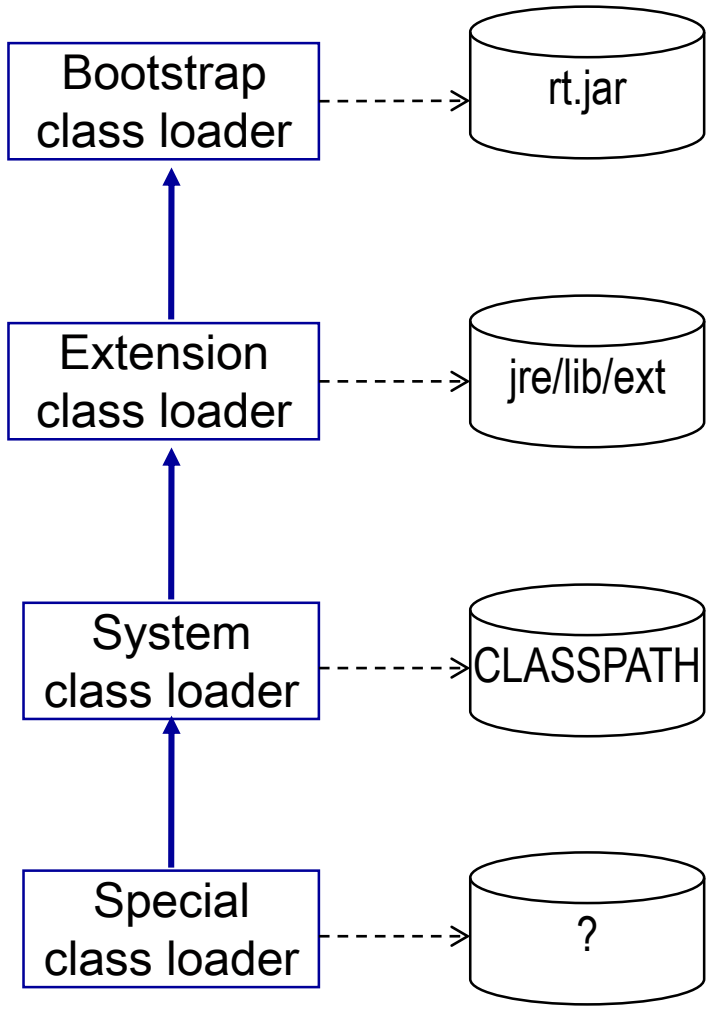
Hierarchy class loader with parent and child relation

Determine priority of class loading

- first Bootstrap class loader
- then Extension class loader
- then System class loader
- finally one of the specializations

Class loaders first delegate loading of a class to its parent class loader

and only loads class if parent fails



Example: Specific Class Loader

URLClassLoader

- Loads classes from URLs

```
URL pluginUrl = new URL("file:c:/plugins.jar");
URLClassLoader pluginLoader = new URLClassLoader(
                                  new URL[] { pluginUrl },
                                  ClassLoader.getSystemClassLoader()
                              );

Class<?> cl = pluginLoader.loadClass("plugin1.PluginClass");
cl.getMethod("test").invoke(null);
```

Plugin-JAR not in CLASSPATH!

superior class loader

Example: Implementation of Class Loader

Class loader as specialization of **`ClassLoader`**

- decryption of encrypted Byte code files
- overriding method **`findClass`**

```
public class CryptoClassLoader extends ClassLoader {
    private final String path;
    private final int key;

    public CryptoClassLoader(String path, int key) {...}

    @Override
    protected Class<?> findClass(String name) throws ClassNotFoundException {
        byte[] classBytes = null;
        try {
            classBytes = loadAndDecryptClassBytes(name);
        } catch (IOException e) { throw new ClassNotFoundException(name); }
        Class<?> clazz = defineClass(name, classBytes, 0, classBytes.length);
        if (clazz == null ) throw new ClassNotFoundException(name);
        return clazz;
    }

    private byte[] loadAndDecryptClassBytes(String name) throws IOException {
        ...
    }
```

Method **findClass** called by **loadClass**!

Uniqueness of Classes by ClassLoader

Uniqueness of classes by:

- fully qualified name (e.g., `java.sql.Date`)
- class loader which has loaded this class

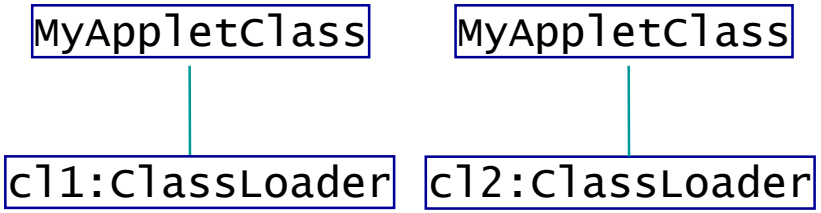
Class loader object defines namespace for classes!

Then VM can

- load and run classes with same name from different sources
- load and use different versions of a class

Example:

- Applets loaded from different servers are loaded by different class loaders
- Applets can use classes with equal name



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Security Manager

Security manager allows checking if certain (possibly dangerous) operations are allowed

For example:

- accessing a file
- opening socket connection
- accessing system properties
- terminating application
- creating and setting a class loader
- accessing the AWT event queue
- opening a top-level window (Frame)
- installation of a security manager
- ...

Security Check

Example: Security check in `System.exit`

```
public void exit(int status) {
    SecurityManager security = System.getSecurityManager();
    if (security != null) {
        checkExit(status);
    }
    Shutdown.exit(status);
}
```

can throw SecurityException!!

Installation of a Security Manager

Per default to security manager installed

- ➔ no checks are performed

Installation of a security manager in application by

```
System.setSecurityManager(SecurityManager sm)
```

or at program start

```
java -Djava.security.manager ...
```

Available security manager :

- `SecurityManager`
- ~~`RMISecurityManager`~~ deprecated
- Application-specific security managers a specialization of `SecurityManager`

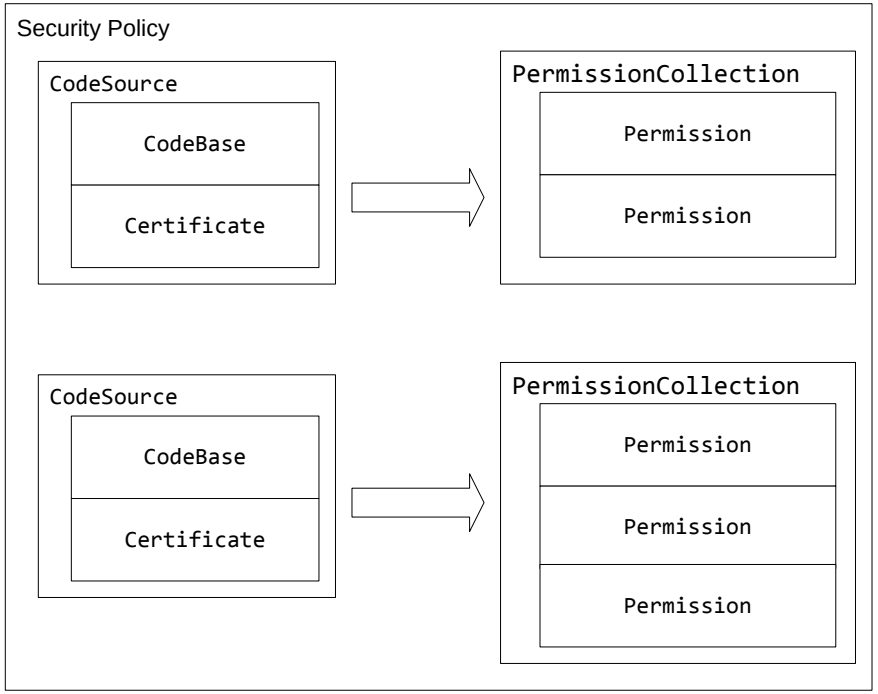
Security Model in Java

Security policies which define mapping
- from code source
- to permissions

i.e., code from specific source is given certain permissions

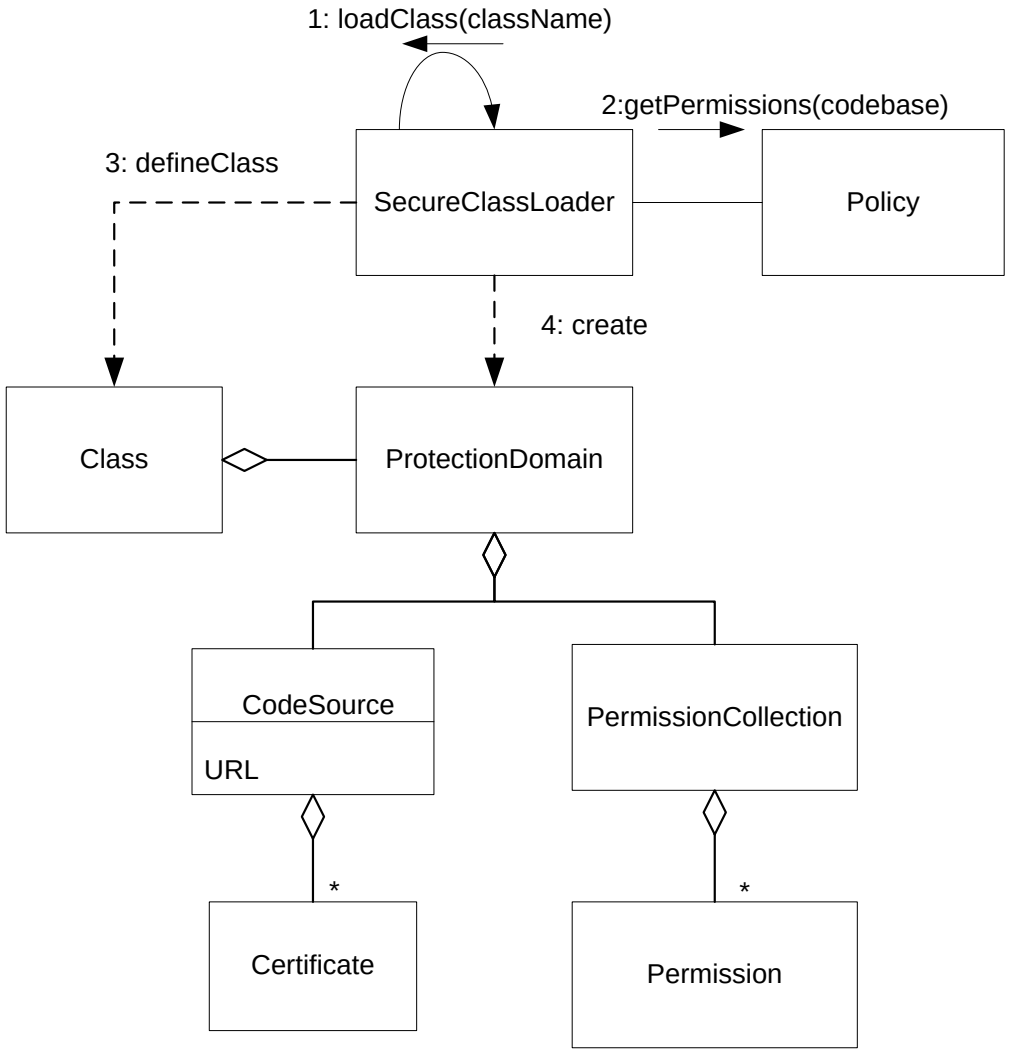
Code sources and permissions represented by classes and objects
- Class **`CodeSource`** with **`CodeBase`** and **`Certificate`**
- Class system of **`Permission`**s
- **`PersmissionCollection`** are collections of permissions

Security policies are defined in policy files (see below)



Process of Creation of a ProtectionDomain

1. Load class by `SecureClassLoader`
2. Getting Permissions from Policy based on CodeBase
3. Definition of class (`defineClass`)
4. Creation of ProtectionDomain for class with CodeSource and PermissionCollections



Operations with Security Checks

Process of a security check

- Accessing installed SecurityManager by **`System.getSecurityManager`**
- When installed (**`!= null`**), calling **`checkPermission`** method of **`SecurityManager`**
- execution of operation after passing check
- or throwing a **`SecurityException`** when check not passed

```
public void <checkedOperation>(...) {
    SecurityManager security = System.getSecurityManager();
    if (security != null) {
        security.checkPermission(new …Permission(…));
    }
    <uncheckedOperation>(...);
}
```

can throw SecurityException!!

```
public void connect(SocketAddress endpoint, int timeout) throws IOException {
    …
    SecurityManager security = System.getSecurityManager();
    if (security != null) {
        security.checkPermission(new SocketPermission(host+":"+port,
                SecurityConstants.SOCKET_CONNECT_ACTION));
    …
}
```

simplified

checkPermission

Check of permissions with method **checkPermission** of **SecurityManager**

```
public void checkPermission(Permission p)
```

Algorithms for checking Permission p

Pseudocode

```
checkPermission(Permission p) throws SecurityException {
   for all classes clazz of methods on call stack {
        permColl =  clazz.getProtectionDomain().getPermissions();
        if (! exists q in permColl with q.implies(p) )
            throw SecurityException(...);
   }
   permission p granted
}
```

Example: read from SocketInputStream

```
public class DemoCallStack {
    public static String readData() throws IOException {
        String fileName = "data.txt";
        try (BufferedReader r = new BufferedReader(new FileReader(fileName))) {
            String line = r.readLine();
            while (line != null) {
                …
                line = r.readLine();
            }
        }
    }
    public static void main(String[] args) throws IOException {
          readData();
    }
```

Method requiring permission

Stacktrace:

- SocketInputStream.read()
- ...
- BufferedReader.readLine()
- DemoCallStack.readLine(BufferedReader) line: 27
- DemoCallStack.readData() line: 17
- DemoCallStack.main(String[]) line: 11

Classes of all methods on call stack must have permission to read from socket!

Method implies of Permission

Permission implements method

```
boolean implies(Permission permission)
```

which checks of this permission implies permission given as parameter

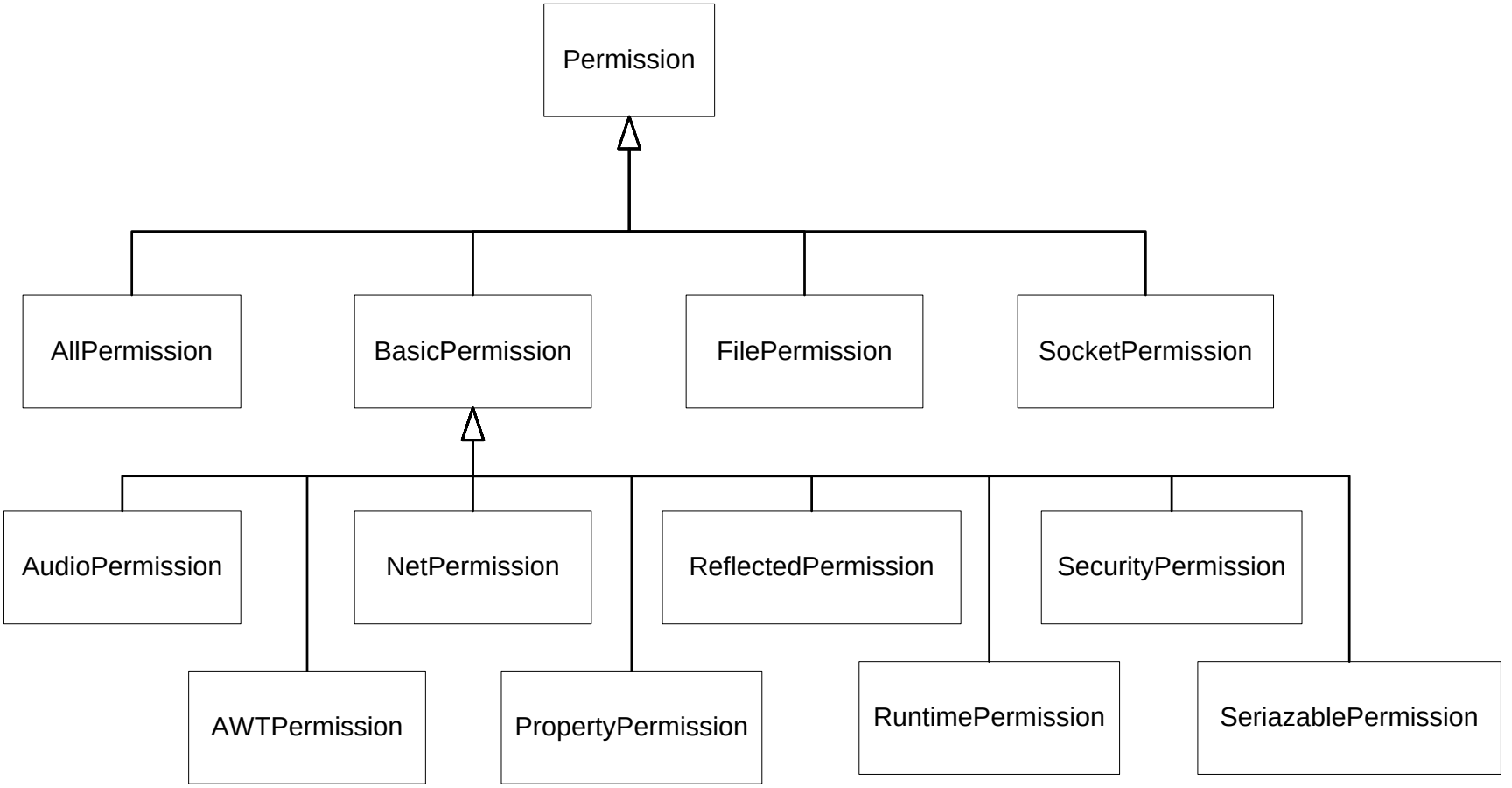
Examples:

```
RuntimePermission("*")
   implies
RuntimePermission("ExitVM")

FilePermission(“C:\temp\*“, “read“)
   implies
FilePermission(“C:\temp\MyFile“, “read“)

SocketPermission( “*:1024-65535", “connect”)
   implies
SocketPermission “yourserver.com:1099", “connect“)
```

Hierarchy of Permission Classes



Are configured with different parameters!

Policy Files

Permissions are usually defined in **policy files**

which contain a sequence of **grant entries**

- mapping of code source
- to set of permissions

```
grant Codesource {
  Permission_1;
  Permission_2;
};
```

Code source consists of

- a URL for the Codebase and
- names of trusted certifiers

```
grant
  codebase codebase-URL
  signedby certificate-name ... {
```

Permission in the form

- keyword **`permission`**
- class name of **`Permission`** class
- a permission-specific target for the permission (e.g. a directory, address, or operation)
- optionally a list of permission-specific actions

```
grant
  codebase codebase-URL
  signedby certificate-name ...
{
permission  permission-className
                  target
                  action1, ...;
...
};
```

Example Policy File

all Codesources!

```
grant {
   permission java.lang.RuntimePermission "stopThread";
   permission java.net.SocketPermission "localhost:1024-", "listen";
   permission java.util.PropertyPermission "java.version", "read";
   permission java.util.PropertyPermission "java.vendor", "read";
        ...
};

grant codeBase "file:${java.home}/lib/ext/*" {
   permission java.security.AllPermission;
};

grant codeBase “www.ssw.uni-linz.ac.at/classes/" {
   permission java.net.SocketPermission “*:1024-65535", "connect";
   permission java.io.FilePermission “${user.home}${/}-“,
                                        “read “, “ write “, “execute“;
   ...
};

...
```

incl. all subdirectories!

Table of Permission (Excerpt)

Permission	Target	Action
java.io.FilePermission	File	read, write, execute, delete
iava.net.SocketPermission	Socket (host, port)	accept,connect, listen, resolve
java.util.PropertyPermission	Property l	read, write
java.lang.RuntimePermission	createClassLoader createSecurityManager exitVM stopThread queuePrintJob ...	
java.net.NetPermission	setDefaultAuthenticator specifyStreamHandler requestPassword-Authentication	
java.awt.AWTPermission	showWindowWithoutWarningBanner accessClipboard acccessEventQueue listenToAllAWTEvents readDisplayPixels	
java.security.SecurityPermission	getPolicy, setPolicy ...	
...		

Example: SecurityManager

Installation of a SecurityManagers

```
System.setSecurityManager(new SecurityManager());
```

Then files cannot be read or written

```
try (BufferedReader reader = new BufferedReader(new InputStreamReader(
                                                  new FileInputStream(filename)))) {
  for (String line = reader.readLine(); line != null; line = reader.readLine()) {
    System.out.println(line);
  }
} catch (Throwable t) { System.out.println("Unable to read file: " + t); }

try (BufferedWriter writer = new BufferedWriter(new OutputStreamWriter(
                                    new FileOutputStream(filename, true)))) {
  writer.append("Hello World!\n");
} catch (Throwable t) { System.out.println("Unable to write file: " + t); }
```

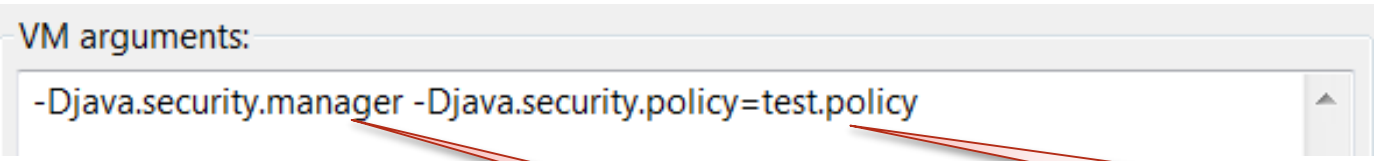
```
Unable to read file: java.security.AccessControlException: access denied
("java.io.FilePermission" "test.txt" "read")
Unable to write file: java.security.AccessControlException: access denied
("java.io.FilePermission" "test.txt" "write")
```

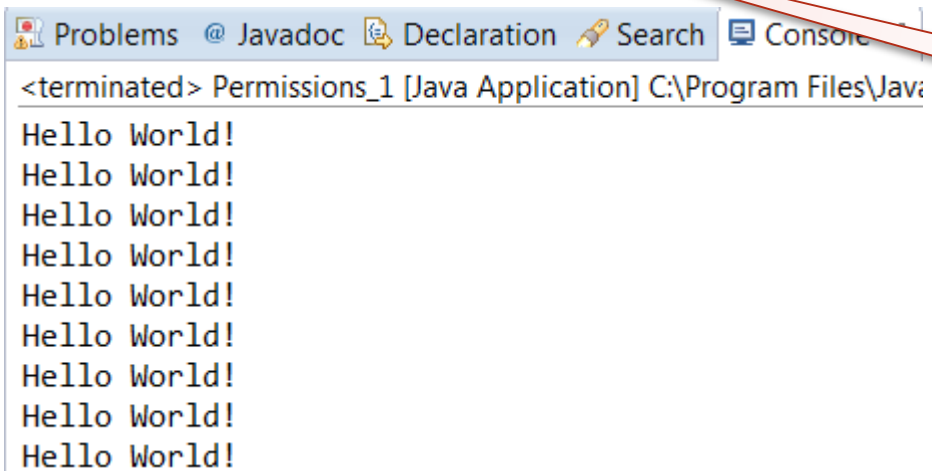
Example: SecurityManager

Policy file with permissions allow access to files

```
grant codeBase "file:C:/.../UE03_WS/Security_Permissions_1/bin/-" {
   permission java.io.FilePermission "test.txt", "read";
   permission java.io.FilePermission "test.txt", "write";
};
```

```
java -Djava.security.manager -Djava.security.policy=test.policy ...
```





Sets Policy-File!

Sets SecurityManager!

Security

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Summary

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