Introduction to Java Reflection

Explained Simply

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Complexity explained simply

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1. Introduction

What is reflection?

- When you look in a mirror:
  - You can see your reflection
  - You can act on what you see, for example, straighten your tie
- In computer programming:
  - *Reflection* is infrastructure enabling a program can see and manipulate itself
  - It consists of *metadata* plus operations to manipulate the metadata
- *Meta* means self-referential
  - So metadata is data (information) about oneself

Widespread ignorance of Java reflection

- Typical way a developer learns Java:
  - Buys a large book on Java
  - Starts reading it
  - Stops reading about half-way through due to project deadlines
  - Starts coding (to meet deadlines) with what he has learned so far
  - Never finds the time to read the rest of the book
- Result is widespread ignorance of many “advanced” Java features:
  - Many such features are *not* complex
  - People just assume they are because they never read that part of the manual
  - Reflection is one “advanced” issue that is not complex

Is reflection difficult?

- When learning to program:
  - First learn iterative programming with if-then-else, while-loop, …
  - Later, learn recursive programming
- Most people find recursion difficult *at first*
  - Because it is an unusual way of programming
  - But it becomes much easier once you “get it”
- Likewise, many people find reflection difficult *at first*
  - It is an unusual way of programming
  - But it becomes much easier once you “get it”
  - Reflection seems natural to people who have written compilers (a parse tree is conceptually similar to metadata in reflection)
- A lot of reflection-based programming uses recursion

2. Metadata

Accessing metadata

- Java stores metadata in classes
  - Metadata for a class: `java.lang.Class`
  - Metadata for a constructor: `java.lang.reflect.Constructor`
  - Metadata for a field: `java.lang.reflect.Field`
  - Metadata for a method: `java.lang.reflect.Method`
- Two ways to access a `Class` object for a class:

```
Class c1 = Class.forName("java.util.Properties");

Object obj = ...;
Class c2 = obj.getClass();
```

- Reflection classes are inter-dependent
  - Examples are shown on the next slide

Examples of inter-relatedness of reflection classes

```
class Class {
    Constructor[] getConstructors();
    Field         getDeclaredField(String name);
    Field[]       getDeclaredFields();
    Method[]      getDeclaredMethods();
    ...
}

class Field {
    Class getType();
    ...
}

class Method {
    Class[] getParameterTypes();
    Class   getReturnType();
    ...
}
```

Metadata for primitive types and arrays

- Java associates a `Class` instance with each primitive type:

```
Class c1 = int.class;
Class c2 = boolean.class;
Class c3 = void.class;
```

Might be returned by `Method.getReturnType()`

- Use `Class.forName()` to access the `Class` object for an array

```
Class c4 = byte.class;              // byte
Class c5 = Class.forName("[B");     // byte[]
Class c6 = Class.forName("[[B");    // byte[][]
Class c7 = Class.forName("[Ljava.util.Properties");
```

- Encoding scheme used by `Class.forName()`
  - B → byte; C → char; D → double; F → float; I → int; J → long; Lclass-name → class-name[]; S → short; Z → boolean
  - Use as many "["s as there are dimensions in the array

Miscellaneous Class methods

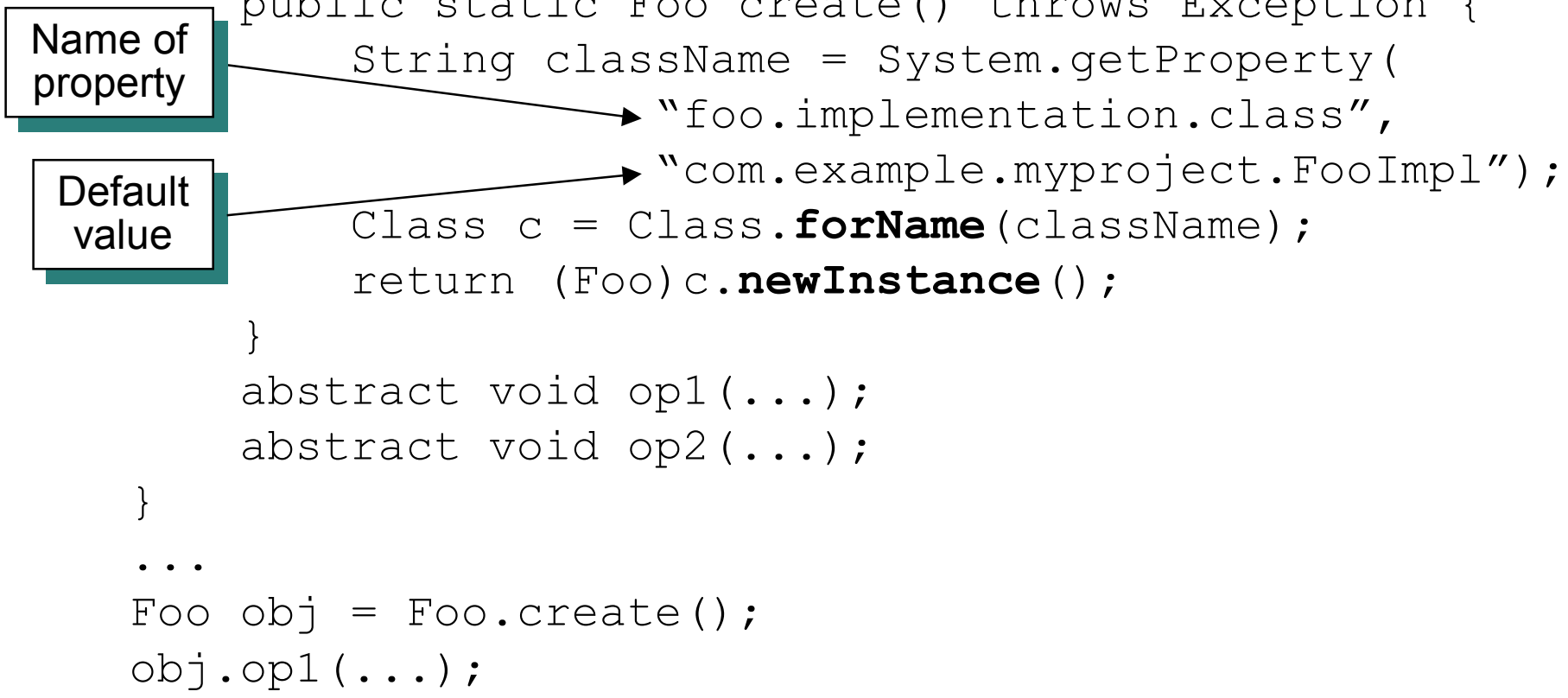
- Here are some useful methods defined in `Class`

```
class Class {
  public String getName(); // fully-qualified name
  public boolean isArray();
  public boolean isInterface();
  public boolean isPrimitive();
  public Class getComponentType(); // only for arrays
  ...
}
```

3. Calling constructors

Invoking a default constructor

- Use `Class.newInstance()` to call the default constructor
  Example:




```
abstract class Foo {
    public static Foo create() throws Exception {
        String className = System.getProperty(
                                "foo.implementation.class",
                                "com.example.myproject.FooImpl");
        Class c = Class.forName(className);
        return (Foo)c.newInstance();
    }
    abstract void op1(...);
    abstract void op2(...);
}
...
Foo obj = Foo.create();
obj.op1(...);
```

Invoking a default constructor (cont')

- This technique is used in CORBA:
  - CORBA is an RPC (remote procedure call) standard
  - There are many competing implementations of CORBA
  - Factory operation is called `ORB.init()`
  - A system property specifies which implementation of CORBA is used
- A CORBA application can be written in a portable way
  - Specify the implementation you want to use via a system property (pass `-D<name>=<value>` command-line option to the Java interpreter)
- Same technique is used for J2EE:
  - J2EE is a collection of specifications
  - There are many competing implementations
  - Use a system property to specify which implementation you are using

A plug-in architecture

- Use a properties file to store a mapping for *plugin name → class name*
  - Many tools support plugins: Ant, Maven, Eclipse, …

```
abstract class Plugin {
    abstract void op1(...);
    abstract void op1(...);
}
abstract class PluginManager {
    public static Plugin load(String name)
                                    throws Exception {
        String className = props.getProperty(name);
        Class c = Class.forName(className);
        return (Plugin)c.newInstance();
    }
}
...
Plugin obj = PluginManager.load("...");
```

Invoking a non-default constructor

- Slightly more complex than invoking the default constructor:
  - Use `Class.getConstructor(Class[] parameterTypes)`
  - Then call `Constructor.newInstance(Object[] parameters)`

```
abstract class PluginManager {
    public static Plugin load(String name)
                                    throws Exception {
        String className = props.getProperty(name);
        Class c = Class.forName(className);
        Constructor cons = c.getConstructor(
           new Class[]{String.class, String.class});
        return (Plugin)cons.newInstance(
                                new Object[]{"x", "y"});
    }
}
...
Plugin obj = PluginManager.load("...");
```

Passing primitive types as parameters

- If you want to pass a primitive type as a parameter:
  - Wrap the primitive value in an object wrapper
  - Then use the object wrapper as the parameter
- Object wrappers for primitive types:
  - `boolean` → `java.lang.Boolean`
  - `byte` → `java.lang.Byte`
  - `char` → `java.lang.Character`
  - `int` → `java.lang.Integer`
  - `...`

4. Methods

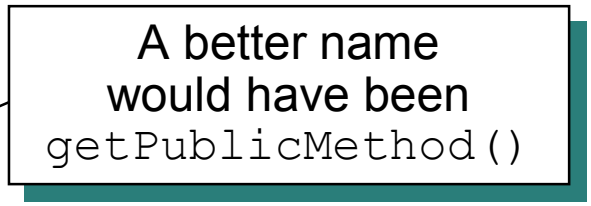
Invoking a method

- Broadly similar to invoking a non-default constructor:
  - Use `Class.getMethod(String name, Class[]parameterTypes)`
  - Then call `Method.invoke(Object target, Object[] parameters)`

```
Object obj = ...
Class c = obj.getClass();
Method m = c.getMethod("doWork",
           new Class[]{String.class, String.class});
Object result= m.invoke(obj, new Object[]{"x","y"});
```

Looking up methods

- The API for looking up methods is fragmented:
  - You can lookup a *public* method in a class or its ancestor classes
  - Or, lookup a public or non-public method *declared* in the specified class




```
class Class {
    public Method getMethod(String name,
                            Class[] parameterTypes);
    public Method[] getMethods();
    public Method getDeclaredMethod(String name,
                            Class[] parameterTypes);
    public Method[] getDeclaredMethods();
    ...
}
```

Finding an inherited method

- This code searches up a class hierarchy for a method
  - Works for both public and non-public methods

```
Method findMethod(Class cls, String methodName,
                  Class[] paramTypes)
{
    Method method = null;
    while (cls != null) {
        try {
            method = cls.getDeclaredMethod(methodName,
                                           paramTypes);
            break;
        } catch (NoSuchMethodException ex) {
            cls = cls.getSuperclass();
        }
    }
    return method;
}
```

5. Fields

Accessing a field

- There are two ways to access a field:
  - By invoking get- and set-style methods (if the class defines them)
  - By using the code shown below

```
Object obj = ...
Class c = obj.getClass();
Field f = c.getField("firstName");
f.set(obj, "John");
Object value = f.get(obj);
```

Looking up fields

- The API for looking up fields is fragmented:
  - You can lookup a *public* field in a class or its ancestor classes
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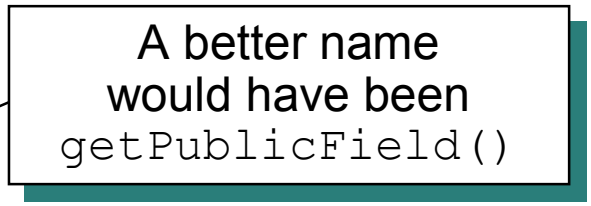


```
class Class {
    public Field   getField(String name);
    public Field[] getFields();
    public Field   getDeclaredField(String name);
    public Field[] getDeclaredFields();
    ...
}
```

Finding an inherited field

- This code searches up a class hierarchy for a field
  - Works for both public and non-public fields

```
Field findField(Class cls, String fieldName)
{
    Field field = null;
    while (cls != null) {
        try {
            field = cls.getDeclaredField(fieldName);
            break;
        } catch (NoSuchFieldException ex) {
            cls = cls.getSuperclass();
        }
    }
    return field;
}
```

6. Modifiers

Java modifiers

- Java defines 11 modifiers:
  - `abstract`, `final`, `native`, `private`, `protected`, `public`, `static`, `strictfp`, `synchronized`, `transient` and `volatile`
- Some of the modifiers can be applied to a class, method or field:
  - Set of modifiers is represented as bit-fields in an integer
  - Access set of modifiers by calling `int getModifiers()`
- Useful static methods on `java.lang.reflect.Modifier`:

```
static boolean isAbstract(int modifier);
static boolean isFinal(int modifier);
static boolean isNative(int modifier);
static boolean isPrivate(int modifier);
...
```

Accessing non-public fields and methods

- Both `Field` and `Method` define the following methods (inherited from `java.lang.reflect.AccessibleObject`):

```
boolean isAccessible();
void setAccessible(boolean flag);
static void setAccessible(AccessibleObject[] array,
                          boolean flag);
```

- Better terminology might have been "SuppressSecurityChecks" instead of "Accessible"
- Example of use:

```
if (!Modifier.isPublic(field.getModifiers()) {
    field.setAccessible(true);
}
Object obj = field.get(obj);
```

Hibernate uses this technique so it can serialize non-public fields of an object to a database

7. Further reading and summary

Further reading

- There are very few books that discuss Java reflection
  - An excellent one is *Java Reflection in Action* by Ira R. Forman and Nate Forman
  - It is concise and easy to understand
- Main other source of information is Javadoc documentation

Summary

- This chapter has introduced the basics of Java reflection:
  - Metadata provides information about a program
  - Methods on the metadata enable a program to examine itself and take actions
- Reflection is an unusual way to program:
  - Its “meta” nature can cause confusion *at first*
  - It is simple to use once you know how
- The next chapter looks at a reflection feature called *dynamic proxies*