Reflection: In practice via Java

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Here comes the code

Java Packages

- The reflection classes **(metaobjects)** are in two packages:
  - **java.lang**
    - **Object**
    - **Class**
  - **java.lang.reflect**
    - **Method**
    - **Field**
    - **Constructor**
    - **etc.**

Stay classy

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Object class

- **java.lang.Object**
  - Is the **root superclass** of every object in a program
  - **Not a metaobject** (helps us get to it)
  - Each base-level object keeps a reference to its class object
    - Accessed with the method:

      public final Class getClass()
    - E.g.

      Object myObj = new …

      Class classObject = myObj.getClass();

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Class metaobject

- java.lang.Class
    - Is the class of metalevel ***class objects***
    - Has many useful reflective methods to:
        - Create new instances
        - Find methods, constructors, and fields of a class
        - Traverse the inheritance hierarchy
        - etc.

Getting Class

- Finding class objects (3 ways)

1. For an already instantiated base-level object, use **getClass()**
   - Demonstrated previously

2. If you know the class object at compile time, use the ***class literal*** **.class**
   - E.g. **Class classObject = Color.class**;

- …

Getting Class (cont'd)

3. If the class name is represented as a **String** (usually at runtime), use the method:

   public static Class forName(String className)

   - If not already loaded, dynamically loads the class from bytecode in the **.class** file
   - If the class is in a named package, use the fully qualified name
   - To work, the classpath must be set properly
   - E.g.

```
String name = “java.io.File”;
Class classObject = Class.forName(name);
```

Class Usage

- Java uses class objects (instances of Class) to represent the types of all entities:
  - Ordinary objects (like previously demonstrated)
  - We need to have meta idea of what everything is in language
  - That even includes no OO things (java has holdovers from c-like design)

- But also
  1. Primitives
     - int, float, char, etc.
  2. Arrays
  3. Interfaces

1.Primitives

- Although primitives are not objects, Java uses class objects to represent their type
    - Use a class literal to specify the class object
        - E.g. **int.class, double.class**
    - **void.class** represents the void return type
    - To check if primitive, use **isPrimitive()** on the class object
        - E.g. **if (classObject.isPrimitive()) …**

2.Arrays

- Java arrays are objects whose classes are created at runtime by the JVM
  - A new class for each element type and dimension
  - Use a class literal to specify the class object
    - E.g. **int[].class, Object[].class**
  - To check if an array, use
    isArray()
  - To find the base type of an array, use
    public Class getComponentType()

3.Interfaces

- Each declared interface is represented with a class object
    - Can be specified with a class literal
        - E.g. **Collection.class**
    - Can be queried for supported methods and constants
    - To check if an interface, use **isInterface()**

Methods, man

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Get a method

- Methods for a class or interface are represented with metaobjects of the type **java.lang.reflect.Method**

- Methods can be found at runtime by querying the class object

  - To find a **public** method (either declared or inherited), use
    Method getMethod(String name, Class[] parameterTypes)

  - E.g.
    Method m;
    m = classObject.getMethod(“setColor”, new Class[] {Color.class});

  - If no parameters, use null or zero-length array for the 2nd argument

Get a method (cont'd)

- The above **getMethod** can access every method attached to a class
  - Including those inherited

- **Use getDeclaredMethod(…)** to find a method explicitly declared by the class (i.e. not inherited)
  - In addition it also returns methods of all visibilities: **public, protected, package,** and **private**

Get ALL methods

- To find ***all*** **public** methods of a class (either declared or inherited), use
  Method[] getMethods()
  - E.g.
    Method mArray[] = classObject.getMethods();

- To find all declared methods of any visibility, use
  Method[] getDeclaredMethods()

Method Parts

- A Method object can be queried with:

  - **String getName()**
  - **Class getDeclaringClass()**
  - **Class[] getExceptionTypes()**
  - **Class[] getParameterTypes()**
  - **Class getReturnType()**
  - **int getModifiers()**
    - The returned int can be decoded with methods in Modifier class

Method acting

Dynamic Method Call

- To call a method dynamically, use

  Object invoke(Object obj, Object[] args)

- E.g.

```
Object myObject = "Hello, world!";
Class classObject = myObject.getClass();
Integer parameter = 5;
Method m = classObject.getMethod("substring", int.class);
Object result = m.invoke(myObject, parameter);
System.out.println(result);
int x = ((Integer) result).intValue();
```

Dynamic Method Call (return primitive)

- If a method normally returns a primitive, **invoke()** will return the primitive in a wrapper object
- Since typed as **Object**, you must cast it to the correct type
- Then unwrap it using a **xxxValue**() method

```
Object myObject = "Hello, world!";
Class classObject = myObject.getClass();
Integer parameter = 5;
Method m = classObject.getMethod("substring", int.class);
Object result = m.invoke(myObject, parameter);
System.out.println(result);
int x = ((Integer) result).intValue();
```

Turtles all the way up

Superclass

- To find the ***superclass object of a class*** object use **Class getSuperClass()**
  - E.g.

    Class superclassObject = classObject.getSuperClass();

- Returns null if **classObject** represents a *primitive type, void, an interface, or* ***Object*** *class*

- Returns *class object* for **Object** if an array

Interfaces

- Use **Class[] getInterfaces()** on a class object to find all interfaces that the class directly implements

  - If used on a class object that represents an interface, then returns the direct superinterfaces

Fielders choice

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Fields

- Fields for a class or interface are represented with metaobjects of the type **java.lang.reflect.Field**

- Fields can be found at runtime by querying the class object
  - To find a public field (either declared or inherited), use

  Field getField(String name)

Fields (cont'd)

- E.g.

  Field f = classObject.getField("id");
  - May throw **NoSuchFieldException**

- Use **getDeclaredField(String name)** to find a field explicitly declared by the class or interface (i.e. not inherited)
  - Returns fields of all visibilities: public, protected, package, and private

Get Fields

- To find all public fields of a class (either declared or inherited), use

  Field[] getFields()

  E.g.

  ```
  Field fArray[] = classObject.getFields();
  ```

- To find all declared fields of any visibility, use **Field[] getDeclaredFields()**

Field Parts

- A Field object can be queried with:

  - **String getName()**
  - **Class getDeclaringClass()**
  - **Class getType()**
  - **int getModifiers()**
    - The returned int can be decoded with methods in Modifier class

Field Type

- You can find the value of a field reflectively using
  - **Object get(Object obj)**
  - E.g.

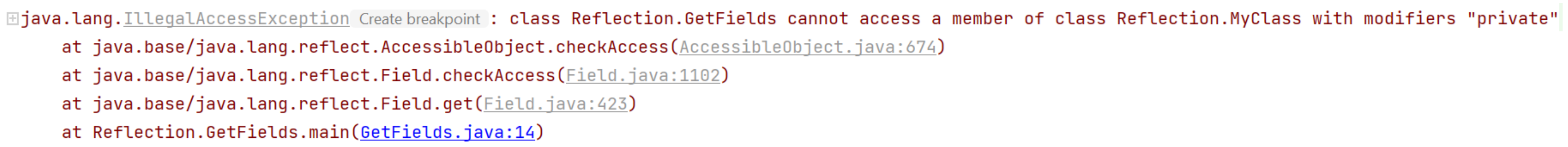
```
Object myObject = new MyClass();
Class classObject = myObject.getClass();
System.out.println(classObject.getDeclaredFields()[0]);
System.out.println(classObject.getDeclaredFields()[1]);
Field f = null;
f = classObject.getDeclaredField("y");
Object value = f.get(myObject);
System.out.println(value);
```

  - If the field type is primitive, the returned value is wrapped in the appropriate wrapper object

Field Type (visibility?)

- You can't always access a field despite being able to find out that it exists

```
f = classObject.getDeclaredField("x");
```



```
java.lang.IllegalAccessException : class Reflection.GetFields cannot access a member of class Reflection.MyClass with modifiers "private"
	at java.base/java.lang.reflect.AccessibleObject.checkAccess(AccessibleObject.java:674)
	at java.base/java.lang.reflect.Field.checkAccess(Field.java:1102)
	at java.base/java.lang.reflect.Field.get(Field.java:423)
	at Reflection.GetFields.main(GetFields.java:14)
```

```
f = classObject.getDeclaredField("x");
f.setAccessible(true);
```

- Set accessible can be denied by the SecurityManager

Fielding it

Field Value

- If you know the type of the primitive, you can access the value directly using methods like
  - **boolean getBoolean(Object obj)**
  - **double getDouble(Object obj)**
  - etc.
- E.g.

```
int value = f.getInt(myObj);
```

Field Setting

- Fields can be set reflectively using
  void set(Object obj, Object value)

  - E.g. **f.set(myObj, newValue);**

  - You must wrap primitive values, or use methods like
    - void setBoolean(Object obj, boolean value)
    - void setDouble(Object obj, double value)
    - etc.
      - E.g. **f.setInt(myObj, 37)**

Field modifiers/access

Modifiers

- Any Class, Method, or Field object can be queried using **getModifiers()**
  - Returns an int where particular bits represent one of the 11 modifiers in Java
    - public, protected, private, static, abstract, etc.
  - Can be decoded using static methods in **java.lang.reflect.Modifier**
    - **boolean isPublic(int mod)**
    - **boolean isProtected(int mod)**
    - etc.

Modifiers (cont'd)

- E.g.

```
Object myObj = new String("Hello, world");
Class classObject = myObj.getClass();
Field f = classObject.getDeclaredField("value");
int mod = f.getModifiers();
if (Modifier.isFinal(mod)) {
    System.out.println("is final");
}
```

- Can print out all modifiers using **toString(int mod)**
  - E.g.

System.out.println(Modifier.toString(mod));

Field Access

- Normally, non-public fields and methods cannot be accessed from outside the class

  - Access checking can be bypassed using void **setAccessible(boolean flag)**

  - Works for all the get and set methods of Field, and the invoke method of Method
  - E.g.

```
f.setAccessible(true);
Object value = f.get(myObj);
```

Array we go

Arrays

- **java.lang.reflect.Array** provides static methods to operate reflectively on array objects

  - **Object newInstance(Class componentType, int length)**
  - E.g.

    Object myArray = Array.newInstance(int.class, 10);

  - **int getLength(Object array)**
  - E.g.

    int length = Array.getLength(anObj);

Arrays Get Entry

- Object **get(Object array, int index)**

  - Returns the element at index, wrapping primitives if necessary
    - E.g. **Object obj = Array.get(myArray, 3);**

  - Also has methods like **getBoolean(…), getDouble(),** etc.
    - E.g. **int i = Array.getInt(myArray, 3);**

Arrays Set Entry

- **void set(Object array, int index, Object value)**
  - Sets the element at index to specified value, unwrapping primitives if necessary
  - Also has methods like **setBoolean(…), setDouble(…),** etc.
  - E.g**. Array.setInt(myArray, i, iVal)**

Bob the constructor

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Constructor

- Constructors for a class are represented with *metaobjects* of the type **java.lang.reflect.Constructor**

  - Constructors can be found at runtime by querying the class object
  -
  - To find a public constructor (either declared or inherited), use **Constructor getConstructor(Class[] parameterTypes)**

Constructor (cont'd)

- E.g.

```
Class classObject = String.class;
for (int i = 0; i < classObject.getDeclaredConstructors().length; i++) {
   System.out.println(classObject.getDeclaredConstructors()[i]);
}
Constructor c = classObject.getConstructor(String.class);
```

- If no parameters, use null or zero-length array for the argument
- Throws **NoSuchMethodException** (!) if not found

- Use **getDeclaredConstructor(…)** to find a constructor (of any visibility) explicitly declared by the class

Constructor (cont'd)

- To find all public constructors of a class (either declared or inherited), use
  Constructor[] getConstructors()
  - E.g.
    Constructor cArray[] = classObject.getConstructors();

- To find all declared constructors of any visibility, use
  Constructor[] getDeclaredConstructors()

Constructor Parts

- A Constructor object can be queried with:
  - **String getName()**
  - **Class getDeclaringClass()**
  - **Class[] getExceptionTypes()**
  - **Class[] getParameterTypes()**
  - **int getModifiers**

Constructor – New Instance

- Reflective instantiation:
  - Can be done using **newInstance()** on the class object
  - E.g.

```
Object y = classObject.newInstance();
System.out.println(y);
```

  - Implicitly uses the no-arg constructor

Constructor – New Instance Arguments

- Can be done using a constructor metaobject and the method:

  Object newInstance(Object[] initargs)

  - E.g.

```
Object x = c.newInstance("Hello, world!");
System.out.println(x);
```

Readings

- Forman & Forman Chapters 1, 2
- Java API: **Class**, **Object**, **reflect** package

Onward to …
new topic (we'll come back to applied reflection later.

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