Programming Language Concepts: Lecture 10

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Reflection

Wikipedia says

> *Reflection is the process by which a computer program can observe and modify its own structure and behaviour.*

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Two components involved in reflection

- Introspection
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Two components involved in reflection

- Introspection
  A program can observe, and therefore reason about its own state.
- Intercession
  A program can modify its execution state or alter its own interpretation or meaning.

Reflection in Java

Simple example of introspection

```
Employee e = new Manager(...);
...
if (e instanceof Manager){
    ...
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Reflection in Java

Simple example of introspection

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Employee e = new Manager(...);
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if (e instanceof Manager){
   ...
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```

What if we don't know the type that we want to check in advance?

Suppose we want to write a function to check if two different objects are both instances of the same class?

```
public static boolean classequal(Object o1, Object o2){
  ...
  // return true iff o1 and o2 point to objects of same type
  ...
}
```

Reflection in Java . . .

```
public static boolean classequal(Object o1, Object o2){...}
```

- Can't use `instanceof`
  - Will have to check across all defined classes
  - This is not even a fixed set!
- Can't use generic type variables
  - The following code is syntactically disallowed

```
if (o1 instance of T) { ...}
```

Introspection in Java

Can extract the class of an object using `getClass()`

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class MyReflectionClass{
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        return (o1.getClass() == o2.getClass());
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```

What does `getClass()` return?

- An object of type `Class` that encodes class information

The class `Class`

A version of `classequal` the explicitly uses this fact

```
import java.lang.reflect.*;

class MyReflectionClass{
    ...
    public static boolean classequal(Object o1, Object o2){
        Class c1, c2;
        c1 = o1.getClass();
        c2 = o2.getClass();
        return (c1 == c2);
    }
}
```

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- For each currently loaded class `C`, Java creates an object of type `Class` with information about `C`

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- For each currently loaded class `C`, Java creates an object of type `Class` with information about `C`
- Encoding execution state as data — reification
  - Representing an abstract idea in a concrete form

Using the `Class` object

Can create new instances of a class at runtime

```
...
Class c = obj.getClass();
Object o = c.newInstance();
  // Create a new object of same type as obj
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Can also get hold of the class object using the name of the class

```
...
String s = "Manager".
Class c = Class.forName(s);
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...
String s = "Manager".
Class c = Class.forName(s);
Object o = c.newInstance();
...
```

. . . , or, more compactly

```
...
Object o = Class.forName("Manager").newInstance();
...
```

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- Constructors, methods and fields themselves have structure
  - Constructors: arguments
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  - All three: modifiers `static`, `private` etc
- Additional classes `Constructor`, `Method`, `Field`
- Use `getConstructors()`, `getMethods()` and `getFields()` to obtain constructors, methods and fields of `C` in an array.

The class `Class` ...

Extracting information about constructors, methods and fields

```
...
Class c = obj.getClass();
Constructor[] constructors = c.getConstructors();
Method[] methods = c.getMethods();
Field[] fields = c.getFields();
...
```

The class `Class` ...

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```

`Constructor`, `Method`, `Field` in turn have functions to get further details

The class `Class` ...

Example: Get the list of parameters for each constructor

```
...
Class c = obj.getClass();
Constructor[] constructors = c.getConstructors();
for (int i = 0; i < constructors.length; i++){
  Class params[] = constructors[i].getParameterTypes();
  ..
}
```

Each parameter list is a list of types

- Return value is an array of type `Class[]`

The class `Class` ...

We can also invoke methods and examine/set values of fields.

```
...
Class c = obj.getClass();
..
Method[] methods = c.getMethods();
Object[] args = { ... }
  // construct an array  of arguments
methods[3].invoke(obj,args);
  // invoke methods[3] on obj with arguments args
...
```

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Field[] fields = c.getFields();
Object o =  fields[2].get(obj);
   // get the value of fields[2] from obj
...
fields[3].set(obj,value);
  // set the value of fields[3] in obj to value
...
```

Reflection and security

- Can we extract information about private methods, fields, . . . ?
- `getConstructors()`, . . . only return publicly defined values
- Separate functions to also include private components
  - `getDeclaredConstructors()`
  - `getDeclaredMethods()`
  - `getDeclaredFields()`
- Should this be allowed to all programs?
- Security issue!
- Access to private components may be restricted

Using reflection

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- Can define and compile Java classes

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Using reflection

- `BlueJ`, a programming environment to learn Java
- Can define and compile Java classes
- For compiled code, create object, invoke methods, examine state
- Uses reflective capabilities of Java — `BlueJ` need not internally maintain "debugging" information about each class
- Look up `http://www.bluej.org`

Limitations of Java reflection

- Cannot create or modify classes at run time
  - The following is not possible

    ```
    Class c = new Class(....);
    ```

  - Note that `BlueJ` must invoke Java compiler before you can use a new class

Limitations of Java reflection

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    ```
    Class c = new Class(....);
    ```

  - Note that BlueJ must invoke Java compiler before you can use a new class
- Languages such as Smalltalk allow redefining methods at run time