# Modul- Fortgeschrittene Programmierkonzepte

## 06- Reflection und Annotations

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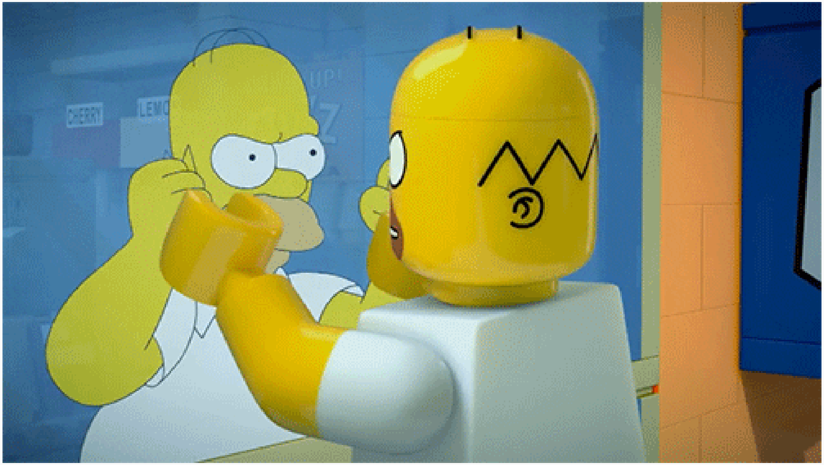
## Agenda for today



- *`java.lang.Class<T>`*: your ticket to reflection - Messing with Objects - Basic Java beans (a simple plugin architecture) - Annotations

## Reflection

*Type introspection* is the ability of programming languages to determine the type (or its properties) of an arbitrary object at runtime.

Java takes this concept one step further with *reflection*, allowing not only to determine the type at runtime, but also modifying it.

At its core, reflection builds on `java.lang.Class`, a generic class that *is* the definition of classes.

Note that most of the classes we will be using when dealing with reflection are in the package `java.lang.reflection` (package summary), and (almost) none of them have public constructors – the JVM will take care of the instantiation.

## Classes

There are different ways to get to the class object of a Class:

```
// at compile time
Class<String> klass1 = String.class;

// or at runtime
Class<? extends String> klass2 = "Hello, World!".getClass();
Class<?> klass3 = Class.forName("java.lang.String");
Class<String> klass4 = (Class<String>) new String().getClass();

System.out.println(klass1.toString());  // java.lang.String
System.out.println(klass2.toString());  // ditto...
System.out.println(klass3.toString());
System.out.println(klass4.toString());

klass1.getName();         // java.lang.String
klass1.getSimpleName();   // String
```

## Class: Class

As a note ...

- use *`Class<T>`* to get the class name if known at compile time (or use an unchecked cast at runtime)
- use the *`?`* (wildcard) and appropriate bounds for *any* type.

**So what can you do with a `Class<?>` object?**

## Basic Type Information

You can use *`Class<?>`* object to get basic type information:

```java
// all of these will return true
int.class.isPrimitive();

String[].class.isArray();

Comparable.class.isInterface();

(new Object() {})
    .getClass()
    .isAnonymousClass();          // also: local and member classes

Deprecated.class.isAnnotation();  // we will talk about those later
```

As you can see, even primitive type like *`int`* or *`float`* have class objects (which are, by the way, different from their wrapper types *`Integer.class`* etc.!).

## Type Internals

You can get even more ...

```java
// family affairs...
String.class.getSuperClass();    // Object.class

// constructors
String.class.getConstructors();  // returns Constructor<String>[]

// public methods
String.class.getMethod("charAt", int.class);
String.class.getMethods();       // returns Method[]

// public fields (attributes)
// Comparator<String>
String.class.getField("CASE_INSENSITIVE_ORDER");
String.class.getFields();       // returns Field[]

// public annotations (more on this later)
String.class.getAnnotation(Deprecated.class);         // null...
String.class.getAnnotationsByType(Deprecated.class);  // []
String.class.getAnnotations();  // returns Annotation[]
```

## Some Remarks

These methods may throw *`NoSuch{Method,Field}Exception`*s and *`SecurityException`*s (more on security later).

You can distinguish between *declared* fields (methods, ...), and “just” fields: *`.getFields()`* (and *`.getMethods()`* etc.) will return *the public* fields of an object, including those inherited by base classes.

Use *`.getDeclaredFields()`* (and *`.getDeclaredMethods()`* etc.) to retrieve *all* fields declared in this particular class.

## Object Instantiation

As you can see, you can also query for *constructors* of a class. This is the base for creating new instances based on class definitions:

```java
Class<?> klass = "".getClass();
String magic = (String) klass.newInstance();  // unchecked cast...
```

Sticking with the example of strings, the documentation tells us that there exist non-default constructors. Consider for example the `String(byte[] bytes)` constructor:

## Object Instantiation

```java
Constructor<String> cons = (Constructor<String>)
    String.class.getConstructor(byte[].class);

String crazy = cons.newInstance(new byte[] {1, 2, 3, 4});
```

*Note that this may trigger quite a few exceptions:* `InstantiationException`, `IllegalAccessException`, `IllegalArgumentException`, `InvocationTargetException`, *all of which make sense if you extrapolate their meaning from the name.*

## Messing with Objects

### Modifying Fields (Attributes)

Remember Rumpelstiltskin?

In short: A very ambitious father claimed his daughter could produce gold. Put under pressure by the king, she cuts a deal with an imp: it spins the gold and in return she would sacrifice her first child –

*unless she could guess the imp's name!*

## Objects

Ok, here's the mean imp and the poor daughter:

```java
class Imp {
    private String name = "Rumpelstiltskin";
    boolean guess(String guess) {
        return guess.equals(name);
    }
}
```

```java
class Daughter {
    public static void main(String... args) {
        Imp imp = new Imp();

        // to save your child...
        imp.guess(???);
    }
}
```

## More about it ...

Since *`Imp.name`* is private, the imp feels safe (it's dancing around the fire pit...). But can we help the daugher save her firstborn?

## Yes, we can!

Using reflection, we will sneak through the imp's “head” to find the string variable that encodes the name.

```
Imp imp = new Imp();
String oracle = null;
// get all fields
for (Field f : imp.getClass().getDeclaredFields()) {

    f.setAccessible(true);  // oops, you said `private`? :-)

    // looking for `private String`
    if (Modifier.isPrivate(f.getModifiers())
            && f.getType() == String.class) {
        oracle = (String) f.get(imp);  // heureka!
    }
}
imp.guess(oracle);  // true :-)
```

## Alternatively

```java
Imp imp = new Imp();

for (Field f : imp.getClass().getDeclaredFields()) {
    f.setAccessible(true);
    if (Modifier.isPrivate(f.getModifiers())
        && f.getType() == String.class) {
        f.set(imp, "Pinocchio");  // oops :-)
    }
}

imp.guess("Pinocchio");  // true :-)
```

The `Field` class allows us to retrieve and modify both the modifiers and the values of fields (given an instance).

## Calling Functions

Similar to accessing and modifying fields, you can enumerate and invoke methods. Sticking with the imp above, what if the imp's name were well-known, but nobody knew how to ask for a guess?

```java
class WeirdImp {
    static final String name = "Rumpelstiltskin";
    private boolean saewlkhasdfwds(String slaskdjh) {
        return name.equals(slaskdjh);
    }
}
```

## Accessability

This time, the *name* is well known, but the guessing function is hidden. Again, reflection to the rescue.

```java
WeirdImp weirdo = new WeirdImp();
for (Method m : weirdo.getClass().getDeclaredMethods()) {
    m.setAccessible(true);

    // ...returns boolean?
    if (m.getReturnType() == boolean.class
            // ...has one arg?
            && m.getParameterCount() == 1
            // which is String?
            && m.getParameterTypes()[0] == String.class) {
        System.out.println(m.invoke(weirdo, Weirdo.name));
    }
}
```

## Basic Java Beans

Reflection can be used to facilitate an architecture where code is dynamically loaded at runtime. This is often called a *plugin mechanism*, and Java Beans have been around for quite a long time.

Consider this simple example: We want to have a game loader that can load arbitrary text-based games which are provided as a third party `.jar` file.

```java
package reflection;
public interface TextBasedGame {
    void run(InputStream in, PrintStream out) throws IOException;
}
```

## Beans Example

A simple *parrot* (echoing) game could be:

```java
package reflection.games;
public class Parrot implements TextBasedGame {
    @Override
    public void run(InputStream in, PrintStream out)
        throws IOException {

        BufferedReader reader = new BufferedReader(
            new InputStreamReader(in));
        out.println("Welcome to parrot. Please say something");

        String line;
        while ((line = reader.readLine()) != null
            && line.length() > 0) {
            out.println("You said: " + line);
        }
        out.println("Bye!");
    }
}
```

## Load Class

These games all implement the `TextBasedGame` interface, and their `.class` files can be packaged into a jar.

Later, if you know the location of the jar file, you can load classes by-name:

```java
package reflection;
public class TextGameLoader {
    public static void main(String... args) throws Exception {

        // load classes from jar file
        URL url = new URL("jar:file:/...hsro-inf-fpk/example/games.jar!/");
        URLClassLoader cl = URLClassLoader.newInstance(new URL[] {url});

        // you can play "Addition" or "Parrot"
        final String choice = "Parrot";
        TextBasedGame g = (TextBasedGame) cl.loadClass
            ("reflection.games." + choice)
            .newInstance();
        g.run(System.in, System.out);
    }
}
```

## Security

The previous sections showed clearly how powerful the tools of reflection are. Naturally, security is a concern: what if someone loads your jars, enumerates all classes, and then tries to steal passwords from a user?

This has indeed been done, and is the reason why Java was historically considered insecure or even unsafe to use. However, newer versions of Java have a sophisticated system of permissions and security settings that can limit or prevent reflection (and other critical functionality).

Two things that do *not* work, at least out of the box: - While you can do a forced write on ***`final`*** *fields*, this typically does not affect the code at runtime, since the values are already bound at compiletime. - It is impossible to swap out *methods* since class definitions are read-only and read-once. If you wanted to facilitate that, you would have to write your own class loader.

## Object Comparison

One last word regarding reflection and object comparison. As you know, we distinguish two types of equality: reference and content-based equality.

```java
class K {
    K(String s) {
        this.s = s;
    }
}

int a = 1;
int b = 1;

a == b;  // true: for primitive types, the values are compared

K k1 = new K("Hans");
K k2 = new K("Hans");

k1 == k2;       // false: they point to different memory
k1.equals(k2);  // ???
```

## *equals()*-Method

If you don’t overwrite the *`.equals`* method in your class, the default version *`Object.equals`* will check for reference equality. If you overwrite it, you need to make sure to - test for *`null`* - test for reference equality (same memory?) - test for same *type* - call *`super.equals()`*, if it was overwritten there - compare all attributes

## *equals()*-Method

Consider this implementation of `equals`:

```java
public boolean equals(Object o) {
    if (o == null) return false;
    if (o == this) return true;    // same memory
    // version A
    if (!this.getClass().equals(o.getClass()))
        return false;
    // version B
    if (this.getClass() != o.getClass())
        return false;
    // version C
    if (!(o instanceof K))
        return false;
    if (!super.equals(o))
        return false;
    // now compare attributes
    return this.s.equals(((K) o).s);
}
```

What works?

## Explanation

Here's the question: Which of the versions A, B or C are correct ways to test if the *types* of the two objects match?

A) is correct, since we compare both runtime classes with `.equals`.

B) is correct, since the class objects are shared among all instances (and parametrized generics; recall type erasure).

C) is however *incorrect*: the `instanceof` operator would also return `true` if there is a match on an interface of derived class.

## Annotations

Annotations are *meta-information*, they can be attached to classes, methods or fields, and can be read by the compiler or using reflection at runtime.

They are denoted using the `@` character, for example `@Override`.

## Defining Annotations

Annotations are similar to interfaces: both as in syntax and as in a method or field can have multiple annotations.

```java
public @interface Fixed {
    String author() ;
    String date() ;
    String bugsFixed() default "" ;
}
```

This defines the annotation `@Fixed(...)` with three arguments; the last one is optional and defaults to the empty string.

```java
@Fixed(author="mustermann", date="2011-11-11")
void method() { ... }
```

**Meta-Annotations**

Even annotations can be annotated. *Meta annotations* define where and how annotations can be used.

- `@Target({ElementType.FIELD, ElementType.METHOD})`: Use this to limit your custom annotation to fields or methods.
- `@Retention(RetentionPolicy.{RUNTIME,CLASS,SOURCE)}`: This controls if the annotation is available at runtime, in the class file, or only in the source code.
- `@Inherited`: Use this to make an annotation to be passed on to deriving classes.

## Method Annotations

In general, there are *marker anotations* (e.g. `@Deprecated`) without arguments, *value annotations* (e.g. `@SuppressWarnings("...")`) that take exactly one value, and more sophisticated annotations (e.g. `@Fixed(...)` above).

```java
class K {
    @Override
    public boolean equals(Object o) {
        // ...
    }
    @Deprecated
    public void useSomethingElseNow() {
        // ...
    }
    @SuppressWarnings("unchecked")
    public void nastyCasts() {

    }
}
```

## Marker Annotations

What are they good for? - *`@Override`* is used to signal the intent of overwriting; results in compile error if its actually no overwrite
(e.g. *`@Override public boolean equals(K k)`*) - *`@Deprecated`* marks a method not to be used anymore; it might be removed in the future. - *`@SuppressWarnings(...)`* turns off certain compiler warnings

## Type (Attribute) Annotations

*@NonNull*: The compiler can determine cases where a code path might receive a null value, without ever having to debug a *NullPointerException*.

*@ReadOnly*: The compiler will flag any attempt to change the object.

*@Regex*: Provides compile-time verification that a *String* intended to be used as a regular expression is a properly formatted regular expression.

*@Tainted* and *@Untainted*: Identity types of data that should not be used together, such as remote user input being used in system commands, or sensitive information in log streams.

```java
abstract void method(@NonNull String value, @Regex re);
```

## Annotations: JUnit5

The new JUnit5 test drivers inspect test classes for certain annotations.

```java
class MyTest {
    BufferedReader reader;

    @BeforeAll
    void setUp() {
        reader = new BufferedReader();  // ...
    }

    @Test
    void testSomeClass() {
        // ...
    }
}
```

Most of the time, you will get around with `@BeforeAll`, `@AfterAll` and `@Test`; see this complete list of annotations.

## Annotations: Gson by Google

Gson by Google helps with de/serializing objects (see today's assignment).

It allows you to map between JSON and Java objects:

```java
class Klass {
    private int value1 = 1;
    private String value2 = "abc";
    @SerializedName("odd-name") private String oddName = "1337";
    private transient int value3 = 3;  // will be excluded

    Klass() {
        // default constructor (required)
    }
}
```

## How to use it?

```java
// Serialization
Klass obj = new Klass();
Gson gson = new Gson();
String json = gson.toJson(obj);
// ==> json is {"value1":1,"value2":"abc","odd-name": "1337"}

// Deserialization
Klass obj2 = gson.fromJson(json, Klass.class);
// ==> obj2 is just like obj
```

## Annotations: Butterknife

Butterknife: GUI bindings for Android ridiculously simplified

```java
class ExampleActivity extends Activity {
    @BindView(R.id.title) TextView title;
    @BindView(R.id.subtitle) TextView subtitle;
    @BindView(R.id.footer) TextView footer;

    @Override public void onCreate(Bundle savedInstanceState) {
        super.onCreate(savedInstanceState);
        setContentView(R.layout.simple_activity);
        ButterKnife.bind(this);
        // TODO Use fields...
    }
}
```

## Annotations: Retrofit

Retrofit: consume REST interfaces without any pain

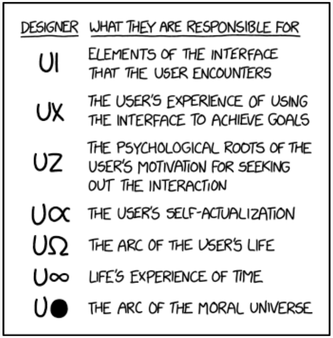
```java
public interface GitHubService {
  @GET("users/{user}/repos")
  Call<List<Repo>> listRepos(@Path("user") String user);
}

Retrofit retrofit = new Retrofit.Builder()
    .baseUrl("https://api.github.com/")
    .build();

GitHubService service = retrofit.create(GitHubService.class);

Call<List<Repo>> repos = service.listRepos("octocat");
```

## Summary

Lessons learned today:

- Reflections
    - Classes, Methods, Attributes
    - Security
- Annotations
- Frameworks
    - Butterknofe
    - GSON
    - Retrofit

## Final Thought!



| DESIGNER | WHAT THEY ARE RESPONSIBLE FOR |
|---|---|
| UI | ELEMENTS OF THE INTERFACE THAT THE USER ENCOUNTERS |
| UX | THE USER'S EXPERIENCE OF USING THE INTERFACE TO ACHIEVE GOALS |
| UZ | THE PSYCHOLOGICAL ROOTS OF THE USER'S MOTIVATION FOR SEEKING OUT THE INTERACTION |
| U∝ | THE USER'S SELF-ACTUALIZATION |
| UΩ | THE ARC OF THE USER'S LIFE |
| U∞ | LIFE'S EXPERIENCE OF TIME |
| U● | THE ARC OF THE MORAL UNIVERSE |