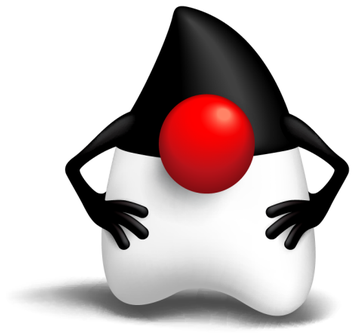
Metadata Features in Java SE 8



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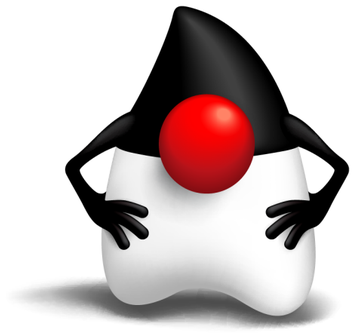

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First, a message from our lawyers:

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Agenda

- Type Annotations
- Repeating Annotations
- Parameter Reflection
- Thoughts from a language hacker/compiler engineer

Annotations

- Java SE 5.0 introduced annotations
- Now an integrated part of the language
  - For example @Override, @Deprecated, @SuppressWarnings
- And the Java ecosystem
  - JPA, Guice, CDI, JAX-RS, JMS

Annotation properties

- Applicability of an annotation can be controlled through @Target
- Retention of an annotation can be specified with @Retention
  - Default is surprisingly Class file
- An annotation can be @Documented, its use showing up in javadoc
- Annotations on classes can be @Inherited

Feature: Type Annotations

- In Java SE 7 annotations can express properties of declarations.

```
@NonNull List<String> f; //Non-null field
```

- How would you express properties of the list elements?

```
class NonNullString extends String {...}
List<NonNullString> f; //List of non-null elements
```

Type Annotations

- To help with this, in Java SE 8 annotations can express properties of type uses:

```
List<@NonNull String> f;
```

```
@Deprecated
class SomeClass { ... }

@Annotated
public void aMethod(@Positive int aParam) {
    @Negative long aVariable;
}

@Foo class ListElement<E> { ... }
```

With Type Annotations

```
new @Interned MyObject();

myString = (@Printable String) myObject;

class UnmodifiableList<T> implements @Readonly List<@Readonly T> {
    void m(List<@NonNull ? extends @NonNull String> x) ...
}

void monitorTemperature() throws @Critical TemperatureException {
    ...
}
```

Type Annotations in core reflection

- Problem: existing methods expose annotations on declarations.

```
class Foo extends @NonNull Bar { ... }

// read annotations on the superclass

Class<?> superClass = Foo.class.getSuperclass();
Annotation a = superClass.getAnnotation(NonNull.class);

// Foo.class.getSuperclass() is:
@ABC @DEF class Bar extends { ... }
```

Type Annotations in core reflection

- New methods expose types

```
class Foo extends @NonNull Bar { ... }

// read annotations on the superclass

AnnotatedType at = Foo.class.getAnnotatedSuperclass();
Annotation a = at.getAnnotation(NonNull.class);
```

Type Annotations in core reflection

- How to “unwrap” parameterized types?

```
List<@NonNull String> f;

Field f = Foo.class.getField(“f”);
AnnotatedType at = f.getAnnotatedType();
if (at instanceof AnnotatedParameterizedType) {
    AnnotatedParameterizedType apt = (AnnotatedParametereizedType) at;
    AnnotatedType[] typeArgs = apt.getAnnotatedActualTypeArguments();
    // typeArgs[0] represents ‘@NonNull String’
    Annotation a typeArgs[0].getAnnotation(NonNull.class);
}
```

Why?

- Annotations on type use is an enabler for static checkers
- Interpreting annotations is the important part
- The Checker framework gives you that interpretation

The Checker framework

- Pluggable type systems
- Lets users develop new useful type checkers
  - Nullness checker that can prove the absence of NPE
  - Lockchecker proves that field access is guarded by lock
  - Regex checker that proves validity of regexps and existence of capture groups

Example: Help with NonNull

```
class BusinessLogic {
    public Entity compute(...) {
        Entity e = (@NonNull Entity) Factory.getEntity();
        //compute compute
        return e;
    }
}
```

The Checker framework

- http://types.cs.washington.edu/checker-framework/
- Example checkers at: http://code.google.com/p/checker-framework/
- We can take the most useful checkers and make them part of Java!

Type Annotations - summary

- The goal is to make it possible extend the type system of Java
  - With for example pluggable checkers from the Checker framework
- Sometimes inference is not enough for the checkers
- Use annotations to help the framework

Feature: Repeating Annotations

Feature: Repeating Annotations

- In Java SE 8 you can now repeat annotations:

```
@Schedule(dayOfMonth="Last")
@Schedule(dayOfWeek="Fri", hour="23")
public void doPeriodicCleanup() { ... }
```

Repeating Annotations

- We added methods to reflection to query for multiple annotations:

```
Method cleanUpMethod = ... ;
Schedule[] schedules =
    cleanupMethod.getAnnotationsByType(Schedule.class);

for (Schedule s : schedules) { ...}
```

Repeating Annotations

- Behind the scenes this is what javac does for you:

```
@Schedule(dayOfMonth="Last"),
@Schedule(dayOfWeek="Fri", hour="23”)
public class MyAction { ... }
```

```
@Schedules(value = {
    @Schedule(dayOfMonth="Last"),
    @Schedule(dayOfWeek="Fri", hour="23”) })
public class MyAction { ... }
```

How to use Repeating Annotations

- Step 1: Create a container annotation

```
public @interface Schedules {
    Schedule[] value;
}
```

- Step 2: Annotate your repeatable annotation, indicating the container

```
@Repeatable(Schedules.class)
public @interface Schedule { ... }
```

Step 2.5

- Your container needs an array valued "`value()`" element with the component type of your repeatable annotation
- All elements non-"`value()`" elements need a default
- The container needs to be retained for at least as long as the contained
- `@Target` for the container must be a subset of `@Target` for the contained
- If contained is `@Documented` the container needs to be `@Documented`

How to use Repeating Annotations

- Step 3: start using the new methods on AnnotatedElement

```
Method cleanUpMethod = ... ;
Schedule[] schedules =
    cleanupMethod.getAnnotationsByType(Schedule.class);

for (Schedule s : schedules) { ...}
```

A real example from our tests

```
@MethodDesc(name = "defaultMethod", modifier = DEFAULT ...)
@MethodDesc(name = "staticMethod", modifier = STATIC ...)
@MethodDesc(name = "method", modifier = ABSTRACT ...)
interface TestIF6 { ... }
```

```
Class<?> typeUnderTest = Class.forName(testTarget);
MethodDesc[] descs = typeUnderTest
    .getAnnotationsByType(MethodDesc.class);

for (MethodDesc desc : descs)
    checkIsFoundByGetMethod(typeUnderTest,
                            desc.name(),
                            argTypes(param));
```

Feature: Parameter Names

Feature: Parameter Names

- In Java SE 7:

```
@Path(“/users”)
class MyResource {
    Response work(@QueryParam(“id”) String id) { ... }
}
```

- In Java SE 8 this could have been written as:

```
@Path(“/users”)
class MyResource {
    Response work(String id) { ... }
}
```

Parameter Names

- Reading parameter names in core reflection:

```
Method workMethod = ...;

Parameter[] parameters = workMethod.getParameters();

for (Parameter p : parameters) { p.getName(); ... }
```

Deep Dive: Language Evolution

```
@Foo @Foo class MyClass { ... }
```

Code assume singular annotations

- Since it wasn't possible to have more than one instance of an annotation per type this is now assumed in lots of code
- Not that hard to find examples of how to upset frameworks, for example:

```
Set<Annotations> set = ...;
for (Annotation a : element.getAnnotations()) {
    // There used to be only one!
    set.add(a);
}
```

Container pattern

- Instead the container pattern was used

```
@Schedule(dayOfMonth="Last"),
@Schedule(dayOfWeek="Fri", hour="23”)
public class MyAction { ... }
```

```
@Schedules(value = {
    @Schedule(dayOfMonth="Last"),
    @Schedule(dayOfWeek="Fri", hour="23”) })
public class MyAction { ... }
```

Compatibility of reflection

- Behavioral compatibility demands that:
  - Repeating annotations are wrapped in a “container” annotation
  - Existing reflection methods treat container annotations as any other annotation
- But the new method `getAnnotationByType(Class)` can look through container annotations

Repeating Annotations

- In order to facilitate the look through in reflection repeatable annotations must nominate their containing type:

```
@Repeatable(Schedules.class)
public @interface Schedule { ... }
```

Deep Dive: Parameter Names

- Parameter names are not used by the JVM
  - If present in the class file at most seen as debug info
  - Not available through Core Reflection - a long-standing “bug”

Issues with Parameter Reflection

- Questions:
  - Should names always be present in the JDK class files?
    - If so, is Oracle committed to their long-term stability?
  - Should names always be present in your own class files?

Issues with Parameter Reflection

- Questions:
  - Should names always be present in the JDK class files? NO
    - If so, is Oracle committed to their long-term stability? N/A
  - Should names always be present in your own class files? NO

The “opt-in” we chose for 8

- We didn’t have the time to get consensus on how to enable method parameter names
- So we made it explicit in the tools
  - Enable parameter name info in tools using a flag like -parameters
- May be revisited in Java SE 9

Deep Dive: Language Evolution

- So you want to change the Java Programming Language?
  - https://blogs.oracle.com/darcy/entry/so_you_want_to_change

- Update JLS
- Implement it in a compiler
- Update essential library support
- Write tests
- Update JVMS
- Update JVM/classfile consumers
- Update JNI
- Update Reflective APIs
- Update serialization support
- Update the javadoc output

Deep Dive: Language Evolution

- Most features requires at least small updates in almost all categories

- Update JLS
- Implement it in a compiler
- Update essential library support
- Write tests
- Update JVMS
- Update JVM/classfile consumers
- Update JNI
- Update Reflective APIs
- Update serialization support
- Update the javadoc output

Essential Library Support

- New enum constants in `java.lang.annotation.ElementType`:
  - TYPE_PARAMETER (Omitted declaration location from Java SE 5)
  - TYPE_USE

Update Reflective APIs

- There is more than one!
  - Core Reflection: `java.lang.Class, java.lang.reflect.*`
  - Language model: `javax.lang.model.{element, type, util}`
  - Annotation Processing: `javax.annotation.processing`
  - Doclet API

j.l.reflect.AnnotatedElement

- New methods in Java SE 8
  - `<T extends Annotation> T getDeclaredAnnotation(Class<T> annotationClass)`
  - `<T extends Annotation> T[] getAnnotationsByType(Class<T> annotationClass)`
  - `<T extends Annotation> T[] getDeclaredAnnotationsByType(Class<T> annotationClass)`
    - The first one can be seen as missing in the 5 API
- Changed to a default method:
  - `boolean isAnnotationPresent(Class<? extends Annotation> annotationClass)`

Adding type use to core reflection

- The current API is focused around declarations
- There is support for generic declarations
  - For example `Class.getField(String name).getGenericType();`
  - Can give you a field of type `List<String>`
  - But the field is tied to a specific (possibly generic) declaration

Adding type use to core reflection

- `Class.getInterfaces()` returns an array of Class objects; per-use annotations can not be stored on Class objects

- Add a suit of sibling getAnnotatedFoo methods for get(Generic)Foo methods in core reflection

  - For example: `Class.getAnnotatedInterfaces()`

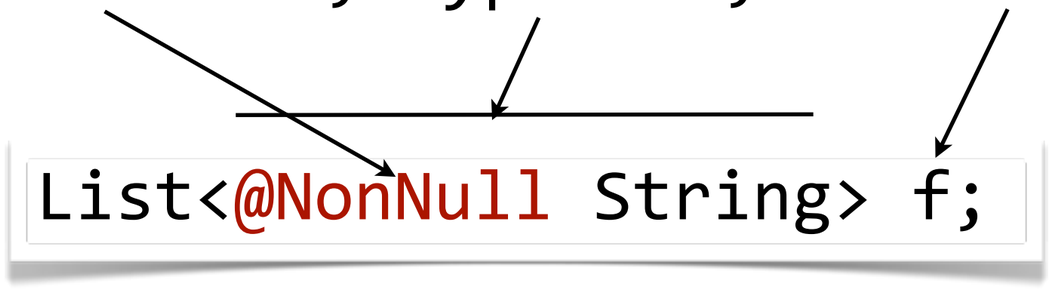
  - returns AnnotatedType

Adding type use to core reflection

- `AnnotatedType`
  - `AnnotatedArrayType`
  - `AnnotatedParameterizedType`
  - `AnnotatedTypeVariable`
  - `AnnotatedWildCardType`

Adding type use to core reflection

- j.l.r.AnnotatedType is conceptually a tuple of (annotations, type-use, declaration)



```
List<@NonNull String> f;
```

- Allows for navigating the declaration that express the uses of the types we are looking at

```
@A List<@B Comparable<@F Object @C [] @D [] @E []>>
```

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Wrapping up

- Annotations in Java SE 8 are easier to write and discover
- Repeating and type annotations enables better framework
- Parameter reflection fixes a long-standing bug in the JDK