Project Lambda in Java SE 8

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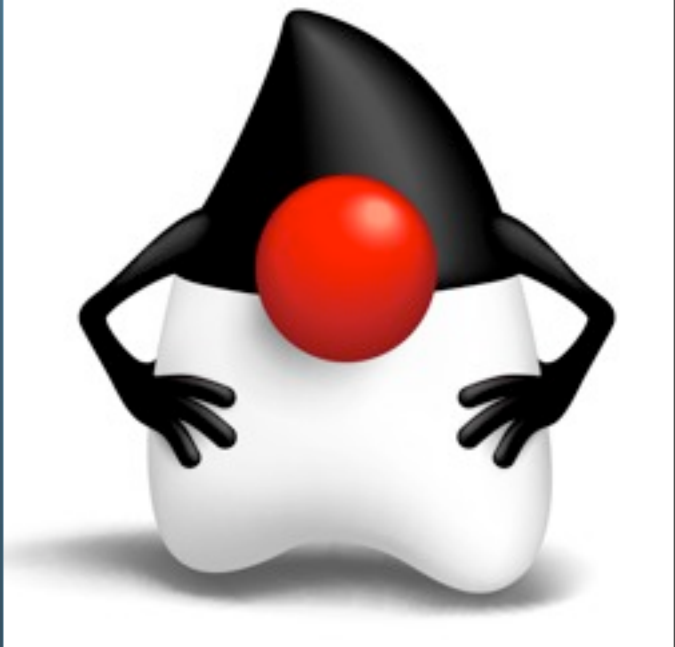


Thursday, November 8, 12

The Java Programming Language

- Around 9,000,000 developers worldwide
- 17 years old
- 4 major revisions (1996, 1997, 2004, 2013...)
- [Insert staggering number] of companies very heavily invested
- Formally standardized and evolved via community

Evolving a Major Language

- Adapting to change
- Righting what’s wrong
- Maintaining compatibility
- Preserving the core

Project Lambda:
Function Values in Java

Code as Data

```
(define f
  (lambda (x) (* x x)))

(map nums f)
```

```
Object subclass: Widget [
  draw: canvas [ ... ]
  click [ ... ]
]

gui add:(Widget new).
```

Status Quo in Java 1.1

```
interface Runnable {
  void run();
}

Thread hello = new Thread(new Runnable() {
  public void run() {
    System.out.println(“Hello, world!”);
  }
});
```

Status Quo in Java 5

```
interface Predicate<T> {
  boolean accept(T arg);
}

lines.removeAll(new Predicate<String>() {
  public boolean accept(String line) {
    return line.startsWith(“#”);
  }
});
```

What We Wish It Looked Like

```
interface Predicate<T> {
  boolean accept(T arg);
}

lines.removeAll(line -> line.startsWith(“#”));
```

Why Functions in Java? Adapting to Change

- Widely-adopted programming style
  - 1995: functions-as-values is too hard to understand
  - Now: almost everybody has them (even C++)
- Physical constraints cause changing models
  - 1995: sequential execution, mutation
  - Today: concurrency, immutability
- A gentle push in the right direction

Why Functions in Java? Better Libraries

- *Lots* of applications...
- Our priorities:
    - Collections
    - Concurrency

```
public class ForkBlur extends RecursiveAction {
  private int[] mSource;
  private int mStart;
  private int mLength;
  private int[] mDestination;

  public ForkBlur(int[] src, int start, int length, int[] dst) {
    mSource = src;
    mStart = start;
    mLength = length;
    mDestination = dst;
  }

  // Average pixels from source, write results into destination.
  protected void computeDirectly() {
    for (int index = mStart; index < mStart + mLength; index++) {
      mDestination[index] = blur(index, mSource);
    }
  }

  protected static int sThreshold = 10000;

  protected void compute() {
    if (mLength < sThreshold) {
      computeDirectly();
      return;
    }

    int split = mLength / 2;

    invokeAll(new ForkBlur(mSource, mStart, split, mDestination),
              new ForkBlur(mSource, mStart + split, mLength - split, mDestination));
  }

}
```

Brief History

- 1997: Odersky/Wadler experimental “Pizza” work
- 1997: Java 1.1 with anonymous classes
- 2006-2008: Vigorous community debate
- 2009: OpenJDK Project Lambda formed
- 2010: JSR 335 filed

Java 8 Language Concepts & Features

- Lambda expressions
- Functional interfaces
- Target typing
- Method references
- Default methods

Lambda Expressions

Lambda Expressions

```
x -> x+1

(s,i) -> s.substring(0,i)

(Integer i) -> list.add(i)

() -> System.out.print(“x”)

cond -> cond ? 23 : 57
```

```
widget -> {
  if (flag) widget.poke();
  else widget.prod();
}

(int x, int y) -> {
  assert x < y;
  return x*y;
}
```

Variable Capture

- Lambdas can refer to variables declared outside the body
- These variables can be final or "effectively final"
  - Works for anonymous classes, too

```
void cut(List<String> l,
              int len) {

   l.updateAll(s ->
     s.substring(0, len));

}
```

Meaning of Names in Lambdas

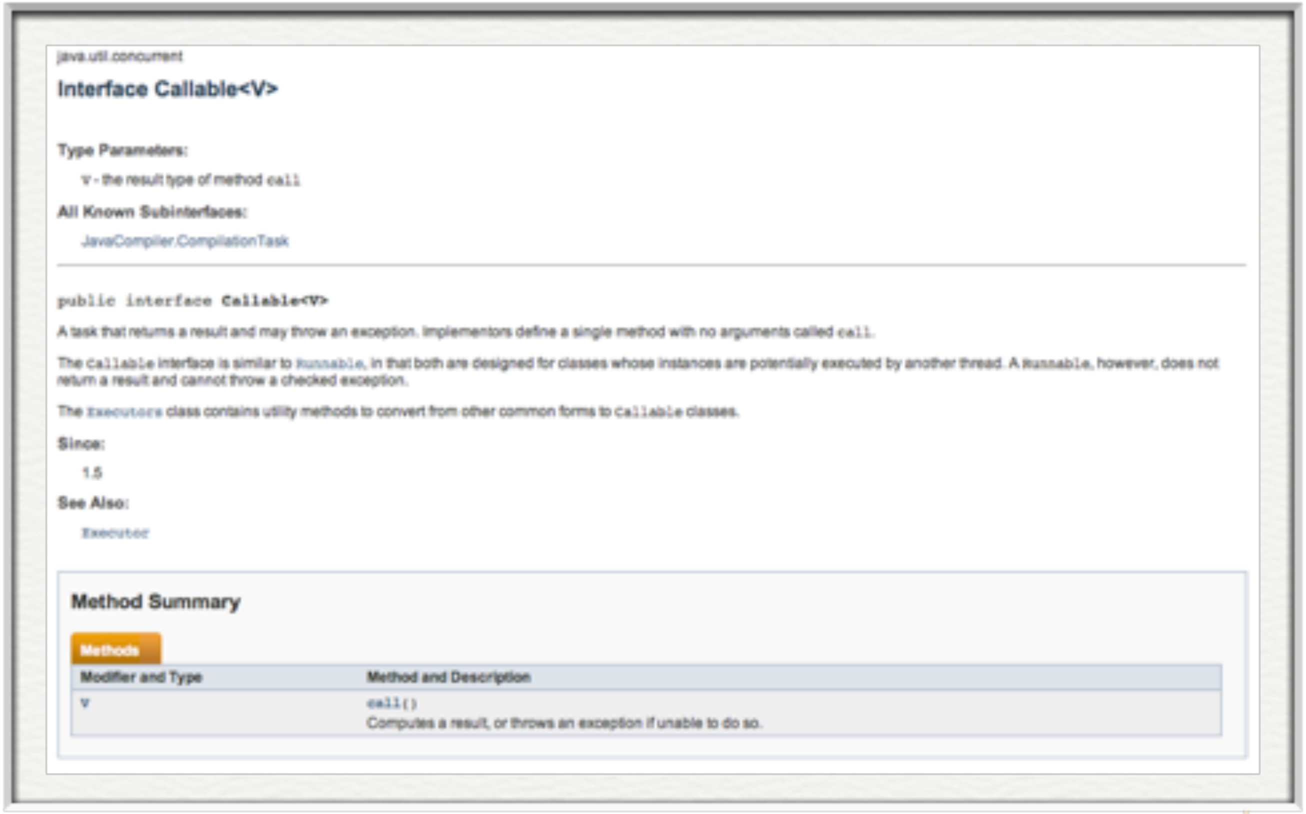
- Anonymous classes introduce a new “level” of scope
  - ‘`this`’ means the inner class instance
  - ‘`ClassName.this`’ is used to get to the enclosing class instance
  - Inherited names can shadow outer-scope names
- Lambdas reside in the same “level” as the enclosing context
  - this refers to the enclosing class
  - No new names are inherited
  - Like local variables, parameter names can’t shadow other locals

Functional Interfaces

Function Types in Java?

```
String -> int

(String, int, boolean) -> List<? extends Integer>

(String, Number) -> Class<?> throws IOException
```

Function Types in Java: Functional Interfaces



java.util.concurrent

Interface Callable<V>

Type Parameters:

`V` - the result type of method `call`

All Known Subinterfaces:

JavaCompiler.CompilationTask

`public interface **Callable<V>**`

A task that returns a result and may throw an exception. Implementors define a single method with no arguments called `call`.

The `Callable` interface is similar to `Runnable`, in that both are designed for classes whose instances are potentially executed by another thread. A `Runnable`, however, does not return a result and cannot throw a checked exception.

The `Executors` class contains utility methods to convert from other common forms to `Callable` classes.

Since:

1.5

See Also:

`Executor`

Method Summary

Methods

Modifier and Type	Method and Description
`V`	`call()` Computes a result, or throws an exception if unable to do so.

Common Existing Functional Interfaces

- java.lang.Runnable
- java.util.concurrent.Callable<V>
- java.security.PrivilegedAction<T>
- java.util.Comparator<T>
- java.io.FileFilter
- java.nio.file.PathMatcher
- java.lang.reflect.InvocationHandler
- java.beans.PropertyChangeListener
- java.awt.event.ActionListener
- javax.swing.event.ChangeListener

Attributes of Functional Interfaces

- Parameter types
- Return type
- Method type arguments
- Thrown exceptions
- An expressive, reifiable type name (possibly generic)
- An informal contract

Shiny New Functional Interfaces*

- java.util.functions.Predicate<T>
- java.util.functions.Factory<T>
- java.util.functions.Block<T>
- java.util.functions.Mapper<T, R>
- java.util.functions.BinaryOperator<T>

* Names and concepts in libraries are still tentative

Declare Your Own

```
/** Creates an empty set. */
public interface SetFactory {
  <T> Set<T> create();
}

/** Performs a blocking, interruptible action. */
public interface BlockingTask<T> {
  <T> T run() throws InterruptedException;
}
```

Target Typing

Assigning a Lambda to a Variable

```
// Runnable: void run()
Runnable r =
            () -> System.out.println(“hi”);

// Predicate<String>: boolean test(String arg)
Predicate<String> pred =
            s -> s.length() < 100;
```

Target Typing Errors

```
Object o =
            () -> System.out.println(“hi”);

// Predicate<String>: boolean test(String arg)
Predicate<String> pred =
            () -> System.out.println(“hi”);
```

Target Typing in Java 7

```
long[][] arr =
          { { 1, 2, 3 }, { 4, 5, 6 } };

List<? extends Number> nums =
          Collections.emptyList();

Set<Map<String, Object>> maps =
          new HashSet<>();
```

Target Typing for Invocations

```
class Thread {
  public Thread(Runnable r) { ... }
}

// Runnable: void run()
new Thread(() -> System.out.println(“hi”));
```

Target Typing for Invocations

```
interface Stream<T> {
  Stream<T> filter(Predicate<T> pred);
}

Stream<String> strings = ...;

// Predicate<T>: boolean test(T arg)
strings.filter(s -> s.length() < 100);
```

A Recipe for Disaster
(Or: A Recipe for Awesome)

- Target typing
- Overload resolution
- Type argument inference

```
<T> int m(Predicate<T> p);
int m(FileFilter f);
<S,T> int m(Mapper<S,T> m);

m(x -> x == null);
```

Other Target Typing Contexts

```
Object o =
        (Runnable) () -> System.out.println(“hi”);

Runnable r =
        condition() ? null : () -> System.gc();

Mapper<String, Runnable> m =
        s -> () -> System.out.println(s);
```

Method References

Boilerplate Lambdas

```
(x, y, z) -> Arrays.asList(x, y, z)

(str, i) -> str.substring(i)

() -> Thread.currentThread().dumpStack()

(s) -> new File(s)
```

Method (and Constructor) References

```
(x, y, z) -> Arrays.asList(x, y, z)
Arrays::asList
(str, i) -> str.substring(i)
String::substring
() -> Thread.currentThread().dumpStack()
Thread.currentThread()::dumpStack
(s) -> new File(s)
File::new
```

Resolving a Method Reference

- Target type provides argument types
- Named method is searched for using those argument types
    - Searching for an instance method, the first parameter is the receiver
- Return type must be compatible with target return

Method References & Generics

```
Mapper<Byte, Set<Byte>> m1 = Collections::singleton;

// SetFactory: <T> Set<T> create()
SetFactory f2 = Collections::emptySet;

Mapper<Queue<Float>, Float> m2 = Queue::peek;

Factory<Set<String>> f3 = HashSet::new;
```

Default Methods

Evolving APIs

New concrete methods: Good

```
abstract class Widget {
  abstract double weight();
  abstract double volume();

  double density() {
    return weight()/volume();
  }
}
```

New abstract methods: Bad

```
interface Widget {
  double weight();
  double volume();

  double density();
}
```

Workaround: Garbage Classes

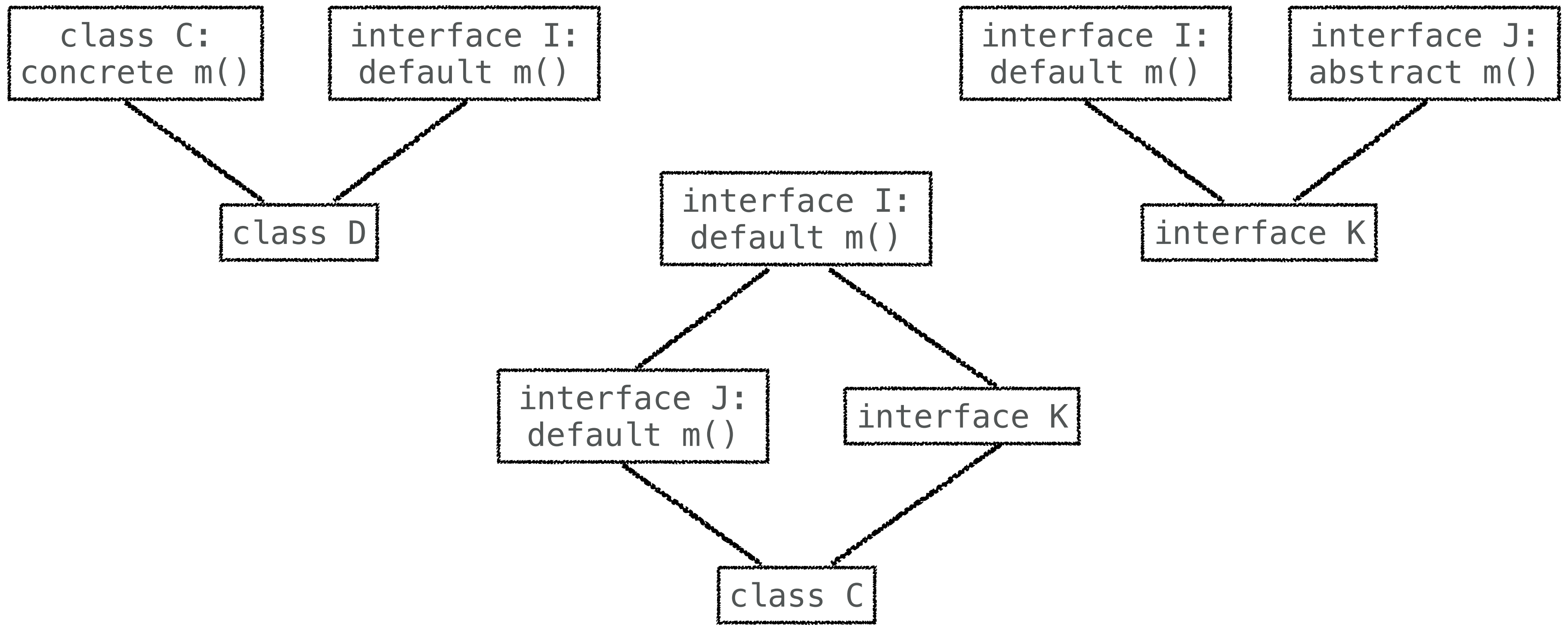
- Not really a class
- Non-idiomatic invocation syntax
- Non-virtual

```
class Widgets {

  static double density(Widget w) {
    return w.weight()/w.volume();
  }

}
```

Default Methods: Code in Interfaces

```
interface Widget {
  double weight();
  double volume();

  default double density() {
    return weight()/volume();
  }
}
```

Multiple Inheritance?



Evolving the Java Standard API

```
interface Enumeration<E> extends Iterator<E> {
  boolean hasMoreElements();
  E nextElement();

  default boolean hasNext() { return hasMoreElements(); }
  default E next() { return getNext(); }
  default void remove() { throw new UnsupportedOperationException(); }

  default void forEachParallel(Block<T> b) { ... }
}
```

Summary

Goals for Project Lambda

- Make dramatic & necessary enhancements to the programming model
- Smooth some rough edges in the language
- Preserve compatibility
- Maintain the essence of the Java language

Learning More

- **OpenJDK:** openjdk.java.net/projects/lambda
- **JSR 335:** www.jcp.org/en/jsr/detail?id=335
- **Me**: daniel.smith@oracle.com

- Download it and try it out!