Project Lambda in Java SE 8

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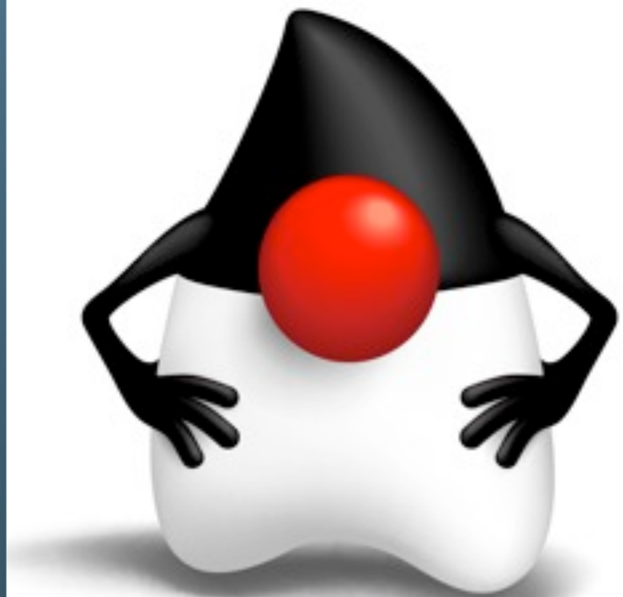

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The Java Programming Language

- Around 9,000,000 developers worldwide
- 17 years old
- 4 major revisions (1996, 2000, 2005, 2013...)
- [Insert staggering number] of companies very heavily invested
- Formally standardized and evolved via community

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- The scope of the Java language is a huge opportunity for the forces of good to move the state of programming forward.
- But there's also a very strong commitment to legacy support, and a disincentive to messing things up.

Evolving a Major Language

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

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Two ideas in this talk: 1) what we're doing in Java 8, along with 2) a meta discussion of how we arrived here
- "Change": we haven't discovered the perfect language yet, and when we do, conditions will change anyway
- "Wrong": the spec has warts, and they're not good for user experience or implementation consistency
- "Compatibility": unusually low tolerance for change between versions
- "Core": can't alienate the base in a quest for something better

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).
```

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- Both functional and object-oriented languages rely fundamentally on the “code as data” concept. (Here, passing a function to ‘map’ and an object to ‘gui’.)
- Compare and contrast...
- They have a lot in common, and each can be easily viewed from the other’s perspective.
- But the approaches are different: functions are small, classes are big.

Status Quo in Java 2

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

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

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- Does Java already have functions?
- We’ve had Runnable since Java 1, and anonymous classes since Java 2. These combine to make it easy to pass a function to the Thread constructor.

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("#");
  }
});
```

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- Java 5 added generics, which make it easier to define interfaces representing general-purpose functions.
- But there is no standard Predicate interface, probably because you can't convince people to write code like this. Too little content in the boilerplate.

What We Wish It Looked Like

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

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

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Problems with anonymous classes:
- Lots of boilerplate
- Everything is explicit
- Multiple lines
- Less obvious: puts stress on heap (class loading, object creation) and disk (lots of class files)

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));
  }

}
```

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- Functional programmers know all sorts of situations where lightweight functions come in handy.
- As a start, we want our collections library to be more convenient/declarative and parallelizable.
- Example: fork-join is powerful, but a naive user is faced with tons of boilerplate just to express a simple parallel computation; we can’t really do much better without lightweight functions.

Java 8 Language Concepts & Features

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

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- Five major new language features & concepts that will facilitate powerful new Java programming patterns.
- Taking the best high-impact ideas we've seen or invented and fitting them into the Java language.

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;
}
```

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- 0, 1, or multiple parameters
- Parameter types can be inferred or explicit
- Bodies can be expressions or blocks
- Block bodies are like methods -- local return
- Minimal delimiters

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));

}
```

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- Lambdas can refer to variables declared outside the body
- Example: declarations and uses of variables are bold
- This is one big reason you would want a local construct (rather than declaring a method)
- Anonymous classes have always required captured variables to be 'final'
- Captured vars still have to be fixed, but don't have to be declared final

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

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- Anonymous classes have a heavyweight resolution strategy
- Lambdas have a lightweight resolution strategy

Functional Interfaces

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Function Types in Java?

```
String -> int

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

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


- What is the type of a lambda expression? We need function types...
- But this isn't going to work!
- Imagine these types in a method signature or as a collection type argument

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.

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Maybe we don’t need something new.

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

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- Already defined
- Already used extensively in APIs

Attributes of Functional Interfaces

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

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- An interface declaration takes up just enough space to give a name and a description to a function type
- Nominal typing is fundamental in Java

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

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We define some functional interfaces fitting basic shapes in our libraries, for both our own use and reuse by others.

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;
}
```

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- The standard API can’t cover everything, and it doesn’t need to.
- Notice the informal contracts.

Target Typing

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Bridging the gap between lambda expressions and functional interfaces...

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;
```

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- A lambda can be assigned to a variable of a functional interface type.
- Bold highlights the target type and the matching expression.
- The type of the lambda expression IS the target type -- it's an implicit part of the expression.
- Implicit parameter types are inferred from the target type.

Target Typing Errors

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

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

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- Lambdas are meaningless without a functional interface target type.
- Parameters and return have to match the target type.

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<>();
```

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- The idea of interpreting an expression based on context is NOT new.
- But it hasn't been formalized very well before.
- And we're stepping it up to a new level.

Target Typing for Invocations

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

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

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A method can ALSO provide a target type (combining information from a declaration and a use).

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);
```

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The target type in a method might depend on generic instantiation (combining information from a declaration, a parameterized type, and a use).

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);
```

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- When we get a target type from a set of overloaded, generic methods, crazy stuff happens.
- Sometimes, it's just ambiguous, but sometimes we can (and should) do much better.
- This is probably where we've spent the majority of our language design time.
- Bonus: new and improved inference features.

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);
```

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- A cast can provide an explicit target type.
- Conditional expression pass down target types.
- Lambdas can be nested.

Method References

Boilerplate Lambdas

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

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

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

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

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- Sometimes, the function you want is just a method that's already defined somewhere.
- There's still some boilerplate involved in this usage.

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
```

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- Static method reference
- Instance method reference
- Bound method reference
- Constructor reference

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

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Since methods can be overloaded, the method being referenced depends on the target type.

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;
```

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- Type arguments are inferred, just like invocations.
- But methods can be referred to generically, too, given an appropriate target type.
- The class name part of the reference doesn't need type arguments.
- Similarly with constructor references: class type arguments can be inferred.

Default Methods

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We’ve got all these great new features, now we need to get people to use them...

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();
}
```

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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();
  }

}
```

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Default Methods: Code in Interfaces

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

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

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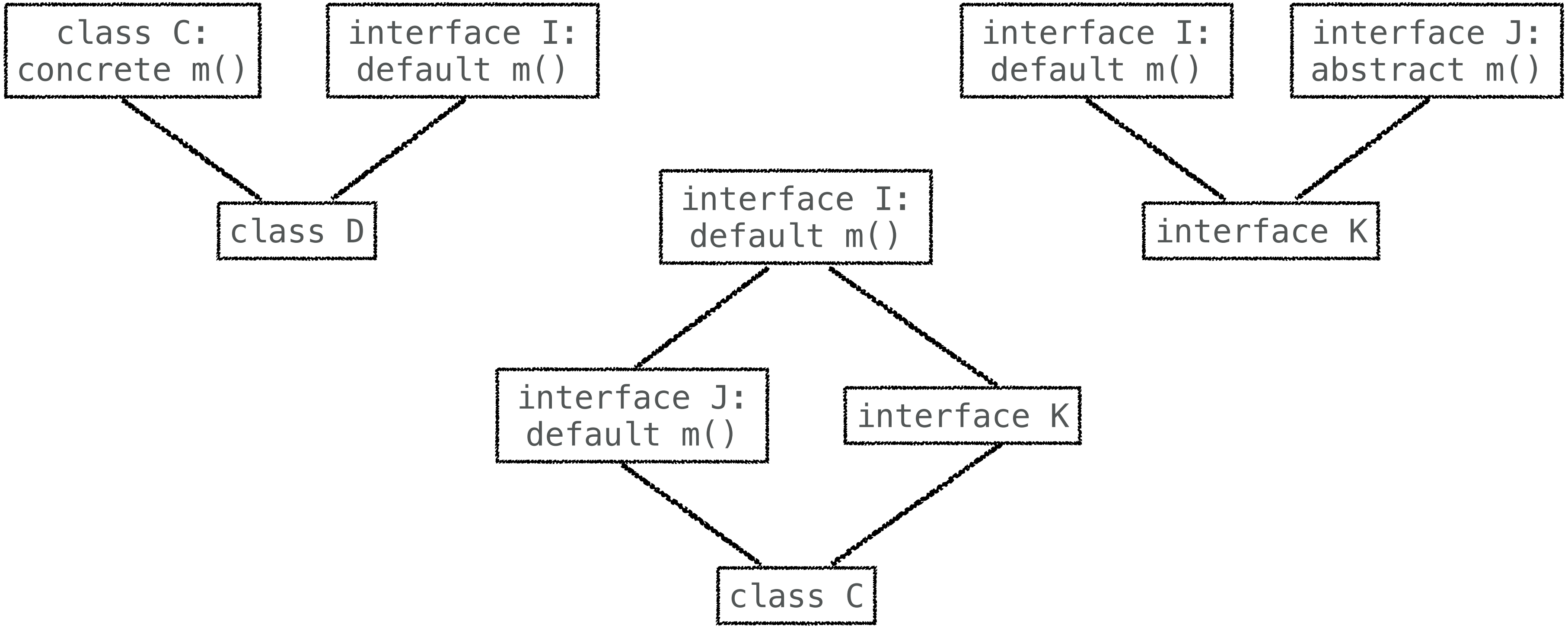
Multiple Inheritance?



- Multiple inheritance of _behavior_, but not _state_.
- Resolve in the “obvious” way whenever possible, but avoid surprises
- Intuitions: class beats interface; overrider beats overridden

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) { ... }
}
```

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Summary

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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

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- Enhancements: lambda expressions, target typing, default methods
- Rough edges: variable capture, type inference
- Essence: functional interfaces, default methods

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!

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Now is a great time to get feedback from real-world usage.