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~~The Future of Java~~

ava: Present And Future
(With A Bit Of The Past)

mon Ritter
ead of Java Technology Evangelism
racle Corporation

Vith much thanks to Brian Goetz

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afe Harbor Statement

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ava SE 8

nhancing The Core Platform

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Java 8

HTTP URL Permissions
Base64
Enhanced Verification Errors
Improve Contended Locking
DocTree API
Prepare for Modularization
Lambda (JSR 335)
Remove the Permanent Generation
Generalized Target-Type Inference
Date/Time API (JSR 310)
Bulk Data Operations
Parallel Array Sorting
Limited doPrivileged
Repeating Annotations
Compact Profiles
Parameter Names
Nashorn
Unicode 6.2
Configurable Secure-Random Number Generation
TLS Server Name Indication
Type Annotations (JSR 308)
Lambda-Form Representation for Method Handles
Fence Intrinsics

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Modernising Java

- Java SE 8 modernises the language
  - Lambda expressions (closures)
  - Interface evolution (default methods)
- Java SE 8 modernises the libraries
  - Bulk data operations on Collections
  - More library support for parallelism
  - Streams API
- Probably the biggest upgrade to the Java programming model

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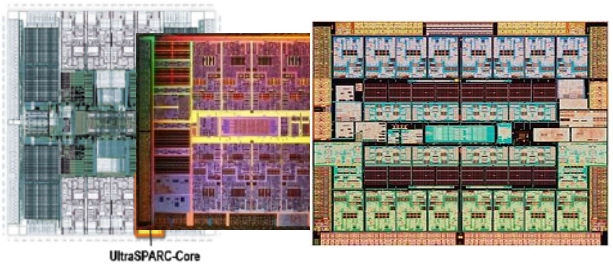
Lambda Expressions

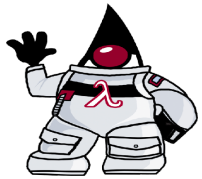
Why Do We Need Them?

- Multi-core, multi-processor machines are the norm
- We need to make writing parallel Java code easier
- To improve the libraries we need language changes

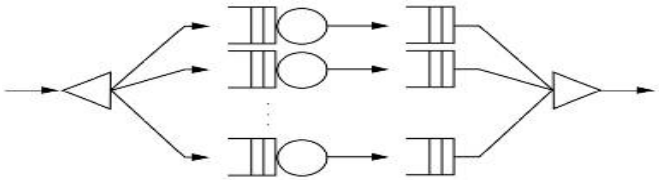


Concurrency in Java

Project Lambda



Fork/Join Framework
(jsr166y)



java.util.concurrent
(jsr166)

Phasers, etc
(jsr166)

lang.Thread

1.0 5.0 6 7 8

1995 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2

Lambda Expressions

What Are They?

- A Lambda expression (closure) is an anonymous function
  - Has an argument list, return type, body and thrown exceptions

```
(Object o) -> o.toString()
```

  - Can refer to values in the surrounding scope

```
(Person p) -> p.getName().equals(name)
```

- A method reference is a reference to an existing method

```
Object::toString
```

- Allows you to treat code as data
  - Simple way to store or pass behaviour as a parameter

Times Move On

Let's Go Way Back To 1995

- Most popular languages did not support closures
- Java was the last holdout that did not before Java SE 8
  - C++ added them in C++11
  - C# added them in version 3.0
  - All languages being designed today include them

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Closures For Java

A Long And Winding Road

- 1997 – Odersky/Wadler experimental "Pizza" work
- 1997 – Java 1.1 added inner classes – a weak form of closures
  - Too bulky, complex name resolution rules, many limitations
- 2006-2008 – A vigorous community debate about Java closures
  - Multiple proposals, including BGGA and CICE
    - BGGA – Creating control abstraction in libraries
    - CICE – Reducing syntactic overhead of inner classes
  - No consensus, other distractions got in the way
- Little language evolution in the last ten years (Java SE 5)
  - Project Coin in Java SE 7

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Closures For Java

A Long And Winding Road

- Dec 2009 – OpenJDK Project Lambda formed
- November 2010 – JSR-335 filed
- JSR-335 = Lambda expressions
  + Interface evolution
  + Bulk collection operations

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Evolving A Mature Language

Key Forces

- Why change the language?
  - Adapt to external changes
    - hardware, attitudes, fashion, problems, solutions
  - Correcting errors
    - Inconsistencies, holes, poor user experience
- Why leave the language alone?
  - Maintaining compatibility
    - Nothing worse than changing working code to make it work
  - Keeping people happy
    - Different does not necessarily mean better
    - Why add a shiny new ball when you can polish the existing ball?

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Adapting To External Changes

Moore's Law Had Different Effects In 1995

- In 1995, language design was all about sequentiality
  - For-loops are sequential and impose a specific order
    - Great feature! Why invite nondeterminism?
    - Determinism is convenient (when it's free)
    - The assumption of sequentiality propagated to libraries (e.g., Iterator)
  - Pervasive mutability
    - Mutability is convenient (when it's free)
    - Object creation was expensive, mutation was cheap
- For today's multicore world these assumptions are wrong
  - Can't outlaw for-loops and mutability
  - Need to offer a choice: Lambda expressions and Streams API

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Problem: External Iteration

The For-Loop

- Take red blocks and colour them blue
- Uses foreach loop
  - Inherently sequential
  - Client has to manage iteration

```
for (Shape s : shapes) {
  if (s.getColour() == RED)
    s.setColour(BLUE);
}
```

- foreach loop hides complex interaction between library and client
  - `Iterable`, `iterator()`, `Iterator.next()`, `Iterator.hasNext()`

Using Internal Iteration

Using A Lambda Expression and Collection.forEach

- Code looks similar, but:
  - Not just a syntactic change
  - Now the library is in control
  - Separate the *how* from the *what*

```
for (Shape s : shapes) {
  if (s.getColour() == RED)
    s.setColour(BLUE);
}
```

- Library free to use parallelism, out-of-order execution, lazy evaluation
- Client passes behaviour (Lambda) as parameter
- Enables API designers to build more powerful, expressive APIs
  - Greater power to abstract over behaviour

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Lambda Expressions

What Type Is It?

- Most languages with closures have some notion of a function type
  - "Function from long to int"
  - Seemed reasonable (at first) to consider adding them to Java
- But…
  - JVM has no native representation of a function type in VM type signatures
  - Obvious tool for function types would be generics
  - Is there a simpler alternative?

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Functional Interfaces

- "Just add function types" was obvious… and wrong
  - Would have interacted badly with erasure and boxing
  - Would have introduced complexity and corner cases
  - Would have created two types of libraries: "old" style and "new" style
- Back to polishing the current ball rather than adding a shiny new one
- Bonus: existing libraries are *forward-compatibl*e with Lambdas
  - Libraries that never imagined Lambdas work with them!
  - Maintains significant investment in existing libraries
  - Fewer new concepts (easier to learn)

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Problem: Interface Evolution

- Earlier example used a new Collection method, `forEach()`
  - This does not exist in Java SE 7
- Interfaces are a double-edged sword
  - Cannot compatibly change them unless you control all implementations
  - Lots of bad options for dealing with aging APIs
    - Let the API stagnate
    - Replace it entirely (every few years, e.g. nio)
    - Nail bits on the side (e.g. Collections.sort())

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Default Methods

Mechanism For Compatibly Evolving APIs

- Virtual interface method with default implementation
- Compatibly evolve libraries over time
  - Default implementation provided in the interface
  - Subclasses can override with better implementations
  - Adding a default method is source and binary compatible

```
interface Collection<T> {
  default void forEach(Consumer<T> action)
    for (T t : this)
      action.apply(t);
  }
}
```

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Default Methods

Wait a minute!

- Isn't this adding multiple inheritance to Java
  - Java has always had multiple inheritance of *types*
  - This adds multiple inheritance of *behaviour*
  - But not of *state*, which is where most of the problems come from
- Primary goal is interface evolution
- Compared to C# extension methods
  - Java default methods are *virtual* and *declaration-site*, not *static* and *use-site*
- Compared to Scala traits
  - Java interfaces are stateless (more like Fortress traits)

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Bulk Operations On Collections

Streams API

- Let's revisit the shape code
  - Further decomposition
  - Use `filter()` and `forEach()`

```
shapes.forEach(s -> {
  if (s.getColour() == RED)
    s.setColour(BLUE);
})
```

```
shapes.stream().
  filter(s -> s.getColour() == RED).
  forEach(s -> s.setColour(BLUE));
```

Streams API

Benefits

- The new bulk operations are expressive and composable
  - Compose compound operations from basic building blocks
  - Each stage does one thing
  - Client code reads more like the problem statement
  - Structure of the client code is less brittle
  - Library can use parallelism, out-of-order execution and lazy evaluation to impro
    performance

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Stream Example 1

Convert words in list to upper case

```
List<String> output = wordList.
  stream().
  map(String::toUpperCase).
  collect(Collectors.toList());
```

Stream Example 1

Convert words in list to upper case (in parallel)

```
List<String> output = wordList.
  parallelStream().
  map(String::toUpperCase).
  collect(Collectors.toList());
```

Stream Example 2

Count lines in a file

```
ong n = Files.newBufferedReader("foo.txt").lines().count()
```

Stream Example 4

List of words in lowercase, in alphabetical order

```
List<String> output = reader.
  lines().
  flatMap(line -> Stream.of(line.split(REGEXP))).
  filter(word -> word.length() > 0).
  collect(toList());
```

Stream Example 4

List of unique words in lowercase, sorted by length

```
List<String> output = reader.
  lines().
  flatMap(line -> Stream.of(line.split(REGEXP))).
  filter(word -> word.length() > 0).
  map(String::toLowerCase).
  distinct().
  sorted((x, y) -> x.length() - y.length()).
  collect(toList());
```

To Java SE 9 and Beyond!

Project Sumatra – Java for GPUs

Improved Integration with Nat

ang Enhancements

Cloud

OpenJFX

esource Management

Self Tuning JVM

Optimizations

Generic Lang Interoperab

Multi-Tenancy Support

Ease of use

Jigsaw

Unified Type Syster

rts: Power PC/AIX

Data Structure Optimizations

Penrose

Hardware and Software
Engineered to Work Together

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