Hotspot & AOT

Now it's time to compile

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Contents

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Introduction

Reminder: It's 2016

- JDK 9 Early Access
  https://jdk9.java.net/
- JDK 8u
- JDK 7 End of Public Updates in April 2015

Overview: Computing

A long time ago in a galaxy far, far away...

- Pre-computer machines appeared
- Computers and their machine codes
- Languages and compilers
- Scripts
- Computer science

Overview: Java

- Is a language
- Set of specifications
- Used to be called *slow*
  ´Because it's interpreted"
  (not true)
- "Write once, run anywhere"
  (true)

Overview: JVM

- Is a code itself
- Can dynamically execute arbitrary correct bytecode

Overview: JVM

- Is a code itself
- Can dynamically execute arbitrary correct bytecode
- May be written in anything
- May produce native code and re-use the result

The Current Situation

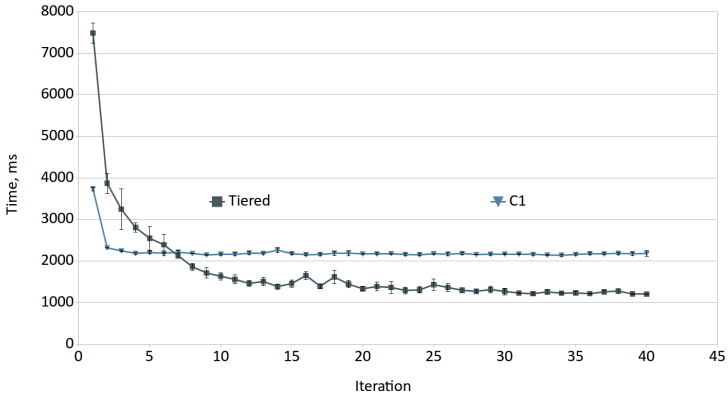
Overview: Hospot

- Is a JVM
- Written in C++
- Native shared libraries (libjvm)
- Produces bytecode dynamically for its own purposes
- Does just-in-time compilation
- Supports many modes
  - Garbage collectors
  - Pointers encoding
  - etc.

Overview: JIT in Hotspot

- Tiered compilation
  - Level 0. Interpreter
  - Level 1. C1 without profiling (optimized), terminal
  - Level 2. C1 with basic profiling
  - Level 3. C1 with full profiling
  - Level 4. C2, terminal, expensive
- Unused method versions are thrown away to save footprint
- Optimizations, resource constraints
  - $\Rightarrow$ de-optimizations to level 0
- All modes (if not switched off), CPU instruction set
  - Custom code

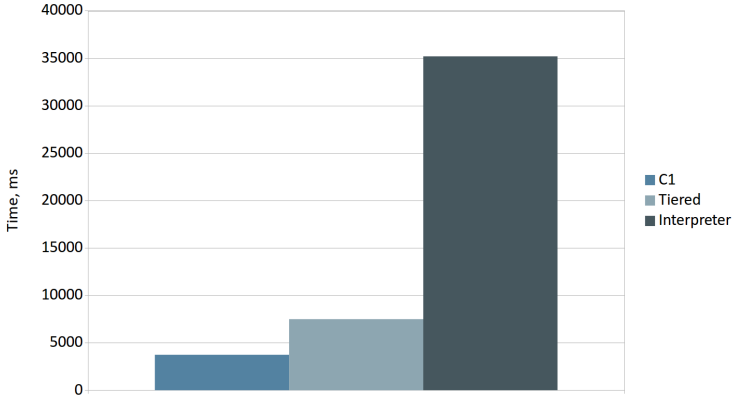
Problem: Application Warm-up



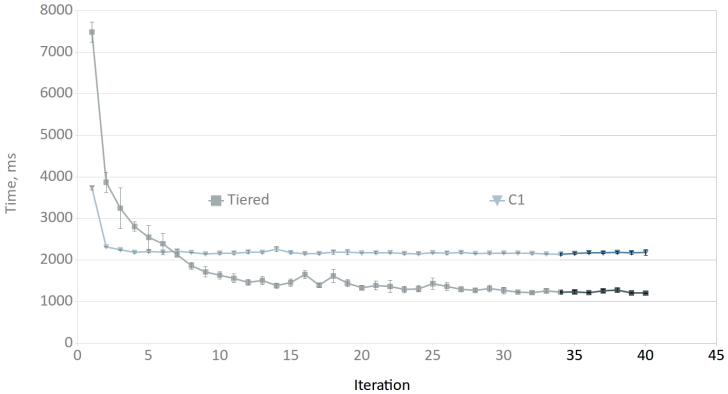
Iterative workload

- Startup time
- Time to performance

Problem: Startup Time

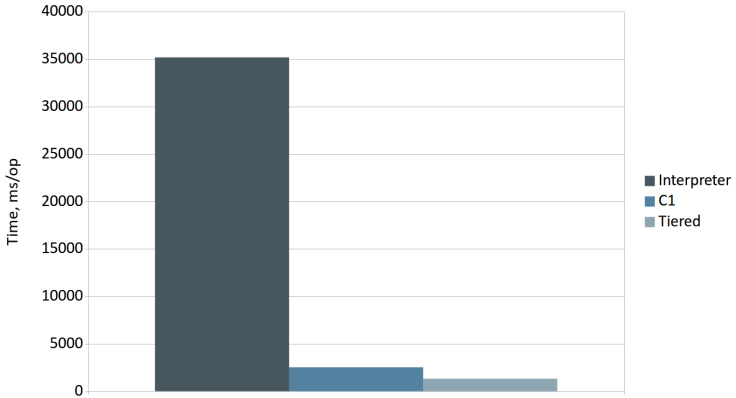


Problem: Time to Performance



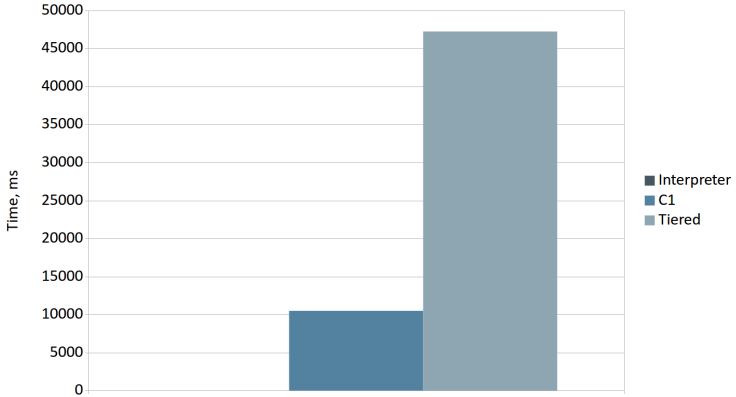
Problem: Time to Performance

Peak Performance

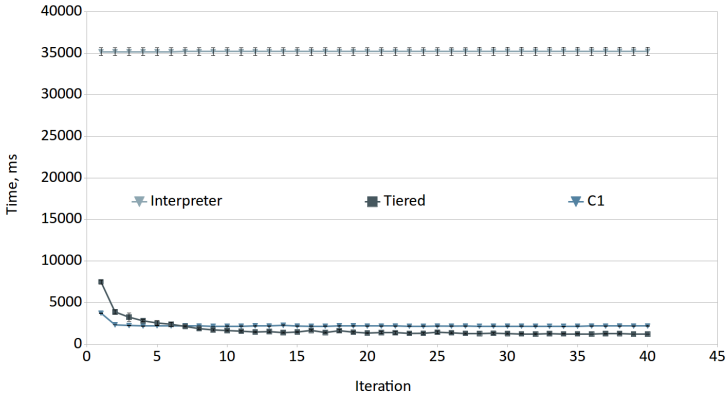


Problem: Time to Performance

Sum of Iterations



Problem: Application Latency



Iterative workload

- Interpreter is slow
- Level 1 (C1) is relatively also slow

Problem: Application Latency

- Wish it to be HFT...

```
@Transactional void buyOrSell(Quote quote)
```

Problem: Application Latency

- Wish it to be HFT...

```
@Transactional void buyOrSell(Quote quote)
```

  - De-optimization when flow changes
  - Training workloads

- And you meet

```
void buy_or_sell [[db:transactional]] (Quote* quote)
```

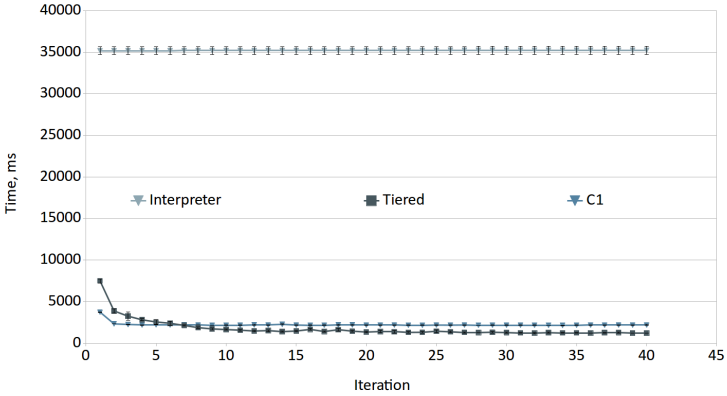
```
CFLAGS_ALL += -O3
```

Problem: Bootstrapping

Meta-circular implementations

- It's possible to write JVM in Java, Scala or JavaScript
- "My dear JVM existing as bytecode image, please start and make yourself efficient in execution of bytecode. Quickly"
- Actually the 3 problems above but doubled

Problem: Bootstrapping



Ahead-of-time Compilation

Solution: Startup time

- Pre-compile initialization code
  - No interpreter for class loading, reflection etc.
  - No resources for compilation

Solution: Time to performance

- Pre-compile critical code
  - Start with much better than interpreter performance
  - No resources for compilation
- Reach peak performance
  - Collect same profiling info
  - JIT with profile-guided optimizations

Solution: Latency

- Pre-compile critical code
  - High and stable performance
    - Optimizations
  - No de-optimization (almost)
  - No re-compilation (almost)

Solution: Density, Power Consumption

For free

- Some critical code is pre-compiled
- Share it

Pre-compilation: Different Solutions Exist

- AOT whole application to native executable
  - Native exe/elf
  - Trial runs for better image layout
  - Bundled or shared VM
  - Deep dependency analysis
  - Pre-defined mode
  - JIT is secondary
- VM with JIT and AOT compilers
  - Optional cache for class data and code
  - Trial runs for methods filtering
- Replay recorded compilations and optimizations

Pre-compilation: For Hotspot

- Need to generate code
  - Mostly no de-optimizations
  - Better than C1
- No tight time budget
- Need to resolve and load generated code

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  - Mostly no de-optimizations
  - Better than C1
- No tight time budget
- Need to resolve and load generated code
- How about one more compiler?

Graal

Graal: Project

- Experimental dynamic compiler written in Java
- Supports Java
- OpenJDK project
  http://openjdk.java.net/projects/graal/
- Oracle Labs team
- GraalVM based on Hotspot
  http://www.oracle.com/technetwork/oracle-labs/program-languages/overview/index.html

Graal: For AOT

- It proven to work
  - SubstrateVM
- Flexible and handy
  - Modular
  - Annotation based way
- Possible to avoid most de-optimizations
  - No speculative optimizations
  - Compile all paths
- Focused on performance

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- Possible to avoid most de-optimizations
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  - Compile all paths
- Focused on performance
- How does it interact with Hotspot?

JVM Compiler Interface

JEP 243: Java-Level JVM Compiler Interface

- OpenJDK feature, already in 9
  http://openjdk.java.net/jeps/243
- Experimental feature

JEP 243: Goals

- Allow the JVM to load Java plug-in code to examine and intercept JVM JIT activity.
- Record events related to compilation, including counter overflow, compilation requests, speculation failure, and deoptimization.
- Allow queries to relevant metadata, including loaded classes, method definitions, profile data, dependencies (speculative assertions), and compiled code cache.
- Allow an external module to capture compilation requests and produce code to be used for compiled methods.

JVMCI: Graal as C2 Replacement

```
-XX:+UnlockExperimentalVMOptions -XX:+EnableJVMCI -XX:+UseJVMCICompiler
[-Djvmci.Compiler=graal]
```

JVMCI: Details

- Not used for C1, C2
- Special module jdk.vm.ci
- Familiar extension patterns
  - CompilerFactory, StartupEventListener, HotSpotJVMCIBackendFactory, HotSpotVMEventListener...

JVMCI: How it works

Hotspot

- Compilation Queue
- Metaspace
- Code Cache

JVMCI Compiler

- Compilation Request
- jdk.vm.ci.meta
- byte[]

JVMCI: How about this?

Hotspot

- Queue
- Metaspace
- Code Cache

Proxy

Network

Proxy

Compilation Server

- Request
- jdk.vm.ci.meta
- byte[]

Artifacts

Code: AOT Modes

- Targeted at problem
  - Tiered. Similar to Level 2
  - Non-Tiered – Latency
- Targeted at VM mode
- Defined by Graal/AOT options (profiling, thresholds etc.)

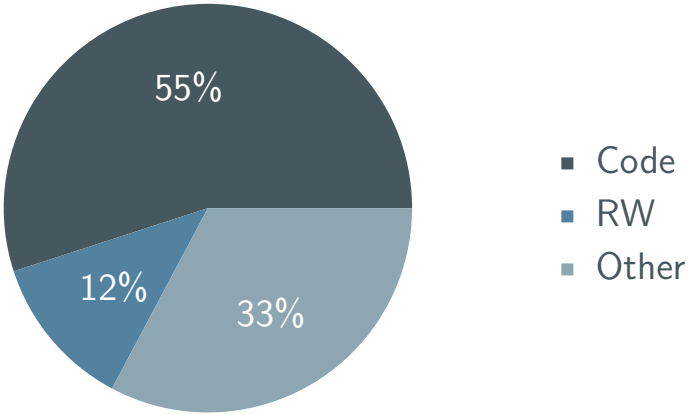
Code: AOT & Tired

- Tiered
  - AOT → level 3 → AOT → level 4
- Non-Tiered
  - AOT

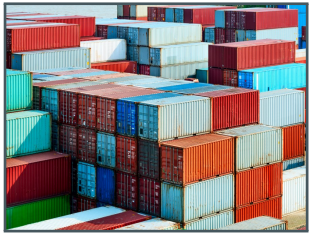
Code: Libraries

- Native shared library (ELF DSO)
  - OS knows how to treat it right
  - Compatible with tools
  - Specific to mode
  - Same runtime
- Modified Hotspot that works with compiled methods from shared libraries
- New `jaotc` tool for compilation
  - Modules
  - Jars
  - Classes

Code: libjava.base.so, 240 MB



Packaging: Self-contained Apps



Packaging: Self-contained Apps

- Java Packager
  - Prepares fancy .dmg for shiny Mac
  - Bundled with 100 Mb JRE
- JEP 275: Modular Java Application Packaging
  http://openjdk.java.net/jeps/275
  - jlink helps to generate a JRE image with the required modules only
  - Extensions
  - AOT libs can be created and added