

Hotspot & AOT

Now it's time to compile

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Safe Harbor Statement

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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

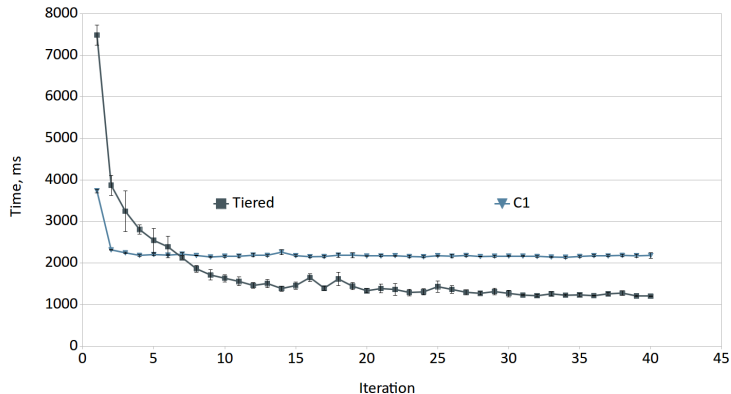
Overview: Hotspot

- 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: Application Latency

- Where is a line for interpreter?

Problem: Application Latency

- Where is a line for interpreter?
- \approx on slide 7

Problem: Application Latency

- Where is a line for interpreter?
- \approx on slide 7
- 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

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

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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- 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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- It proven to work
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- 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:+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[]`

Artifacts

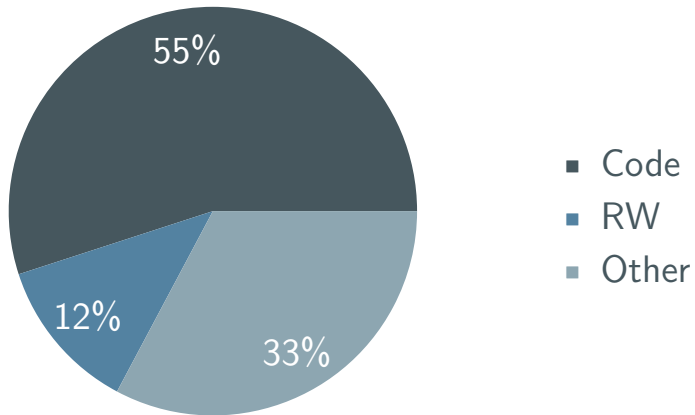
Code: AOT Modes

- Targeted at problem
 - Tiered. Similar to Level 2
 - Non-Tiered – Latency
- Targeted at VM mode

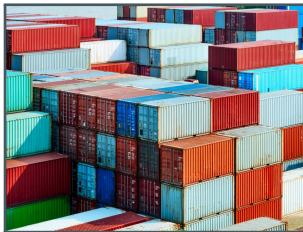
Code: Libraries

- Native shared library (ELF DSO)
 - OS knows how to treat it right
 - Compatible with tools
- Modified Hotspot that works with compiled methods from shared libraries

Code: libjava.base.so



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