Just in Time Compilation

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JIT Compilation: What is it?

“Compilation done during execution of a program (at run time) rather than prior to execution” -Wikipedia

- Seen in today’s JVMs and elsewhere

Outline

- Traditional Java Compilation and Execution
- What JIT Compilation brings to the table
- Optimization Techniques
- JIT Compilation in JRockit/HotSpot JVMs
- JRockit Breakdown Optimization Example
- JIT Compilation elsewhere

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Traditional Java Compilation and Execution

- 2 steps
- A Java Compiler compiles high level Java source code to Java bytecode readable by JVM
- JVM interprets bytecode to machine instructions at runtime

Traditional Java Compilation and Execution

- Advantages
  - platform independence (JVM present on most machines)
  - reflection: modification of program at runtime
- Drawbacks
  - need memory
  - not as fast as running pre-compiled machine instructions

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Goals in JIT Compilation

- combine speed of compiled code w/ flexibility of interpretation

Goal: **“**surpass the performance of static compilation, while maintaining the advantages of bytecode interpretation” -Wikipedia

JIT Compilation (in JVM)

- Builds off of bytecode idea
- A Java Compiler compiles high level Java source code to Java bytecode readable by JVM
- JVM compiles bytecode at runtime into machine readable instructions as opposed to interpretting
- run compiled machine readable code
- Seen in many JVM implementations today

Advantages of JIT Compilation

- Compiling: can perform AOT optimizations
- Compiling bytecode (not high level code) => can perform AOT optimizations faster
- can perform runtime optimizations
- executing machine code is faster than interpretting bytecode

Drawbacks of JIT Compilation

- Startup Delay
  - must wait to compile bytecode into machine-readable instructions before running
  - bytecode interpretation may run faster early on
- Limited AOT optimizations b/c of time
- JVM needs compiler packaged in now
- Compilers for different types of arches
  - for some JITs like .net
  - (not for JVM)

Security issues

- Executable space protection
  - Bytecode compiled into machine instructions that are stored directly in memory
  - those instructions in memory are run
  - Have to check that memory

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Optimization techniques

- Detect frequently used bytecode instructions & optimize
  - # of times a method executed
  - detection of loops
- Combine interpretation with JIT Compilation
  - method used in popular Hotspot JVM incorporated as of Java8's release
- Server & Client specific optimizations
- More useful in longer running programs
  - have time to reap benefits of compiling/optimizing

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A look at a traditional JVM

- HotSpot JVM (pre-Java 8)
  - straight bytecode interpretation
  - limited optimizations

JRockit JVM

- “The industry’s highest performing JVM now built into Oracle Fusion Middleware.” -Oracle
- Currently integrated with Sun’s (now Oracle’s) HotSpot JVM
- Why?
    - JIT

When to use which?

Hotspot

- Desktop application
- UI (swing) based application
- Desktop daemon
- Fast starting JVM

JRockit

- Java application server
- High performance application
- Need of a full monitoring environment

HotSpot’s JRockit Integration

- Launched with Java8
- By default interprets
- Optimizes and compiles hot sections
- runs compiled code for hot sections

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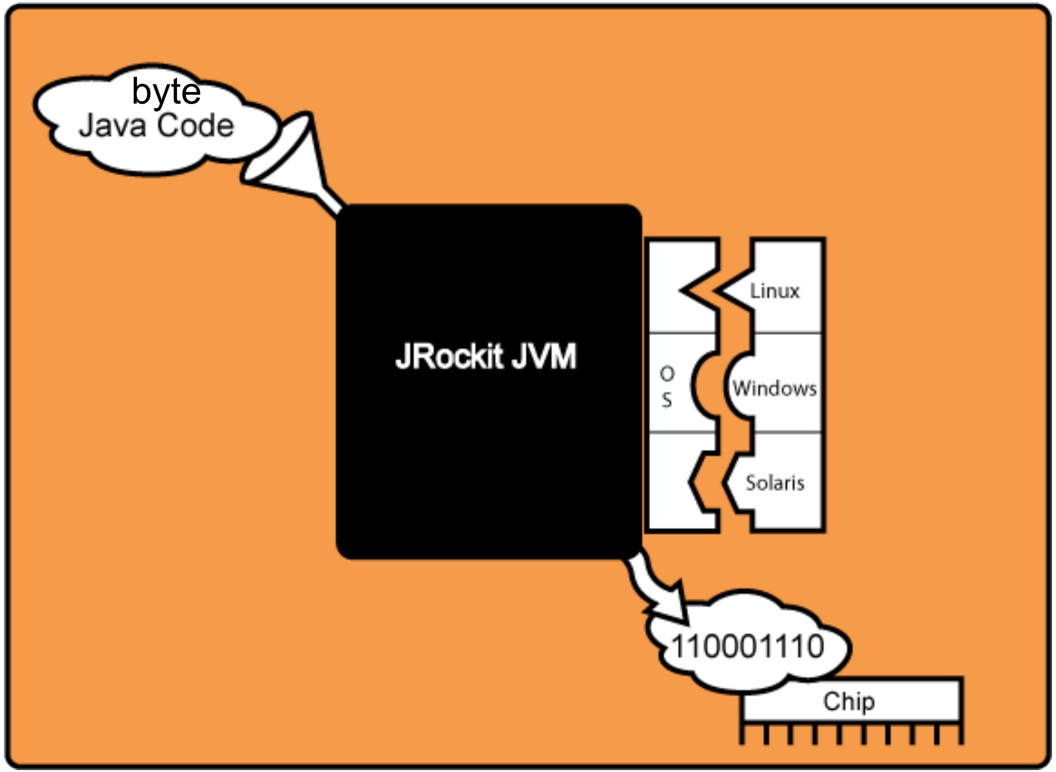
JRockit Breakdown

- NOTE: Compilation and optimizations are performed on java **BYTE**code in the JVM.

JRockit JVM



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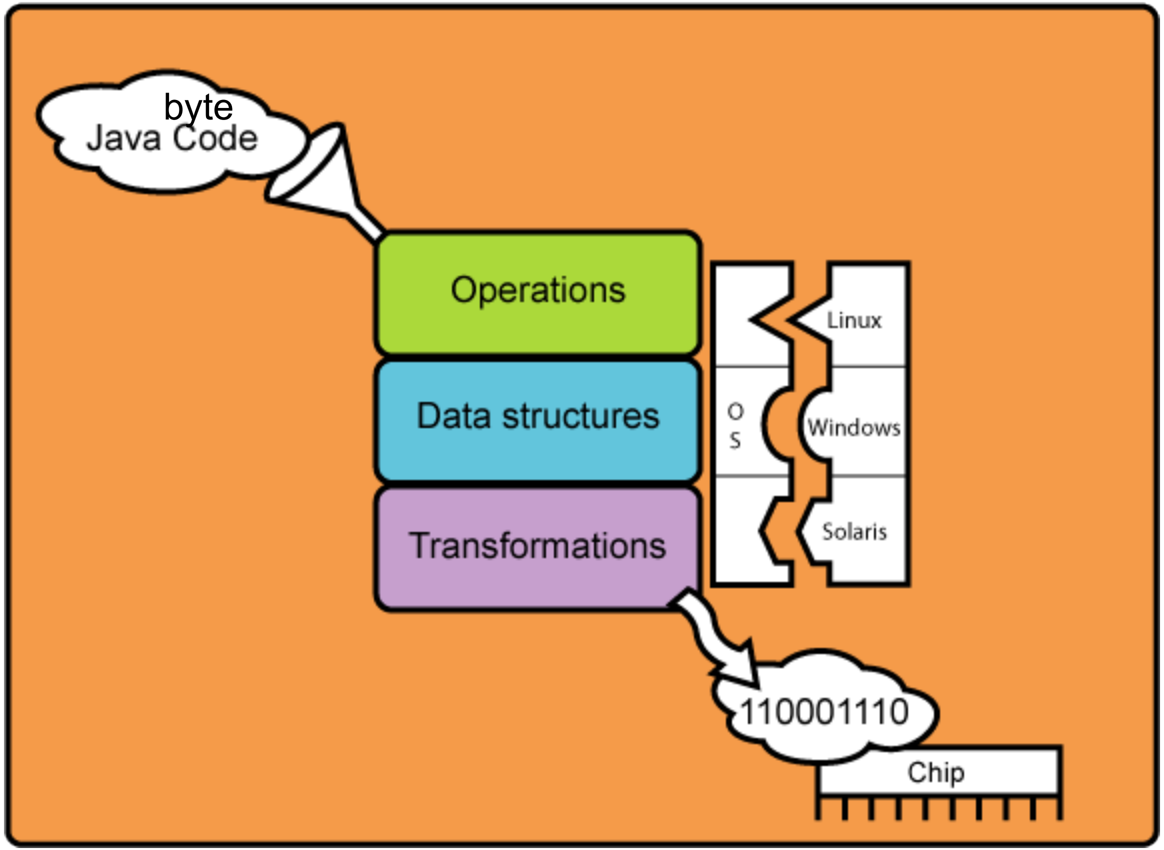
JRockit JVM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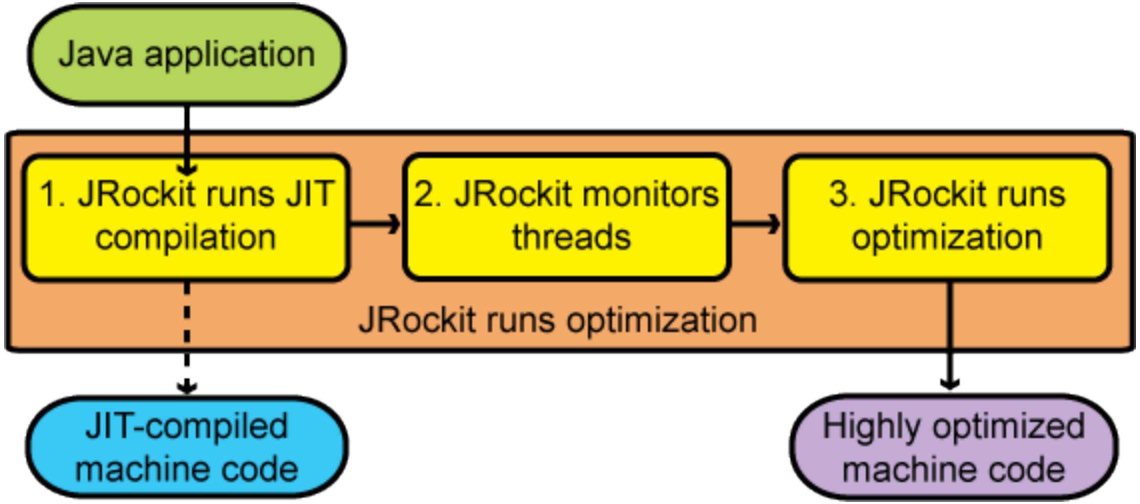
JRockit JIT Compilation



JRockit Step 1: JIT Compilation

- When section of instructions called
  - compile bytecode into machine code just in time
  - run compiled machine code
- Not fully optimized
- May be slower than bytecode interpretation
- JVM Startup may be slower than execution

JRockit Step 2: Monitor Threads

- Identify which functions merit optimization
- Sampler thread
  - checks status of active threads
- Hot methods are ear-marked for optimization
- Optimization opportunities occur early on

JRockit Step 3: Optimization

In background, run compilation of optimized "hot" methods

(Compile optimized bytecode into machine readable instructions)

JRockit Optimization Example

- NOTE: Optimizations are performed on java **BYTE**code in the JVM.
- In the following example from Oracle, the code is written in Java so that it is easier to read, but the JRockit JVM is performing the optimizations on the bytecode instructions

JRockit Optimization Example

Class A before optimization	Class A after optimization

`class A {`
`B b;`
`public void foo() {`
`        y = b.get();`
`        ...do stuff...`
`        z = b.get();`
`        sum = y + z;`
`}`
`}`
 	
`class B {`
`        int value;`
`        final int get() {`
`                return value;`
`        }`
`}`
	`class A {`
	`B b;`
	`public void foo() {`
	`        y = b.value;`
	`        ...do stuff...`
	`        sum = y + y;`
	`}`
	`}`
	
	`class B {`
	`        int value;`
	`        final int get() {`
	`                return value;`
	`        }`
	`}`

Optimization Step 1: Starting Point

```
public void foo() {
    y = b.get();
    ...do stuff...
    z = b.get();
    sum = y + z;
}
```

Step 2: Inline Final Method

```
public void foo() {
    y = b.value;
    ...do stuff...
    z = b.value;
    sum = y + z;
}
```

- `swap b.get() with get() method's contents`

Step 3: Remove Redundant Loads

```
public void foo() {
    y = b.value;
    ...do stuff...
    z = y;
    sum = y + z;
}
```

- swap `z=b.value();` with `z=y;`

Step 4: Copy Propagation

```
public void foo() {
   y = b.value;
   ...do stuff...
   y = y;
   sum = y + y;
}
```

- no use for z

Step 5: Eliminate Dead Code

```
public void foo() {
    y = b.value;
    ...do stuff...
    // nothing
    sum = y + z;
}
```

- y=y does nothing, delete it

JRockit Example

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JIT Elsewhere: More bytecode langs

JIT in JVM has been driving force in movement of more languages to compile to java byte code

- Jython
- JRuby
- Groovy

JIT Elsewhere: C++ like languages

- by default, C++ uses AOT
- C#
  - MSIL == java bytecode
  - JIT
- *Not certain how these work
- CLANG
  - Uses LLVM on backend
  - can benefit from JIT Compilation of bytecode
- C++/CLI (Common Language Infrastructure)
  - Language from Microsoft

JIT Elsewhere: Web Browsers

- Goal: optimize javascript
- Seen today in
  - Mozilla’s Tamarin
  - safari webkit FTL JIT compiler
  - chrome’s V8
  - all browsers except ie8 and earlier

Questions?

Sources

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