## What does the JVM do with my code?

**Manas Thakur** 

PACE Lab, IIT Madras





## **Language Translator**

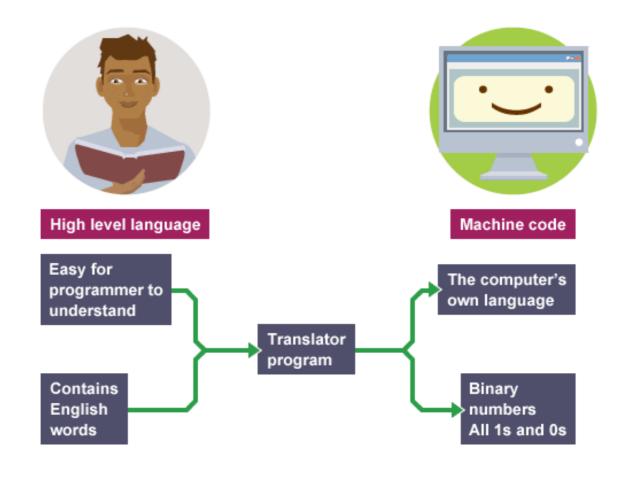


Image source: http://www.bbc.co.uk/education/guides/zgmpr82/revision



## **Compiler vs Interpreter**

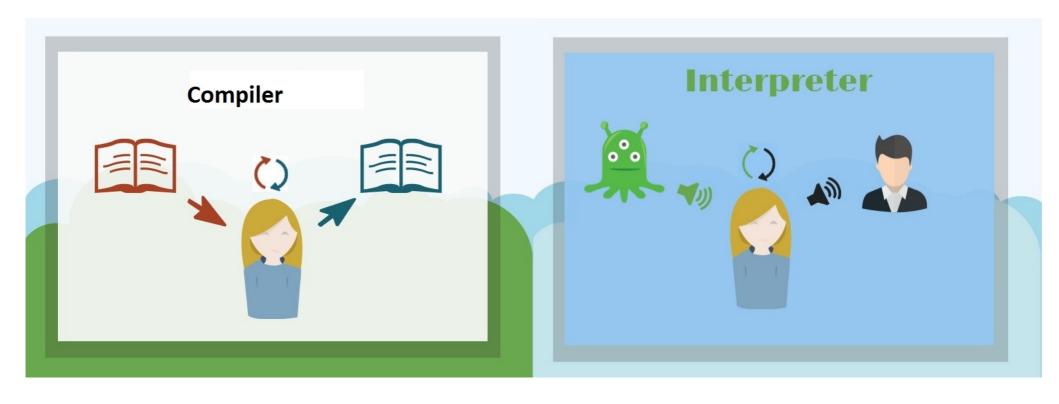


Image source: https://stackoverflow.com/a/31551282



## **Compiler vs Interpreter**

#### A COMPILER

Input

... takes an entire program as its input.

Output

... generates intermediate object code.

Speed

... executes faster.

Memory

... requires more memory in order to create object code.

Workload

... doesn't need to compile every single time, just once.

**Errors** 

... displays errors once the entire program is checked.

#### AN INTERPRETER

- ... takes a single line of code, or instruction, as its input.
- ... does not generate any intermediate object code.
- ... executes slower.
- ... requires less memory (doesn't create object code).
- ... has to convert high-level languages to low-level programs at execution.
- ... displays errors when each instruction is run.

Image source: https://www.upwork.com



#### Outline

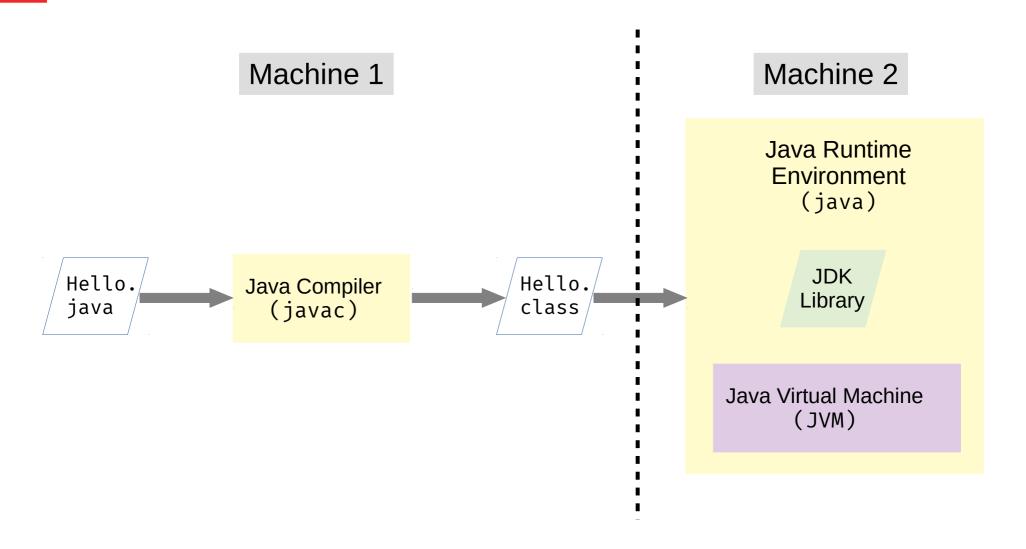
- Basics
- The Java way
- HotSpot under the hood
- Playing around



Ways to begin a talk: The Overdone Overview



#### The Java Compilation+Execution Model





## A Bit of Bytecode

```
int a = 10;
int b = 20;
int c = a + b;
```

Bytecode indices

javap -c class\_name



#### What does the JVM do with my code?

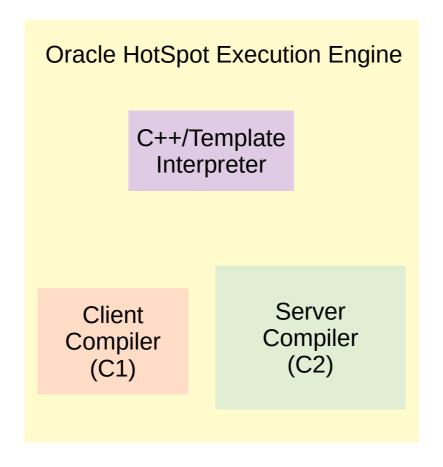
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#### Is Java Bytecode interpreted or compiled?

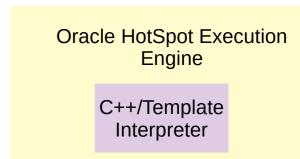
#### Java Bytecode is interpreted as well as compiled!!





# The "HotSpot" JVM

- HotSpot uses tiered compilation with profiling
  - Starts off with interpreter
  - Hot spots get compiled as they get executed
    - Method entry-points changed dynamically
    - Loops replaced on-the-stack
- Interpreters:
  - C++ interpreter (deprecated)
  - Template interpreter
- Just-In-Time (JIT) Compilers:
  - C1 (aka client)
  - C2 (aka server)



Client Compiler (C1) Server Compiler (C2)



## The C++ Interpreter

Simple switch-case

- Disadvantage: Slow
  - Too many comparisons
  - No idea where to go for the next bytecode



# The C1 Compiler

- Targets fast compilation
- Still performs several optimizations:
  - Method inlining
  - Dead code/path elimination
  - Heuristics for optimizing call sites
  - Constant folding
  - Peephole optimizations
  - Linear-scan register allocation, etc.
- Threshold: 1000 to 2000



# The C2 Compiler

- Targets more-and-more optimization
- Performs expensive optimizations (*apart from the ones performed by C1*):
  - Escape analysis
  - Null-check elimination
  - Loop unrolling/unswitching
  - Branch prediction
  - Graph-coloring based register allocation, etc.
- Threshold: 10000 to 15000



# **Compilation Levels**

- 0 Interpreter
- 1 Pure C1
- 2 C1 with invocation and backedge counting
- 3 C1 with full profiling

4 – C2 (full optimization)



0 --- 1



## Deoptimization

- Optimistic optimizations:
  - Branch prediction
  - Implicit null checks
  - Morphism
- When an assumption fails, the compiled method may be invalidated, and the execution falls back to the interpreter
- Consistency maintained using safepoints
- Method states: in use, not entrant, zombie, unloaded

Deoptimization is costly; happens lesser the better



# **HotSpot in Action**





#### When Theory becomes Practice

- Basics
- The Java way
- HotSpot under the hood
- Playing around



"It was here when Harris decided to 'tweak' things a bit..."

17



## Some Important Flags: Compilation

- Compilation details: -XX:+PrintCompilation
- Dump assembly: -XX:+PrintInterpreter
- Interpreter-only mode: -Xint
- Compiler-only mode: -Xcomp
- Disable levels 1, 2, and 3: -XX:-TieredCompilation
- Stop compilation at level n: -XX:TieredStopAtLevel=n



## Some key learnings

- Java programs are not inherently slow.
- Compiler analyses/optimizations tremendously affect the program performance.
- Java programs are interpreted as well as compiled.
- Trust the JVM, and help it.
- Keep experimenting.



#### Pointers for the enthusiast

- https://www.cubrid.org/blog/understanding-jvm-internals
- https://www.artima.com/insidejvm/ed2/jvmP.html
- https://declara.com/content/3gBB6Jge
- https://www.infoq.com/presentations/hotspot-memory-datastructures
- http://www.progdoc.de/papers/Jax2012/jax2012.html
- https://www.ibm.com/developerworks/library/j-jtp12214/index.html



Manas Thakur 20

#### Stay Hungry, Stay Foolish, Stay Connected

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github.com/manasthakur gist.github.com/manasthakur

manasthakur17@gmail.com





manasthakur.wordpress.com

linkedin.com/in/manasthakur



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