Bachelor Thesis

Profile Caching for the Java Virtual Machine

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Introduction

Virtual Machines like the Java Virtual Machine (JVM) are used as the execution environment of choice for many modern programming languages. The VMs interpret a suitable intermediate language (e.g., Java Byte Code for the JVM) and provide the runtime system for application programs and usually include a garbage collector, a thread scheduler, interfaces to the host operating system. As interpretation of intermediate code is time-consuming, VMs include usually a Just-in-Time (JIT) compiler that translates frequently-executed functions or methods to "native" code (e.g., x86 instructions).

The JIT compiler executes in parallel to a program's interpretation by the VM, and as a result, compilation speed is a critical issue in the design of a JIT compiler. Unfortunately, it is difficult to design a compiler such that the compiler produces good (or excellent) code while limiting the resource demands of this compiler (the compiler requires storage and cycles – and even on a multi-core processor, compilation may slow down the execution of the application program). Consequently, most VMs adopt a multi-tier compilation system. At program startup, all methods are interpreted by the VM (execution at Tier-0). The interpreter performs profiling, and if a method is determined to be "hot", this method is then compiled by the Tier-1 compiler. Methods compiled to Tier 1 are then profiled further and based on these profiling information, some methods are eventually compiled at Tier 2. One of the drawbacks of this setup is that for all programs, all methods start in Tier 0, with interpretation and profiling by the VM. However, for many programs the set of "hot" methods does not change from one execution to another and there is no reason to gather again and again the profiling information.

The main idea of this thesis is to cache these profiles from a prior execution to be used in further runs of the same program. This would allow the JIT compiler to use more sophisticated profiles early in program execution and avoid gathering the same profiling as well as prevent further compilations when more information about the method is available. I present an implementation on top of the Java Hotspot Virtual Machine as well as profound performance analysis using state-of-the-art benchmarks.

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1 Motivation

1.1 Tiered Compilation in Hotspot

As mentioned in the introduction, Programming Language Virtual Machines like Java Hotspot feature a multi-tier system when compiling methods during execution. Java VM's typically use Java Bytecode as input, a platform independent intermediate code generated by a Java Compiler like `javac`. The Bytecode is meant to be interpreted by the virtual machine or further compiled into platform dependend machine code. Hotspot includes one interpreter and two different compilers with different profiling levels resulting in a total of 5 different levels. The following Figure 1.1 gives a short overview as well as showing the standard transitions.

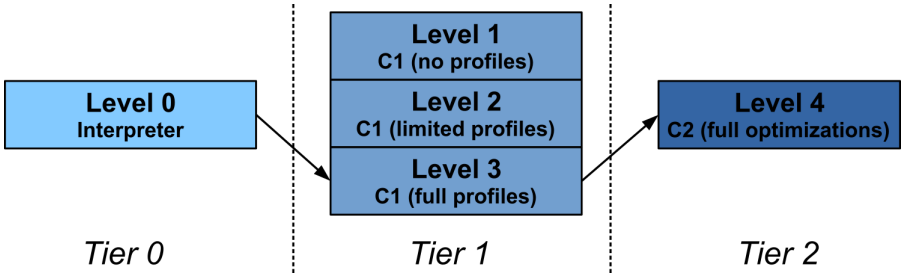

Figure 1.1: Overview over compilation tiers

All methods start being executed by Tier-0 also called the Interpreter. The interpreter is template-based meaning for each bytecode instruction it emits a predefined assembly code snippet. During execution this code is also profiled. This means method execution counters and loop back-branches are counted. Once these counters exceed a predefined, constant threshold the method is further compiled. The standard behaviour of Hotspot is to proceed with Tier 3

1.2 On Stack Replacement

1.3 Deoptimizations

1.4 Compile Thresholds

1.5 Examples

2 Implementation / Design

3 Performance

3.1 Examples

3.2 SPECjvm 2008

3.3 Nashorn / Octane

4 Conclusion

A Extra Stuff

Additional material such as long mathematical derivations.

Bibliography

[1] T. Hartmann, A. Noll, and T. R. Gross. Efficient code management for dynamic multi-tiered compilation systems. In *2014 International Conference on Principles and Practices of Programming on the Java Platform Virtual Machines, Languages and Tools, PPPJ '14, Cracow, Poland, September 23-26, 2014*, pages 51–62, 2014.