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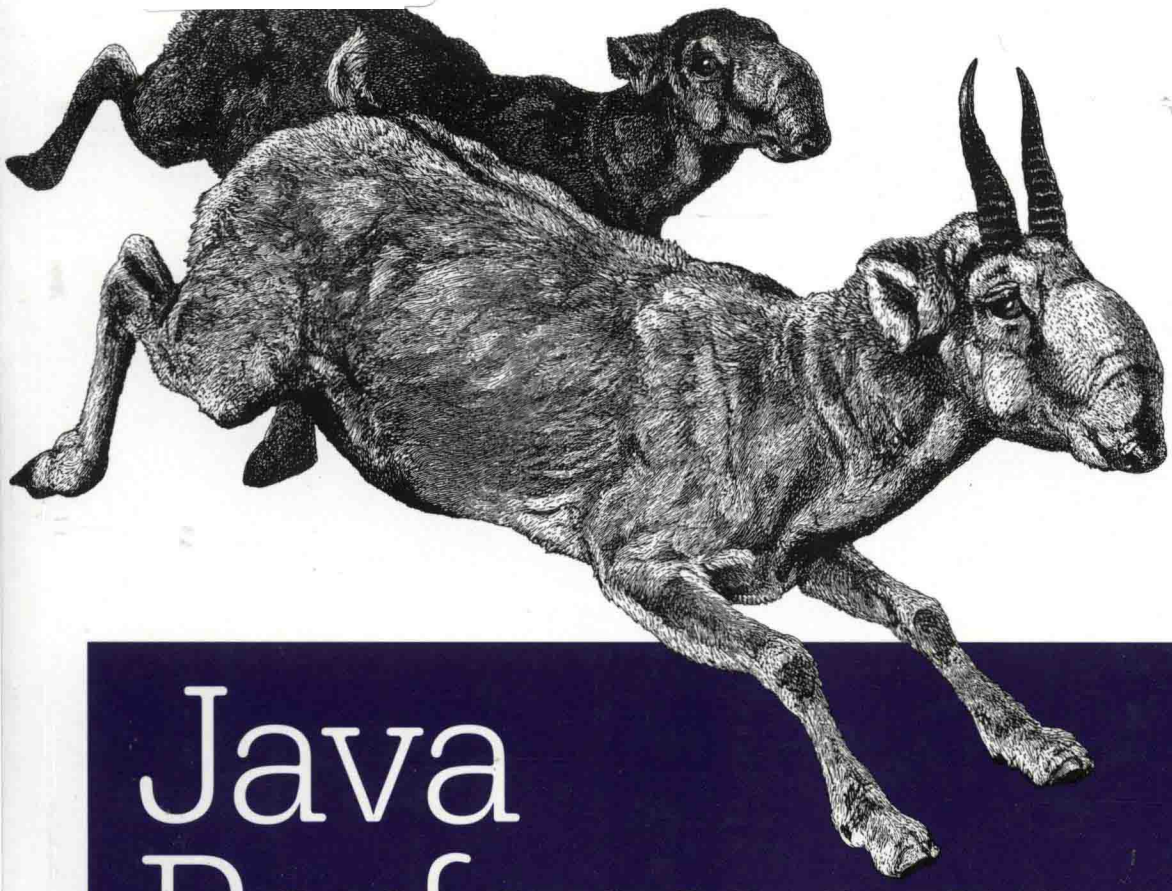

Java Performance
The Definitive Guide

Java性能权威指南（影印版）

東南大學出版社

Scott Oaks 著

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Java Performance: The Definitive Guide

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Beijing · Cambridge · Farnham · Köln · Sebastopol · Tokyo O'REILLY

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Preface

When O'Reilly first approached me about writing a book on Java performance tuning, I was unsure. Java performance, I thought—aren't we done with that? Yes, I still work on performance of Java (and other) applications on a daily basis, but I like to think that I spend most of my time dealing with algorithmic inefficiences and external system bottlenecks rather than on anything directly related to Java tuning.

A moment's reflection convinced me that I was (as usual) kidding myself. It is certainly true that end-to-end system performance takes up a lot of my time, and that I sometimes come across code that uses an $O(n^2)$ algorithm when it could use one with O(log N) performance. Still, it turns out that every day, I think about GC performance, or the performance of the JVM compiler, or how to get the best performance from Java Enterprise Edition APIs.

That is not to minimize the enormous progress that has been made in the performance of Java and JVMs over the past 15-plus years. When I was a Java evangelist at Sun during the late 1990s, the only real "benchmark" available was CaffeineMark 2.0 from Pendragon software. For a variety of reasons, the design of that benchmark quickly limited its value; yet in its day, we were fond of telling everyone that Java 1.1.8 performance was eight times faster than Java 1.0 performance based on that benchmark. And that was true—Java 1.1.8 had an actual just-in-time compiler, where Java 1.0 was pretty much completely interpreted.

Then standards committees began to develop more rigorous benchmarks, and Java performance began to be centered around them. The result was a continuous improvement in all areas of the JVM—garbage collection, compilations, and within the APIs. That process continues today, of course, but one of the interesting facts about performance work is that it gets successively harder. Achieving an eightfold increase in performance by introducing a just-in-time compiler was a straightforward matter of engineering, and even though the compiler continues to improve, we're not going to see an improvement like that again. Paralellizing the garbage collector was a huge performance improvement, but more recent changes have been more incremental.

This is a typical process for applications (and the JVM itself is just another application): in the beginning of a project, it's easy enough to find archictural changes (or code bugs) which, when addressed, yield huge performance improvements. In a mature application, finding such performance improvements is quite rare.

That precept was behind my original concern that, to a large extent, the engineering world might be done with Java performance. A few things convinced me I was wrong. First is the number of questions I see daily about how this or that aspect of the JVM performs under certain circumstances. New engineers come to Java all the time, and JVM behavior remains complex enough in certain areas that a guide to how it operates is still beneficial. Second is that environmental changes in computing seem to have altered the performance concerns that engineers face today.

What's changed in the past few years is that performance concerns have become bifurcated. On the one hand, very large machines capabable of running JVMs with very large heaps are now commonplace. The JVM has moved to address those concerns with a new garbage collector (G1), which—as a new technology—requires a little more hand-tuning than traditional collectors. At the same time, cloud computing has renewed the importance of small, single-CPU machines: you can go to Oracle or Amazon or a host of other companies and very cheaply rent a single CPU machine to run a small application server. (You're not actually getting a single-CPU machine: you're getting a virtual OS image on a very large machine, but the virtual OS is limited to using a single CPU. From the perspective of Java, that turns out to be the same as single-CPU machine.) In those environments, correctly managing small amounts of memory turns out to be quite important.

The Java platform also continues to evolve. Each new edition of Java provides new language features and new APIs that improve the productivity of developers—if not always the performance of their applications. Best practice use of these language features can help to differentiate between an application that sizzles, and one that plods along. And the evolution of the platform brings up interesting performance questions: there is no question that using JSON to exchange information between two programs is much simpler than coming up with a highly optimized proprietary protocol. Saving time for developers is a big win—but making sure that productivity win comes with a performance win (or at least breaks even) is the real goal.

Who Should (and Shouldn't) Read This Book

This book is designed for performance engineers and developers who are looking to understand how various aspects of the JVM and the Java APIs impact performance.

If it is late Sunday night, your site is going live Monday morning, and you're looking for a quick fix for performance issues, this is not the book for you.

If you are new to performance analysis and are starting that analysis in Java, then this book can help you. Certainly my goal is to provide enough information and context that novice engineers can understand how to apply basic tuning and performance principles to a Java application. However, system analysis is a very broad field. There are a number of excellent resources for system analysis in general (and those pricincples of course apply to Java), and in that sense, this book will hopefully be a useful companion to those texts.

At a fundamental level, though, making Java go really fast requires a deep understanding about how the JVM (and Java APIs) actually work. There are literally hundreds of Java tuning flags, and tuning the JVM has to be more than an approach of blindly trying them and seeing what works. Instead, my goal is to provide some very detailed knowledge about what the JVM and APIs are doing, with the hope that if you understand how those things work, you'll be able to look at the specific behavior of an application and understand *why* it is performing badly. Understanding that, it becomes a simple (or at least simpler) task to get rid of undesirable (badly performing) behavior.

One interesting aspect to Java performance work is that developers often have a very different background than engineers in a performance or QA group. I know developers who can remember thousands of obscure method signatures on little-used Java APIs but who have no idea what the flag `-Xmn` means. And I know testing engineers who can get every last ounce of performance from setting various flags for the garbage collector but who could barely write a suitable "Hello, World" program in Java.

Java performance covers both of these areas: tuning flags for the compiler and garbage collector and so on, and best-practice uses of the APIs. So I assume that you have a good understanding of how to write programs in Java. Even if your primary interest is not in the programming aspects of Java, I do spent a fair amount of time discussing programs, including the sample programs used to provide a lot of the data points in the examples.

Still, if your primary interest is in the performance of the JVM itself—meaning how to alter the behavior of the JVM without any coding—then large sections of this book should still be beneficial to you. Feel free to skip over the coding parts and focus in on the areas that interest you. And maybe along the way, you'll pick up some insight into how Java applications can affect JVM performance and start to suggest changes to developers so they can make your performance-testing life easier.

Conventions Used in This Book

The following typographical conventions are used in this book:

Italic
: Indicates new terms, URLs, email addresses, filenames, and file extensions.

`Constant width`
: Used for program listings, as well as within paragraphs to refer to program elements such as variable or function names, databases, data types, environment variables, statements, and keywords.

`Constant width bold`
: Shows commands or other text that should be typed literally by the user.

`Constant width italic`
: Shows text that should be replaced with user-supplied values or by values determined by context.

This element signifies a tip or suggestion.

This element signifies a general note.

This element indicates a warning or caution.

Using Code Examples

Supplemental material (code examples, exercises, etc.) is available for download at *https://github.com/ScottOaks/JavaPerformanceTuning*.

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Acknowledgments

I would like to thank everyone who helped me as I worked on this book. In many ways, this book is an accumulation of knowledge gained over my past 15 years in the Java Performance Group at Sun Microsystems and Oracle, so the list of people who have provided positive input into this book is quite broad. To all the engineers I have worked with during that time, and particularly to those who patiently answered my random questions over the past year, thank you!

I would especially like to thank Stanley Guan, Azeem Jiva, Kim LiChong, Deep Singh, Martijn Verburg, and Edward Yue Shung Wong for their time reviewing draft copies and providing valuable feedback. I am sure that they were unable to find all my errors, though the material here is greatly improved by their input.

The production staff at O'Reilly was as always very helpful, and thanks to my editor Meg Blanchette for all your encouragement during the process. Finally, I must thank my husband James for putting up with the long nights and those weekend dinners where I was in a continual state of distraction.

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CHAPTER 1
Introduction

This is a book about the art and science of Java performance.

The science part of this statement isn't surprising; discussions about performance include lots of numbers and measurements and analytics. Most performance engineers have a background in the sciences, and applying scientific rigor is a crucial part of achieving maximum performance.

What about the art part? The notion that performance tuning is part art and part science is hardly new, but it is rarely given explicit acknowledgment in performance discussions. This is partly because the idea of "art" goes against our training.

Part of the reason is that what looks like art to some people is fundamentally based on deep knowledge and experience. It is said that magic is indistinguishable from sufficiently advanced technologies, and certainly it is true that a cell phone would look magical to a knight of the Round Table. Similarly, the work produced by a good performance engineer may look like art, but that art is really an application of deep knowledge, experience, and intuition.

This book cannot help with the experience and intuition part of that equation, but its goal is to help with the deep knowledge—with the view that applying knowledge over time will help you develop the skills needed to be a good Java performance engineer. The goal is to give you an in-depth understanding of the performance aspects of the Java platform.

This knowledge falls into two broad categories. First is the performance of the Java Virtual Machine (JVM) itself: the way in which the JVM is configured affects many aspects of the performance of a program. Developers who are experienced in other languages may find the need for tuning to be somewhat irksome, though in reality tuning the JVM is completely analogous to testing and choosing compiler flags during compilation for C++ programmers, or to setting appropriate variables in a *php.ini* file for PHP coders, and so on.

The second aspect is to understand how the features of the Java platform affect performance. Note the use of the word *platform* here: some features (e.g., threading and synchronization) are part of the language, and some features (e.g., XML parsing performance) are part of the standard Java API. Though there are important distinctions between the Java language and the Java API, in this case they will be treated similarly. This book covers both facets of the platform.

The performance of the JVM is based largely on tuning flags, while the performance of the platform is determined more by using best practices within your application code. In an environment where developers code and a performance group tests, these are often considered separate areas of expertise: only performance engineers can tune the JVM to eke out every last bit of performance, and only developers worry about whether their code is written well. That is not a useful distinction—anyone who works with Java should be equally adept at understanding how code behaves in the JVM and what kinds of tuning is likely to help its performance. Knowledge of the complete sphere is what will give your work the patina of art.

A Brief Outline

First things first, though: Chapter 2 discusses general methodologies for testing Java applications, including pitfalls of Java benchmarking. Since performance analysis requires visibility into what the application is doing, Chapter 3 provides an overview of some of the tools available to monitor Java applications.

Then it is time to dive into performance, focusing first on common tuning aspects: just-in-time compilation (Chapter 4) and garbage collection (Chapter 5 and Chapter 6). The remaining chapters focus on best practice uses of various parts of the Java platform: memory use with the Java heap (Chapter 7), native memory use (Chapter 8), thread performance (Chapter 9), Java Enterprise Edition APIs (Chapter 10), JPA and JDBC (Chapter 11), and some general Java SE API tips (Chapter 12).

Appendix A lists all the tuning flags discussed in this book, with cross-references to the chapter where they are examined.

Platforms and Conventions

This book is based on the Oracle HotSpot Java Virtual Machine and the Java Platform, Standard Edition (Java SE), versions 7 and 8. Within versions, Oracle provides update releases periodically. For the most part, update releases provide only bug fixes; they never provide new language features or changes to key functionality. However, update releases do sometimes change the default value of tuning flags. Oracle will doubtless provide update releases that postdate publication of this book, which is current as of Java 7 update 40 and Java 8 (as of yet, there are no Java 8 update releases). When an