

Adaptive Optimizing Compilers for the 21st Century

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Abstract

Historically, compilers have operated by applying a fixed set of optimizations in a predetermined order. We call such an ordered list of optimizations a *compilation sequence*. This paper describes a prototype system that uses biased random search to discover a program-specific compilation sequence that minimizes an explicit, external objective function. The result is a compiler framework that adapts its behavior to the applications being compiled, to the pool of available transformations, to the objective function, and to the target machine.

This paper describes experiments that attempt to characterize the space that the adaptive compiler must search. The preliminary results suggest that optimal solutions are rare and that local minima are frequent. If this holds true, biased random searches, such as a genetic algorithm, should find good solutions more quickly than simpler strategies, such as hill climbing.

1 The Changing Landscape

Each year, microprocessors, microcontrollers, and other computing engines find application in new areas. The number of computers in use is growing rapidly, as is the diversity of those systems. The variety among processors—different instruction sets, different performance parameters, different memory hierarchies—is increasing. Even commodity microprocessors come in low-power versions, embedded versions, and a variety of high-performance versions; the performance parameters of these versions can differ widely. Processors have also grown more complex, with multiple functional units, exposed pipelines, and myriad latencies that must be managed. In most cases, these computers execute code produced by a compiler—a translator that consumes source code and produces equivalent code for some target machine.

At the same time, the application of computing to new problems has created demand for compilers that optimize programs for new criteria, or new *objective functions*. In the 1980s and the early 1990s, the speed of compiled code was the dominant concern of users. In the late 1990s, the size of compiled code became an issue, driven by limited memory in embedded systems and by the importance of compiled applications transmitted over the Internet. The rise of embedded systems has also sparked interest in compiler techniques that can reduce the power consumed during execution [27, 28, 4, 15]. The classic approach to the appearance of a new objective function has been to formulate new transformations and add them to the optimizer.

The community has been building optimizing compilers for forty years. We know how to build optimizing compilers that produce efficient code for a single uniprocessor target. We can do this for most modern processors. We have learned to build compilers that are easier to retarget but produce less optimized code. Such “retargetable” compilers are used in many situations where the economics cannot justify a large standalone compiler effort. What we have not developed is an economical way to produce high-quality compilers for a wide variety of target machines.¹ Unfortunately, we have also learned that building high-quality compilers is expensive, primarily because it requires years of effort by experts, who are usually in short supply.

¹The resources devoted to compiler development vary widely. Contrast, for example, the excellent code produced by the compiler for Cray’s (Tera’s) MTA architecture (with 1 or 2 installed systems) against the code quality achieved by typical compilers for Pentium-based systems (with a huge number of installed units).

21st Century Compilers

**Alfred V. Aho, Ravi Sethi, Jeffrey D.
Ullman, Monica S. Lam**



21st Century Compilers:

21st Century Compilers Alfred V. Aho, Ravi Sethi, Jeffrey D. Ullman, Monica S. Lam, 2003-10-01 This classic text known to lecturers, students, and developers world wide as the Dragon Book is the bible of compiler design. It provides a thorough grounding in the theory and practice of compilers. The book begins with an introduction to the principal ideas behind compilation.

Automatic Tuning of Compilers Using Machine Learning Amir H. Ashouri, Gianluca Palermo, John Cavazos, Cristina Silvano, 2017-12-22 This book explores breakthrough approaches to tackling and mitigating the well-known problems of compiler optimization using design space exploration and machine learning techniques. It demonstrates that not all the optimization passes are suitable for use within an optimization sequence and that in fact many of the available passes tend to counteract one another. After providing a comprehensive survey of currently available methodologies including many experimental comparisons with state-of-the-art compiler frameworks, the book describes new approaches to solving the problem of selecting the best compiler optimizations and the phase ordering problem, allowing readers to overcome the enormous complexity of choosing the right order of optimizations for each code segment in an application. As such, the book offers a valuable resource for a broad readership including researchers interested in Computer Architecture, Electronic Design Automation, and Machine Learning, as well as computer architects and compiler developers.

The Compiler Design Handbook Y.N. Srikant, Priti Shankar, 2018-10-03 Today's embedded devices and sensor networks are becoming more and more sophisticated, requiring more efficient and highly flexible compilers. Engineers are discovering that many of the compilers in use today are ill-suited to meet the demands of more advanced computer architectures. Updated to include the latest techniques, *The Compiler Design Handbook, Second Edition* offers a unique opportunity for designers and researchers to update their knowledge, refine their skills, and prepare for emerging innovations. The completely revised handbook includes 14 new chapters addressing topics such as worst-case execution time estimation, garbage collection, and energy-aware compilation. The editors take special care to consider the growing proliferation of embedded devices, as well as the need for efficient techniques to debug faulty code. New contributors provide additional insight into chapters on register allocation, software pipelining, instruction scheduling, and type systems. Written by top researchers and designers from around the world, *The Compiler Design Handbook, Second Edition* gives designers the opportunity to incorporate and develop innovative techniques for optimization and code generation.

Languages and Compilers for Parallel Computing Charith Mendis, Lawrence Rauchwerger, 2023-05-09 This book constitutes the thoroughly refereed post-conference proceedings of the 35th International Workshop on Languages and Compilers for Parallel Computing (LCPC 2022) held in Chicago, IL, USA in October 2022. The 9 revised full papers were carefully reviewed and selected from 12 submissions. The conference covers all aspects of languages, compiler techniques, run-time environments, and compiler-related performance evaluation for parallel and high-performance computing. The scope of the workshop encompasses foundational results as well as practical

experience reports and bold new ideas for future systems *Program Logics for Certified Compilers* Andrew W. Appel,2014-04-21 This tutorial for graduate students covers practical and theoretical aspects of separation logic with constructions and proofs in Coq Principles of Compilers Yunlin Su,Song Y. Yan,2011-11-22 Principles of Compilers A New Approach to Compilers Including the Algebraic Method introduces the ideas of the compilation from the natural intelligence of human beings by comparing similarities and differences between the compilations of natural languages and programming languages The notation is created to list the source language target languages and compiler language vividly illustrating the multilevel procedure of the compilation in the process The book thoroughly explains the LL 1 and LR 1 parsing methods to help readers to understand the how and why It not only covers established methods used in the development of compilers but also introduces an increasingly important alternative the algebraic formal method This book is intended for undergraduates graduates and researchers in computer science Professor Yunlin Su is Head of the Research Center of Information Technology Universitas Ma Chung Indonesia and Department of Computer Science Jinan University Guangzhou China Dr Song Y Yan is a Professor of Computer Science and Mathematics at the Institute for Research in Applicable Computing University of Bedfordshire UK and Visiting Professor at the Massachusetts Institute of Technology and Harvard University USA **Retargetable Compiler Technology for Embedded Systems** Rainer Leupers,Peter Marwedel,2013-03-09 It is well known that embedded systems have to be implemented efficiently This requires that processors optimized for certain application domains are used in embedded systems Such an optimization requires a careful exploration of the design space including a detailed study of cost performance tradeoffs In order to avoid time consuming assembly language programming during design space exploration compilers are needed In order to analyze the effect of various software or hardware configurations on the performance retargetable compilers are needed that can generate code for numerous different potential hardware configurations This book provides a comprehensive and up to date overview of the fast developing area of retargetable compilers for embedded systems It describes a large set important tools as well as applications of retargetable compilers at different levels in the design flow Retargetable Compiler Technology for Embedded Systems is mostly self contained and requires only fundamental knowledge in software and compiler design It is intended to be a key reference for researchers and designers working on software compilers and processor optimization for embedded systems Statistics of Protestant Missionary Societies. 1872-3. [The Compiler's Preface Signed: W. B. B., I.e. William Binnington Boyce.] W. B. B.,1874 **IBM z16 Technical Introduction** Octavian Lascu,Ewerson Palacio,Bill White,IBM Redbooks,2023-10-11 This IBM Redbooks publication introduces the latest members of the IBM Z family IBM z16™ which is built with the IBM Telum™ processor and available in three different configuration options IBM z16 A01 IBM z16 A02 IBM z16 AGZ The IBM Z platform is recognized for its security resiliency performance and scale It is relied on for mission critical workloads and as an essential element of hybrid cloud infrastructures IBM z16 adds capabilities and value with innovative technologies that are

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In a fast-paced world fueled by information and interconnectivity, the spellbinding force of linguistics has acquired newfound prominence. Its capacity to evoke emotions, stimulate contemplation, and stimulate metamorphosis is really astonishing. Within the pages of "**21st Century Compilers**," an enthralling opus penned by a very acclaimed wordsmith, readers set about an immersive expedition to unravel the intricate significance of language and its indelible imprint on our lives. Throughout this assessment, we shall delve into the book's central motifs, appraise its distinctive narrative style, and gauge its overarching influence on the minds of its readers.

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