RETARGETABLE COMPILER TECHNOLOGY FOR EMBEDDED SYSTEMS

TOOLS AND APPLICATIONS

RAINER LEUPERS &
PETER MARWEDEL

Retargetable Compiler Technology For Embedded Systems

Stamatis Vassiliadis,Mladen Berekovic,Timo D. Hämäläinen

Retargetable Compiler Technology For Embedded Systems:

Retargetable Compiler Technology for Embedded Systems Rainer Leupers,Peter Marwedel,2001-10-31 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 *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 *Software and Compilers for Embedded Systems* Andreas Krall,2003-10-24 This volume contains the proceedings of the 7th International Workshop on Software and Compilers for Embedded Systems SCOPES 2003 held in Vienna Austria September 24 26 2003 Initially the workshop was referred to as the International Workshop on Code Generation for Embedded Systems The rst workshop took place in 1994 in Schloss Dagstuhl Germany From its beg nings the intention of the organizers was to create an atmosphere in which the researcherscould participateactively in dynamic discussionsand pro t from the assembly of international experts in the eld It was at the fourth workshop in St Goar Germany in 1999 that the spectrum of topics of interest for the workshop was extended and not only code generation but also software and compilers for embedded systems were considered The change

in elds of interest led to a change of name and this is when the present name was used for the rst time Since then SCOPES has been held again in St Goar Germany in 2001 Berlin Germany in 2002 and this year 2003 in Vienna Austria In response to the call for papers 43 very strong papers from all over the world were submitted The program committee selected 26 papers for pres tation at SCOPES 2003 All submitted papers were reviewed by at least three experts in order to ensure the quality of the work presented at the workshop   **Embedded Microprocessor System Design using FPGAs** Uwe Meyer-Baese,2025-05-29 This textbook for courses in Embedded Systems introduces students to necessary concepts through a hands on approach It gives a great introduction to FPGA based microprocessor system design using state of the art boards tools and microprocessors from Altera Intel and Xilinx HDL based designs soft core parameterized cores Nios II and MicroBlaze and ARM Cortex A9 design are discussed compared and explored using many hand on designs projects Custom IP for HDMI coder Floating point operations and FFT bit swap are developed implemented tested and speed up is measured New additions in the second edition include bottom up and top down FPGA based Linux OS system designs for Altera Intel and Xilinx boards and application development running on the OS using modern popular programming languages Python Java and JavaScript HTML CSSs Downloadable files include all design examples such as basic processor synthesizable code for Xilinx and Altera tools for PicoBlaze MicroBlaze Nios II and ARMv7 architectures in VHDL and Verilog code as well as the custom IP projects For the three new OS enabled programing languages a substantial number of examples ranging from basic math and networking to image processing and video animations are provided Each Chapter has a substantial number of short quiz questions exercises and challenging projects   **Retargetable Compilers for Embedded Core Processors** Clifford Liem,2013-03-09 Embedded core processors are becoming a vital part of today s system on a chip in the growing areas of telecommunications multimedia and consumer electronics This is mainly in response to a need to track evolving standards with the flexibility of embedded software Consequently maintaining the high product performance and low product cost requires a careful design of the processor tuned to the application domain With the increased presence of instruction set processors retargetable software compilation techniques are critical not only for improving engineering productivity but to allow designers to explore the architectural possibilities for the application domain Retargetable Compilers for Embedded Core Processors with a Foreword written by Ahmed Jerraya and Pierre Paulin overviews the techniques of modern retargetable compilers and shows the application of practical techniques to embedded instruction set processors The methods are highlighted with examples from industry processors used in products for multimedia telecommunications and consumer electronics An emphasis is given to the methodology and experience gained in applying two different retargetable compiler approaches in industrial settings The book also discusses many pragmatic areas such as language support source code abstraction levels validation strategies and source level debugging In addition new compiler techniques are described which support address generation for DSP architecture trends The contribution is an address calculation transformation

based on an architectural model Retargetable Compilers for Embedded Core Processors will be of interest to embedded system designers and programmers the developers of electronic design automation EDA tools for embedded systems and researchers in hardware software co design   Embedded Computer Systems: Architectures, Modeling, and Simulation Stamatis Vassiliadis,Mladen Berekovic,Timo D. Hämäläinen,2007-08-30 Researchers and professionals in the appropriate subject areas will find this book an essential update on where research has got to in what is after all a hugely important area It constitutes the refereed proceedings of the 7th International Workshop on Systems Architectures Modeling and Simulation held in Samos Greece in July 2007 The 44 revised full papers presented together with 2 keynote talks were thoroughly reviewed and selected from 116 submissions   **Instruction Selection** Gabriel Hjort Blindell,2016-06-03 This book presents a comprehensive structured up to date survey on instruction selection The survey is structured according to two dimensions approaches to instruction selection from the past 45 years are organized and discussed according to their fundamental principles and according to the characteristics of the supported machine instructions The fundamental principles are macro expansion tree covering DAG covering and graph covering The machine instruction characteristics introduced are single output multi output disjoint output inter block and interdependent machine instructions The survey also examines problems that have yet to be addressed by existing approaches The book is suitable for advanced undergraduate students in computer science graduate students practitioners and researchers   Embedded Systems Design Bruno Bouyssounouse,2005-03-30 This extensive and increasing use of embedded systems and their integration in everyday products mark a significant evolution in information science and technology Nowadays embedded systems design is subject to seamless integration with the physical and electronic environment while meeting requirements like reliability availability robustness power consumption cost and deadlines Thus embedded systems design raises challenging problems for research such as security reliable and mobile services large scale heterogeneous distributed systems adaptation component based development and validation and tool based certification This book results from the ARTIST FP5 project funded by the European Commision By integration 28 leading European research institutions with many top researchers in the area this book assesses and strategically advances the state of the art in embedded systems The coherently written monograph like book is a valuable source of reference for researchers active in the field and serves well as an introduction to scientists and professionals interested in learning about embedded systems design   **System-on-Chip** Bashir M. Al-Hashimi,2006-01-31 This book highlights both the key achievements of electronic systems design targeting SoC implementation style and the future challenges presented by the continuing scaling of CMOS technology   **Code Optimization Techniques for Embedded Processors** Rainer Leupers,2013-03-09 The building blocks of today s and future embedded systems are complex intellectual property components or cores many of which are programmable processors Traditionally these embedded processors mostly have been pro grammed in assembly languages due to efficiency reasons This implies time

consuming programming extensive debugging and low code portability The requirements of short time to market and dependability of embedded systems are obviously much better met by using high level language e g C compil ers instead of assembly However the use of C compilers frequently incurs a code quality overhead as compared to manually written assembly programs Due to the need for efficient embedded systems this overhead must be very low in order to make compilers useful in practice In turn this requires new compiler techniques that take the specific constraints in embedded system de sign into account An example are the specialized architectures of recent DSP and multimedia processors which are not yet sufficiently exploited by existing compilers **Customizable Embedded Processors** Paolo Ienne,Rainer Leupers,2006-08-30 Customizable processors have been described as the next natural step in the evolution of the microprocessor business a step in the life of a new technology where top performance alone is no longer sufficient to guarantee market success Other factors become fundamental such as time to market convenience energy efficiency and ease of customization This book is the first to explore comprehensively one of the most fundamental trends which emerged in the last decade to treat processors not as rigid fixed entities which designers include as is in their products but rather to build sound methodologies to tailor fit processors to the specific needs of such products This book addresses the goal of maintaining a very large family of processors with a wide range of features at a cost comparable to that of maintaining a single processor First book to present comprehensively the major ASIP design methodologies and tools without any particular bias Written by most of the pioneers and top international experts of this young domain Unique mix of management perspective technical detail research outlook and practical implementation **Multi-Core Embedded Systems** Georgios Kornaros,2018-10-08 Details a real world product that applies a cutting edge multi core architecture Increasingly demanding modern applications such as those used in telecommunications networking and real time processing of audio video and multimedia streams require multiple processors to achieve computational performance at the rate of a few giga operations per second This necessity for speed and manageable power consumption makes it likely that the next generation of embedded processing systems will include hundreds of cores while being increasingly programmable blending processors and configurable hardware in a power efficient manner Multi Core Embedded Systems presents a variety of perspectives that elucidate the technical challenges associated with such increased integration of homogeneous processors and heterogeneous multiple cores It offers an analysis that industry engineers and professionals will need to understand the physical details of both software and hardware in embedded architectures as well as their limitations and potential for future growth Discusses the available programming models spread across different abstraction levels The book begins with an overview of the evolution of multiprocessor architectures for embedded applications and discusses techniques for autonomous power management of system level parameters It addresses the use of existing open source and free tools originating from several application domains such as traffic modeling graph theory parallel computing and network

simulation In addition the authors cover other important topics associated with multi core embedded systems such as Architectures and interconnects Embedded design methodologies Mapping of applications   Modeling, Verification and Exploration of Task-Level Concurrency in Real-Time Embedded Systems Filip Thoen,Francky Catthoor,2012-12-06 system is a complex object containing a significant percentage of elec A tronics that interacts with the Real World physical environments humans etc through sensing and actuating devices A system is heterogeneous i e is characterized by the co existence of a large number of components of disparate type and function for example programmable components such as micro processors and Digital Signal Processors DSPs analog components such as AID and D A converters sensors transmitters and receivers Any approach to system design today must include software concerns to be viable In fact it is now common knowledge that more than 70% of the development cost for complex systems such as automotive electronics and communication systems are due to software development In addition this percentage is increasing constantly It has been my take for years that the so called hardware software co design problem is formulated at a too low level to yield significant results in shorten ing design time to the point needed for next generation electronic devices and systems The level of abstraction has to be raised to the Architecture Function co design problem where Function refers to the operations that the system is supposed to carry out and Architecture is the set of supporting components for that functionality The supporting components as we said above are heteroge neous and contain almost always programmable components   **Embedded System Design** Peter Marwedel,2010-11-16 Until the late 1980s information processing was associated with large mainframe computers and huge tape drives During the 1990s this trend shifted toward information processing with personal computers or PCs The trend toward miniaturization continues and in the future the majority of information processing systems will be small mobile computers many of which will be embedded into larger products and interfaced to the physical environment Hence these kinds of systems are called embedded systems Embedded systems together with their physical environment are called cyber physical systems Examples include systems such as transportation and fabrication equipment It is expected that the total market volume of embedded systems will be significantly larger than that of traditional information processing systems such as PCs and mainframes Embedded systems share a number of common characteristics For example they must be dependable efficient meet real time constraints and require customized user interfaces instead of generic keyboard and mouse interfaces Therefore it makes sense to consider common principles of embedded system design Embedded System Design starts with an introduction into the area and a survey of specification models and languages for embedded and cyber physical systems It provides a brief overview of hardware devices used for such systems and presents the essentials of system software for embedded systems like real time operating systems The book also discusses evaluation and validation techniques for embedded systems Furthermore the book presents an overview of techniques for mapping applications to execution platforms Due to the importance of resource efficiency the book also contains a selected set of optimization techniques for

embedded systems including special compilation techniques The book closes with a brief survey on testing Embedded System Design can be used as a text book for courses on embedded systems and as a source which provides pointers to relevant material in the area for PhD students and teachers It assumes a basic knowledge of information processing hardware and software Courseware related to this book is available at http ls12 www cs tu dortmund de marwedel **Source Code Optimization Techniques for Data Flow Dominated Embedded Software** Heiko Falk,Peter Marwedel,2013-03-19 This book focuses on source to source code transformations that remove addressing related overhead present in most multimedia or signal processing application programs This approach is complementary to existing compiler technology What is particularly attractive about the transformation flow pre sented here is that its behavior is nearly independent of the target processor platform and the underlying compiler Hence the different source code trans formations developed here lead to impressive performance improvements on most existing processor architecture styles ranging from RISCs like ARM7 or MIPS over Superscalars like Intel Pentium PowerPC DEC Alpha Sun and HP to VLIW DSPs like TI C6x and Philips TriMedia The source code did not have to be modified between processors to obtain these results Apart from the performance improvements the estimated energy is also significantly reduced for a given application run These results were not obtained for academic codes but for realistic and rep resentative applications all selected from the multimedia domain That shows the industrial relevance and importance of this research At the same time the scientific novelty and quality of the contributions have lead to several excellent papers that have been published in internationally renowned conferences like e g DATE This book is hence of interest for academic researchers both because of the overall description of the methodology and related work context and for the detailed descriptions of the compilation techniques and algorithms **UML for SOC Design** Grant Martin,Wolfgang Müller,2006-07-01 A tutorial approach to using the UML modeling language in system on chip design Based on the DAC 2004 tutorial applicable for students and professionals Contributions by top level international researchers The best work at the first UML for SoC workshop Unique combination of both UML capabilities and SoC design issues Condenses research and development ideas that are only found in multiple conference proceedings and many other books into one place Will be the seminal reference work for this area for years to come **Software and Compilers for Embedded Systems** Henk Schepers,2004-10-29 This volume contains the proceedings of the 8th International Workshop on Software and Compilers for Embedded Systems SCOPES 2004 held in A terdam The Netherlands on September 2 and 3 2004 Initially the workshop was referred to as the International Workshop on Code Generation for Emb ded Systems The rst took place in 1994 in Schlo Dagstuhl Germany From its beginnings the intention of the organizers has been to create an interactive atmosphere in which the participants can discuss and pro t from the assembly of international experts in the eld The name SCOPES has been used since the fourth edition in St Goar G many in1999whenthescopeoftheworkshopwasextendedtoalsocovergeneral issues in embedded software design Since then SCOPES has been held again in St Goar in 2001 Berlin Germany in 2002 Vienna

Austria in 2003 and now in Amsterdam The Netherlands In response to the call for papers almost 50 very strong papers were s mitted from all over the world All submitted papers were reviewed by at least three experts to ensure the quality of the workshop In the end the program committee selected 17 papers for presentation at the workshop These papers are divided into the following categories application speci c co design system and application synthesis data ow analysis data partitioning task scheduling and code generation In addition to the selected contributions the keynote address was delivered by Mike Uhler from MIPS Technologies An abstract of his talk is also included in this volume *System-Level Design Techniques for Energy-Efficient Embedded Systems* Marcus T. Schmitz,Bashir M. Al-Hashimi,Petru Eles,2006-01-16 System Level Design Techniques for Energy Efficient Embedded Systems addresses the development and validation of co synthesis techniques that allow an effective design of embedded systems with low energy dissipation The book provides an overview of a system level co design flow illustrating through examples how system performance is influenced at various steps of the flow including allocation mapping and scheduling The book places special emphasis upon system level co synthesis techniques for architectures that contain voltage scalable processors which can dynamically trade off between computational performance and power consumption Throughout the book the introduced co synthesis techniques which target both single mode systems and emerging multi mode applications are applied to numerous benchmarks and real life examples including a realistic smart phone *Automated Technology for Verification and Analysis* Farn Wang,2004-10-11 It was our great pleasure to hold the 2nd International Symposium onAutomated Te nology on Veri cation and Analysis ATVA in Taipei Taiwan ROC October 31 November3 2004 TheseriesofATVAmeetingsisintendedforthepromotionofrelated research in eastern Asia In the last decade automated technology on veri cation has become the new strength in industry and brought forward various hot research activities in both Europe and USA In comparison easternAsia has been quiet in the forum With more and more IC design houses moving from SiliconValley to easternAsia we believe this is a good time to start cultivating related research activities in the region TheemphasisoftheATVAworkshopseriesisonvariousmechanicalandinformative techniques which can give engineers valuable feedback to fast converge their designs according to the speci cations The scope of interest contains the following research eas model checking theory theorem proving theory state space reduction techniques languages in automated veri cation parametric analysis optimization formal perf mance analysis real time systems embedded systems in nite state systems Petri nets UML synthesis tools and practice in industry **Retargetable Code Generation for Digital Signal Processors** Rainer Leupers,2013-03-09 According to market analysts the market for consumer electronics will con tinue to grow at a rate higher than that of electronic systems in general The consumer market can be characterized by rapidly growing complexities of appli cations and a rather short market window As a result more and more complex designs have to be completed in shrinking time frames A key concept for coping with such stringent requirements is re use Since the re use of completely fixed large hardware blocks is limited to subproblems of system level applications for example MPEG 2

flexible programmable pro cessors are being used as building blocks for more and more designs Processors provide a unique combination offeatures they provide flexibility and re use The processors used in consumer electronics are however in many cases dif ferent from those that are used for screen and keyboard based equipment such as PCs For the consumer market in particular efficiency of the product plays a dominating role Hence processor architectures for these applications are usually highly optimized and tailored towards a certain application domain

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