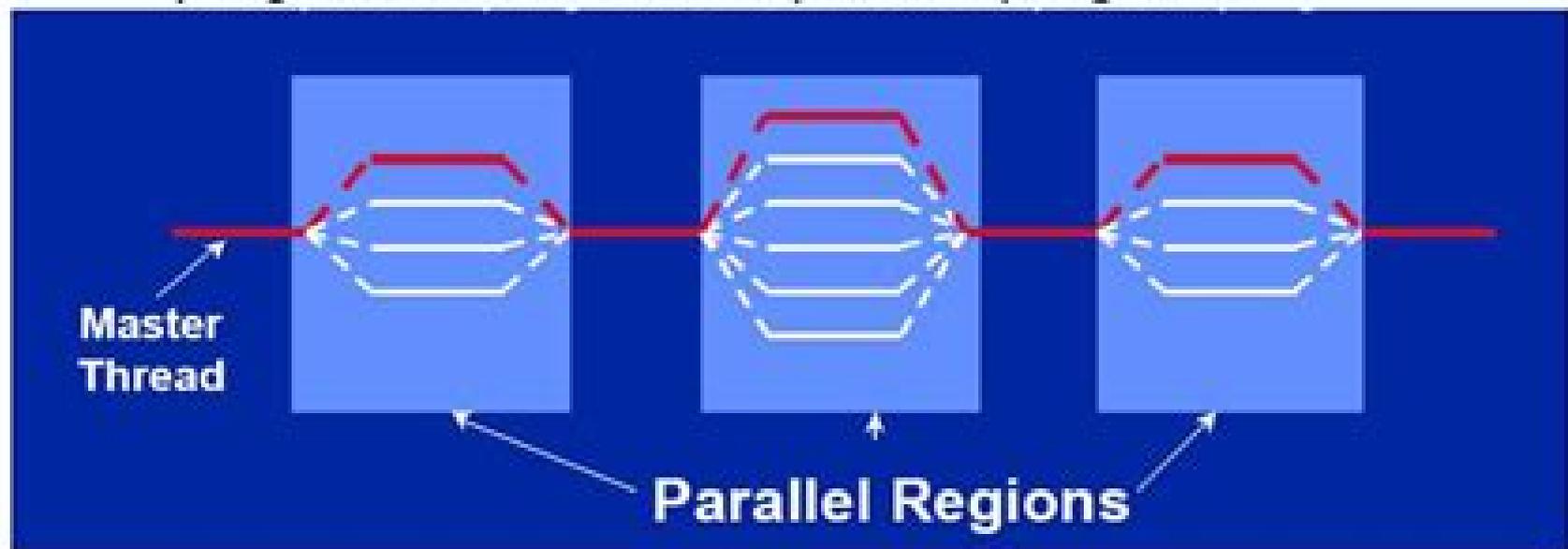


OpenMP: Programming Model

- Fork-Join Parallelism:
 - **Master thread** spawns a **team of threads** as needed.
 - Parallelism is added incrementally: i.e. the sequential program evolves into a parallel program.



Parallel Programming In Openmp

E Durkheim



Parallel Programming In Openmp:

Parallel Programming in OpenMP Rohit Chandra, Ramesh Menon, Leo Dagum, David Kohr, Dror Maydan, Jeff McDonald, 2000-10-11 The rapid and widespread acceptance of shared memory multiprocessor architectures has created a pressing demand for an efficient way to program these systems At the same time developers of technical and scientific applications in industry and in government laboratories find they need to parallelize huge volumes of code in a portable fashion OpenMP developed jointly by several parallel computing vendors to address these issues is an industry wide standard for programming shared memory and distributed shared memory multiprocessors It consists of a set of compiler directives and library routines that extend FORTRAN C and C codes to express shared memory parallelism *Parallel Programming in OpenMP* is the first book to teach both the novice and expert parallel programmers how to program using this new standard The authors who helped design and implement OpenMP while at SGI bring a depth and breadth to the book as compiler writers application developers and performance engineers Designed so that expert parallel programmers can skip the opening chapters which introduce parallel programming to novices and jump right into the essentials of OpenMP Presents all the basic OpenMP constructs in FORTRAN C and C Emphasizes practical concepts to address the concerns of real application developers Includes high quality example programs that illustrate concepts of parallel programming as well as all the constructs of OpenMP Serves as both an effective teaching text and a compact reference Includes end of chapter programming exercises

Using OpenMP Barbara Chapman, Gabriele Jost, Ruud Van Der Pas, 2007-10-12 A comprehensive overview of OpenMP the standard application programming interface for shared memory parallel computing a reference for students and professionals I hope that readers will learn to use the full expressibility and power of OpenMP This book should provide an excellent introduction to beginners and the performance section should help those with some experience who want to push OpenMP to its limits from the foreword by David J Kuck Intel Fellow Software and Solutions Group and Director Parallel and Distributed Solutions Intel Corporation OpenMP a portable programming interface for shared memory parallel computers was adopted as an informal standard in 1997 by computer scientists who wanted a unified model on which to base programs for shared memory systems OpenMP is now used by many software developers it offers significant advantages over both hand threading and MPI *Using OpenMP* offers a comprehensive introduction to parallel programming concepts and a detailed overview of OpenMP *Using OpenMP* discusses hardware developments describes where OpenMP is applicable and compares OpenMP to other programming interfaces for shared and distributed memory parallel architectures It introduces the individual features of OpenMP provides many source code examples that demonstrate the use and functionality of the language constructs and offers tips on writing an efficient OpenMP program It describes how to use OpenMP in full scale applications to achieve high performance on large scale architectures discussing several case studies in detail and offers in depth troubleshooting advice It explains how OpenMP is translated into explicitly multithreaded code providing a valuable

behind the scenes account of OpenMP program performance Finally Using OpenMP considers trends likely to influence OpenMP development offering a glimpse of the possibilities of a future OpenMP 3.0 from the vantage point of the current OpenMP 2.5 With multicore computer use increasing the need for a comprehensive introduction and overview of the standard interface is clear Using OpenMP provides an essential reference not only for students at both undergraduate and graduate levels but also for professionals who intend to parallelize existing codes or develop new parallel programs for shared memory computer architectures

Basic Parallel Programming with OpenMP Thomas la Cour Jansen,2015-05-16 This book provides the basic description of writing parallel programmes using the OpenMP language Simple examples related to common problems faced in scientific applications are given The reader is assumed to know either C or FORTRAN The book was written for a two hour crash course on OpenMP programming for master and PhD students in Chemistry and Physics

OpenMP Shared Memory Parallel Programming Michael J. Voss,2007-03-05 The refereed proceedings of the International Workshop on OpenMP Applications and Tools WOMPAT 2003 held in Toronto Canada in June 2003 The 20 revised full papers presented were carefully reviewed and selected for inclusion in the book The papers are organized in sections on tools and tool technology OpenMP implementations OpenMP experience and OpenMP on clusters

Parallel Programming in OpenMP Rohit Chandra,2001 Software Programming Techniques

OpenMP Shared Memory Parallel Programming Rudolf Eigenmann,2001-07-18 This book constitutes the refereed proceedings of the International Workshop on OpenMP Applications and Tools WOMPAT 2001 held in West Lafayette IN USA in July 2001 The 15 full papers presented were carefully reviewed and revised for inclusion in the volume The book presents a state of the art overview on OpenMP shared memory parallel programming The papers are organized in topical sections on benchmarking compiler implementation and optimization tools and tool technology OpenMP experience NUMA machines and clusters and OpenMP extensions

Parallel Programming in C with MPI and OpenMP Michael Jay Quinn,2003

Openmp Shared Memory Parallel Programming Michael J. Voss,2014-01-15

OpenMP in a New Era of Parallelism Rudi Eigenmann,Bronis R. Supinski,2008-04-25 OpenMP is a widely accepted standard application programming interface API for high level shared memory parallel programming in Fortran C and C Since its introduction in 1997 OpenMP has gained support from most high performance compiler and hardware vendors Under the direction of the OpenMP Architecture Review Board ARB the OpenMP specification has evolved including the recent release of Specification 3.0 Active research in OpenMP compilers runtime systems tools and environments drives its evolution including new features such as tasking The community of OpenMP researchers and developers in academia and industry is united under cOMPunity www.compunity.org This organization has held workshops on OpenMP around the world since 1999 the European Workshop on OpenMP EWOMP the North American Workshop on OpenMP Applications and Tools WOMPAT and the Asian Workshop on OpenMP Experiences and Implementation WOMPEI attracted annual audiences from academia and industry The International Workshop on

OpenMP IWOMP consolidated these three workshop series into a single annual international event that rotates across the previous workshop sites The first IWOMP meeting was held in Eugene Oregon USA IWOMP 2006 took place in Reims France and IWOMP 2007 in Beijing China Each workshop drew over 60 participants from research and industry throughout the world IWOMP 2008 continued the series with technical papers panels tutorials and OpenMP status reports The first IWOMP workshop was organized under the auspices of cOMPunity

OpenMP Shared Memory Parallel Programming Rudolf Eigenmann, Michael J. Voss, 2003-05-15 This book contains the presentations given at the Workshop on OpenMP Applications and Tools WOMPAT 2001 The workshop was held on July 30 and 31 2001 at Purdue University West Lafayette Indiana USA It brought together designers users and researchers of the OpenMP application programming interface OpenMP has emerged as the standard for shared memory parallel programming For the first time it is possible to write parallel programs that are portable across the majority of shared memory parallel computers WOMPAT 2001 served as a forum for all those interested in OpenMP and allowed them to meet share ideas and experiences and discuss the latest developments of OpenMP and its applications WOMPAT 2001 was co sponsored by the OpenMP Architecture Review Board ARB It followed a series of workshops on OpenMP including WOMPAT 2000 EWOMP 2000 and WOMPEI 2000 For WOMPAT 2001 we solicited papers formally and published them in the form of this book The authors submitted extended abstracts which were reviewed by the program committee All submitted papers were accepted The authors were asked to prepare a final paper in which they addressed the reviewers comments The proceedings in the form of this book were created in time to be available at the workshop In this way we hope to have brought out a timely report of ongoing OpenMP related research and development efforts as well as ideas for future improvements

OpenMP Shared Memory Parallel Programming Matthias S. Müller, 2008-05-21 This book constitutes the thoroughly refereed post workshop proceedings of the First and the Second International Workshop on OpenMP IWOMP 2005 and IWOMP 2006 held in Eugene OR USA and in Reims France in June 2005 and 2006 respectively The first part of the book presents 16 revised full papers carefully reviewed and selected from the IWOMP 2005 program and organized in topical sections on performance tools compiler technology run time environment applications as well as the OpenMP language and its evaluation In the second part there are 19 papers of IWOMP 2006 fully revised and grouped thematically in sections on advanced performance tuning aspects of code development applications and proposed extensions to OpenMP

Shared Memory Parallel Programming with Open MP Barbara M. Chapman, 2005-01-25 This book contains the Proceedings of the 5th Workshop on OpenMP Applications and Tools WOMPAT 2004 which took place at the University of Houston Houston Texas on May 17 and 18 2004 Previous workshops in this series took place in Toronto Canada Fairbanks Alaska Purdue Indiana and San Diego California The purpose of the workshop was to bring together users and developers of the OpenMP API for shared memory parallel programming to disseminate their ideas and experiences and discuss the latest developments in OpenMP and its application

To support this aim the program comprised a mixture of invited talks from research and industry experience reports and submitted papers the last of which are presented in this volume A tutorial introduction to OpenMP was held at the same location on May 18 by Ruud van der Pas from Sun Microsystems Further a two day lab session called OMPlab was held immediately following the workshop and the tutorial on May 19 and 20 and was attended by both novice and advanced users Many of the hardware vendors and several researchers gave in depth tutorials on their software and made their systems available to both novice and advanced attendees during OMPlab Contributors to the WOMPAT 2004 OMPlab included IBM Intel Sun the University of Tennessee NASA the University of Greenwich Cornell University the University of Oregon and the University of Houston The OpenMP API is a widely accepted standard for high level shared memory parallel programming that was put forth by a consortium of vendors in 1997 Beyond Loop Level Parallelism in OpenMP: Accelerators, Tasking and More Mitsuhiro Sato, Toshihiro Hanawa, Matthias S. Müller, Barbara Chapman, Bronis R. de Supinski, 2010-06-16 Annotation This book constitutes the refereed proceedings of the 6th International Workshop on OpenMP IWOMP 2010 held in Tsukuba City Japan in June 2010 The papers are organized in topical sections on Runtime and Optimization Proposed Extensions to OpenMP Scheduling and Performance as well as Hybrid Programming and Accelerators with OpenMP *Shared Memory Parallel Programming With OpenMP* Barbara M. Chapman, 2005 Parallel Programming in MPI and OpenMP Victor Eijkhout, 2017-11-27 This is a textbook about parallel programming of scientific application on large computers using MPI and OpenMP **An Introduction to Parallel Programming** Peter Pacheco, Matthew Malensek, 2021-08-27 An Introduction to Parallel Programming Second Edition presents a tried and true tutorial approach that shows students how to develop effective parallel programs with MPI Pthreads and OpenMP As the first undergraduate text to directly address compiling and running parallel programs on multi core and cluster architecture this second edition carries forward its clear explanations for designing debugging and evaluating the performance of distributed and shared memory programs while adding coverage of accelerators via new content on GPU programming and heterogeneous programming New and improved user friendly exercises teach students how to compile run and modify example programs Takes a tutorial approach starting with small programming examples and building progressively to more challenging examples Explains how to develop parallel programs using MPI Pthreads and OpenMP programming models A robust package of online ancillaries for instructors and students includes lecture slides solutions manual downloadable source code and an image bank New to this edition New chapters on GPU programming and heterogeneous programming New examples and exercises related to parallel algorithms **Patterns for Parallel Programming** Timothy G. Mattson, Beverly Sanders, Berna Massingill, 2004-09-15 The Parallel Programming Guide for Every Software Developer From grids and clusters to next generation game consoles parallel computing is going mainstream Innovations such as Hyper Threading Technology HyperTransport Technology and multicore microprocessors from IBM Intel and Sun are accelerating the movement s growth

Only one thing is missing programmers with the skills to meet the soaring demand for parallel software That s where Patterns for Parallel Programming comes in It s the first parallel programming guide written specifically to serve working software developers not just computer scientists The authors introduce a complete highly accessible pattern language that will help any experienced developer think parallel and start writing effective parallel code almost immediately Instead of formal theory they deliver proven solutions to the challenges faced by parallel programmers and pragmatic guidance for using today s parallel APIs in the real world Coverage includes Understanding the parallel computing landscape and the challenges faced by parallel developers Finding the concurrency in a software design problem and decomposing it into concurrent tasks Managing the use of data across tasks Creating an algorithm structure that effectively exploits the concurrency you ve identified Connecting your algorithmic structures to the APIs needed to implement them Specific software constructs for implementing parallel programs Working with today s leading parallel programming environments OpenMP MPI and Java Patterns have helped thousands of programmers master object oriented development and other complex programming technologies With this book you will learn that they re the best way to master parallel programming too [Introduction to Parallel Computing](#) Roman Trobec,Boštjan Slivnik,Patricio Bulić,Borut Robič,2018-09-27

Advancements in microprocessor architecture interconnection technology and software development have fueled rapid growth in parallel and distributed computing However this development is only of practical benefit if it is accompanied by progress in the design analysis and programming of parallel algorithms This concise textbook provides in one place three mainstream parallelization approaches Open MPP MPI and OpenCL for multicore computers interconnected computers and graphical processing units An overview of practical parallel computing and principles will enable the reader to design efficient parallel programs for solving various computational problems on state of the art personal computers and computing clusters Topics covered range from parallel algorithms programming tools OpenMP MPI and OpenCL followed by experimental measurements of parallel programs run times and by engineering analysis of obtained results for improved parallel execution performances Many examples and exercises support the exposition **Parallel Computing** Christian Bischof,2008 ParCo2007 marks a quarter of a century of the international conferences on parallel computing that started in Berlin in 1983 The aim of the conference is to give an overview of the developments applications and future trends in high performance computing for various platforms **Towards Object-Oriented OpenMP Parallel Programming** Xing Fan,2017 With the coming of the data driven era software applications are becoming increasingly more computationally demanding High performance computing is more important than ever Since Moore s Law has reached its limit parallelization is the key technique to reduce computational time However writing parallel programs is still notoriously difficult because it involves a great deal of expert knowledge as well as programming and tuning efforts Even though there are already many tools and languages addressing this challenge it is still rare to see parallel techniques employed in the software industry

OpenMP is a programming interface standard that facilitates writing multi threaded applications It adopts the fork join model allowing programs to be parallelized incrementally By adding directives a sequential program can be compiled to a parallel version without extra coding effort The good usability of OpenMP makes it widely used in many practical parallel programs however it has been discovered that OpenMP is not closely incorporated with object oriented programming concepts This thesis addresses that a good parallel programming model should be closely incorporated with software design principles especially object oriented programming concepts This research identifies the gaps between object oriented programming and OpenMP and provides solutions to combine these two models in harmony The ultimate aim of this research is to help programmers write parallel code in a more efficient and less error prone way Throughout the thesis Pyjama is demonstrated which is a research project developed as an extended OpenMP parallel programming model for high level object oriented languages The implementation is dedicated to Java The first important aspect contributed in this thesis is the proposal of enhanced exception handling within OpenMP for object oriented languages The research identifies existing problems and proposes a robust exception handling mechanism to solve the problems The evaluation shows that the new approach provides an elegant and robust mechanism without causing any performance degradation The second significant contribution of this research is the development of an asynchronous model for event driven programming This model is regarded as compensation for the fork join model making Pyjama more powerful for event driven programming patterns New OpenMP directives are proposed to endow sequential code with an asynchronous execution nature This idea has been tested in different event driven environments and shows the effectiveness of boosting the performance of event handling In order to analyze the performance of an event driven application a mathematical model for parallel event driven programming is developed This model reveals how factors such as asynchronization scale and parallelization scale influence event driven performance This theoretical guidance can help programmers to tune the performance for the event driven system and make proper decisions on choosing the number of asynchronous workers and the number of parallel threads for each event handler Extensive experimental tests and benchmarks have been conducted and the results show that Pyjama is both a useful and productive tool for parallelizing Java code The benchmarks show the Pyjama directives are effective in parallelizing work and that the speedups are comparable to C C OpenMP implementations Different aspects of the evaluation demonstrate that using the new proposed virtual target programming model is efficient to boost the performance of event driven applications

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