

An Introduction to Parallel Programming Solutions, Chapter 1

Jinyoung Choi and Peter Pacheco

February 1, 2011

- ```
1. quotient = n / p;
 remainder = n % p;
 if (my_rank < remainder) {
 my_n_count = quotient + 1;
 my_first_i = my_rank + my_n_count;
 } else {
 my_n_count = quotient;
 my_first_i = my_rank + my_n_count + remainder;
 }
 my_last_i = my_first_i + my_n_count;
```
- We are assigning blocks of elements to cores in order (the first  $n/p$  elements to core 0, the next  $n/p$  elements to core 1, so on). So, for example, if  $n = 12$  and  $p = 4$ , core 0 spends 12 milliseconds in the call to `Compute_next_value` ( $i = 0, 1, 2$ ), core 1 spends 30 milliseconds ( $i = 3, 4, 5$ ), core 2 spends 48 milliseconds ( $i = 6, 7, 8$ ), and core 3 spends 66 milliseconds ( $i = 9, 10, 11$ ). So clearly this assignment will do a very poor job of load balancing.

A better approach uses a *cyclic* assignment of the work to the cores:

```
/* assign[c][j] is the jth value of i assigned to core c */
/* work[c] is the total amount of work assigned to core c */
c = j = 0;
for (i = 0; i < n; i++) {
 work[c] += 2*(i+1);
 assign[c][j] = i;
 c = (c + 1) % p;
 if (c == 0) j++;
}
```

# Parallel Programming Solution Manual

**Thomas Rauber, Gudula Rünger**



## **Parallel Programming Solution Manual:**

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.

**Analysis and Design of Parallel Algorithms** S. Lakshminarayanaiah, 1989-09-01      **Numerical Solution of Partial Differential Equations on Parallel Computers** Are Magnus Bruaset, Aslak Tveito, 2006-03-05 Since the dawn of computing, the quest for a better understanding of Nature has been a driving force for technological development. Groundbreaking achievements by great scientists have paved the way from the abacus to the supercomputing power of today. When trying to replicate Nature in the computer's silicon test tube, there is a need for precise and computable process descriptions. The scientific fields of Mathematics and Physics provide a powerful vehicle for such descriptions in terms of Partial Differential Equations (PDEs). Formulated as such equations, physical laws can become subject to computational and analytical studies. In the computational setting, the equations can be discretized for efficient solution on a computer, leading to valuable tools for simulation of natural and man-made processes. Numerical solution of PDE-based mathematical models has been an important research topic over centuries and will remain so for centuries to come. In the context of computer-based simulations, the quality of the computed results is directly connected to the model's complexity and the number of data points used for the computations. Therefore, computational scientists tend to, even the largest and most powerful computers, they can get access to, either by increasing the size of the data sets or by introducing new model terms that make the simulations more realistic, or a combination of both. Today, many important simulation problems cannot be solved by one single computer but call for parallel computing.

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 Introduction to Parallel Computing Wesley P. Petersen, Peter Arbenz, 2004 This is a practical student guide to scientific computing on parallel computers working up from a hardware instruction level to shared memory machines and finally to distributed memory machines Parallel Programming Thomas Rauber, Gudula Runger, 2013-06-13 Innovations in hardware architecture like hyper threading or multicore processors mean that parallel computing resources are available for inexpensive desktop computers In only a few years many standard software products will be based on concepts of parallel programming implemented on such hardware and the range of applications will be much broader than that of scientific computing up to now the main application area for parallel computing Rauber and Runger take up these recent developments in processor architecture by giving detailed descriptions of parallel programming techniques that are necessary for developing efficient programs for multicore processors as well as for parallel cluster systems and supercomputers Their book is structured in three main parts covering all areas of parallel computing the architecture of parallel systems parallel programming models and environments and the implementation of efficient application algorithms The emphasis lies on parallel programming techniques needed for different architectures For this second edition all chapters have been carefully revised The chapter on architecture of parallel systems has been updated considerably with a greater emphasis on the architecture of multicore systems and adding new material on the latest developments in computer architecture Lastly a completely new chapter on general purpose GPUs and the corresponding programming techniques has been added The main goal of the book is to present parallel programming techniques that can be used in many situations for a broad range of application areas and which enable the reader to develop correct and efficient parallel programs Many examples and exercises are provided to show how to apply the techniques The book can be used as both a textbook for students and a reference book for professionals The material presented has been used for courses in parallel programming at different universities for many years **Solution of Partial Differential Equations on Vector and Parallel Computers** James M. Ortega, Robert G. Voigt, 1985-01-01 This volume reviews in the context of partial differential equations algorithm development that has been specifically aimed at computers that exhibit some form of parallelism Emphasis is on the solution of PDEs because these are typically the problems that generate high computational demands The authors discuss architectural features of these computers inasmuch as they influence algorithm performance and provide insight into algorithm characteristics that allow effective use of hardware **Parallel Computing** D.J Evans, C.N Sutti, 1989-05-01 *Parallel Computing Methods Algorithms and Applications* presents a collection of original papers presented at the international meeting on parallel processing methods algorithms and applications at Verona Italy in September 1989 *Parallel Computing Technologies - Proceedings Of The International Conference* Nikolay N Mirenkov, 1991-08-24 The proceedings of this UNESCO supported conference

consist of papers covering new trends and experiences in parallel computing technologies Emphasis is made on the practical aspects of parallel programming especially all aspects of the applications of parallel computing technologies hardware languages and software tools for parallel processing operating systems general architecture concepts enabling technologies performance measurements and the teaching of parallel processing technology

**Parallel Scientific Computing and Optimization** Raimondas Ciegis, David Henty, Bo Kågström, Julius Žilinskas, 2008-10-08 Parallel Scientific Computing and Optimization introduces new developments in the construction analysis and implementation of parallel computing algorithms This book presents 23 self contained chapters including survey chapters and surveys written by distinguished researchers in the field of parallel computing Each chapter is devoted to some aspects of the subject parallel algorithms for matrix computations parallel optimization management of parallel programming models and data with the largest focus on parallel scientific computing in industrial applications This volume is intended for scientists and graduate students specializing in computer science and applied mathematics who are engaged in parallel scientific computing

Advanced Environments, Tools, and Applications for Cluster Computing Dan Grigoras, Alex Nicolau, Bernard Tournel, Bertil Folliot, 2003-08-01 Started by small group of well known scientists with the aim of sharing knowledge experiences and results on all aspects of cluster computing the initiative of a workshop on cluster computing received more attention after IFIP WG 10.3 and IEEE Romania Section accepted our request for sponsorship Moreover the application for a NATO ARW grant was successful leading to a greater interest in the workshop In this respect we have to say that we chose Romania in order to attract scientists from Central and Eastern European countries and improve the cooperation in the region in the field of cluster computing We had an extremely short time to organize the event but many people joined us and enthusiastically contributed to the process The success of the workshop is wholly due to the hard work of the organizing committee members of the program committee key speakers speakers from industry and authors of accepted papers The workshop consisted of invited and regular paper presentations followed by discussions on many important current and emerging topics ranging from scheduling and load balancing to grids The key speakers devoted their time and efforts to presenting the most interesting results of their research groups and we all thank them for this All papers were peer reviewed by two or three reviewers

**Parallel and Distributed Processing** Jose Rolim, 1998-03-18 This book constitutes the refereed proceedings of 10 international workshops held in conjunction with the merged 1998 IPPS SPDP symposia held in Orlando Florida US in March April 1998 The volume comprises 118 revised full papers presenting cutting edge research or work in progress In accordance with the workshops covered the papers are organized in topical sections on reconfigurable architectures run time systems for parallel programming biologically inspired solutions to parallel processing problems randomized parallel computing solving combinatorial optimization problems in parallel PC based networks of workstations fault tolerant parallel and distributed systems formal methods for parallel programming embedded HPC systems and applications and parallel and distributed real

time systems     **Parallel Computing Technologies** Victor Malyshkin,2009-08-04 This book constitutes the proceedings of the 10th International Conference on Parallel Computing Technologies PaCT 2009 held in Novosibirsk Russia on August 31 September 4 2009 The 34 full papers presented together with 2 invited papers and 7 poster papers were carefully reviewed and selected from 72 submissions The papers are organized in topical sections on models of parallel computing methods and algorithms fine grained parallelism parallel programming tools and support and applications     Scientific and Technical Aerospace Reports ,1995     *Computers and Artificial Intelligence* ,1996     **Computational Technologies** Petr N.

Vabishchevich,2014-12-11 This book discusses questions of numerical solutions of applied problems on parallel computing systems Nowadays engineering and scientific computations are carried out on parallel computing systems which provide parallel data processing on a few computing nodes In the development of up to date applied software this feature of computers must be taken into account for the maximum efficient usage of their resources In constructing computational algorithms we should separate relatively independent subproblems in order to solve them on a single computing node

**Object Oriented Methods for Interoperable Scientific and Engineering Computing** Michael E.

Henderson,Christopher Radcliff Anderson,Stephen L. Lyons,1999-01-01 Contains papers presented at the October 1998 SIAM Workshop on Object Oriented Methods for Interoperable Scientific and Engineering Computing that covered a variety of topics and issues related to designing and implementing computational tools for science and engineering     Applied Parallel Computing Bo Kagström,Erik Elmroth,Jack Dongarra,Jerzy Wasniewski,2007-09-22 This book constitutes the

thoroughly refereed post proceedings of the 8th International Workshop on Applied Parallel Computing PARA 2006 It covers partial differential equations parallel scientific computing algorithms linear algebra simulation environments algorithms and applications for blue gene L scientific computing tools and applications parallel search algorithms peer to peer computing mobility and security algorithms for single chip multiprocessors     **Progress in Landslide Research and Technology,**

**Volume 1 Issue 1, 2022** Kyoji Sassa,Kazuo Konagai,Binod Tiwari,Željko Arbanas,Shinji Sassa,2023-01-10 This open access book provides an overview of the progress in landslide research and technology and is part of a book series of the International Consortium on Landslides ICL The book provides a common platform for the publication of recent progress in landslide research and technology for practical applications and the benefit for the society contributing to the Kyoto Landslide Commitment 2020 which is expected to continue up to 2030 and even beyond to globally promote the understanding and reduction of landslide disaster risk as well as to address the 2030 Agenda Sustainable Development Goals

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