

Task Clustering and Scheduling for Distributed Memory Parallel Architectures

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Abstract—This paper addresses the problem of scheduling parallel programs represented as directed acyclic task graphs for execution on distributed memory parallel architectures. Because of the high communication overhead in existing parallel machines, a crucial step in scheduling is task clustering, the process of coarsening fine grain tasks into single coarser ones so that the overall execution time is minimized. The task clustering problem is NP-hard, even when the number of processors is unbounded and task duplication is allowed. A simple greedy algorithm is presented for this problem which, for a task graph with arbitrary granularity, produces a schedule whose makespan is at most twice optimal. Indeed, the quality of the schedule improves as the granularity of the task graph becomes larger. For example, if the granularity is at least 1/2, the makespan of the schedule is at most 5/3 times optimal. For a task graph with n tasks and r inter-task communication constraints, the algorithm runs in $O(n \log n + r)$ time, which is n times faster than the currently best known algorithm for this problem. Similar algorithms are developed that produce: (1) optimal schedules for coarse grain graphs; (2) 2-optimal schedules for trees with no task duplication; and (3) optimal schedules for coarse grain trees with no task duplication.

Index Terms—Program task graph, task granularity, task scheduling, distributed memory architectures, approximation algorithms.

1 INTRODUCTION

THE efficiency of execution of parallel programs on distributed memory parallel architectures critically depends on the strategies used to partition the program into modules or tasks and to schedule these tasks onto physical processors. In a distributed memory architecture, tasks mapped to different processors communicate solely by message-passing. In existing parallel machines, the message-passing overhead is quite large, typically in excess of 500 instruction cycles [6]. This imposes a minimum threshold on task granularity below which performance degrades significantly. To avoid performance degradation, one solution would be to coalesce several fine grain tasks into single coarser grain tasks. This reduces the communication overhead but increases the processing time of the (now coarser grain) tasks. Because of this inherent tradeoff, the goal is to determine the optimal task granularity that results in the fastest overall execution time.

The aforementioned problem, called grain packing in [10] or task clustering in [7], is well studied. The most commonly used program model is a weighted directed acyclic graph (DAG) in which the node weights represent task execution times and the arc weights represent communication times between tasks when mapped to different processors. Re-

searchers have investigated two versions of this problem, depending on whether or not task duplication (or recomputation) is allowed. In task clustering without duplication, the tasks are partitioned into disjoint sets or clusters and exactly one copy of each task is scheduled. In task clustering with duplication, a task may have several copies belonging to different clusters, each of which is independently scheduled. In general, for the same DAG, task clustering with duplication produces a schedule with a smaller makespan (i.e., total execution time) than when task duplication is not allowed.

For example, for the fork DAG shown in Fig. 1a, the optimal makespan with no task duplication is 16 while that with task duplication is 11. Note that when two communicating tasks are mapped to the same processor, the communication delay becomes zero because the data transfer is effectively a local memory write followed by a local memory read.

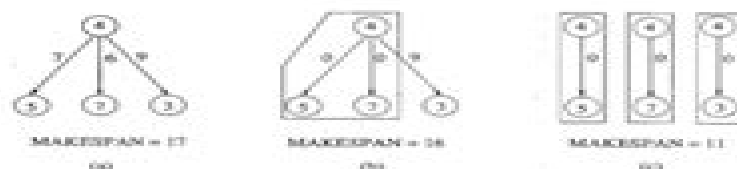


Fig. 1. (a) A fork DAG; (b) optimal clustering with no task duplication; (c) optimal clustering with task duplication.

Task clustering—with or without task duplication—is an NP-hard problem [3], [15], [17]. Consequently, practical solutions will have to sacrifice optimality for the sake of

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Task Scheduling In Parallel And Distributed Systems

M Carnoy



Task Scheduling In Parallel And Distributed Systems:

Task Scheduling in Parallel and Distributed Systems Hesham El-Rewini, Theodore Gyle Lewis, Hesham H. Ali, 1994 El Rewini and Lewis were among the first researchers to recognize the problem of resource allocation scheduling inherent in parallel and distributed programs Here they offer a clear explanation of the problems methods to solve the problems under a variety of conditions and an evaluation of the goodness of the solutions **Parallel and Distributed Computing**

Handbook Albert Y. Zomaya, 1996 With over 1 000 pages and a wealth of illustrations and data tables this handbook offers readers the first information source with the scope to encompass the parallel and distributed computing revolution Written by an international team of experts the book summarizes the current state of the art interprets the most promising trends and spotlights commercial applications **Task Scheduling for Parallel Systems** Oliver Sinnen, 2007-05-04 A new model for task scheduling that dramatically improves the efficiency of parallel systems Task scheduling for parallel systems can become a quagmire of heuristics models and methods that have been developed over the past decades The author of this innovative text cuts through the confusion and complexity by presenting a consistent and comprehensive theoretical framework along with realistic parallel system models These new models based on an investigation of the concepts and principles underlying task scheduling take into account heterogeneity contention for communication resources and the involvement of the processor in communications For readers who may be new to task scheduling the first chapters are essential They serve as an excellent introduction to programming parallel systems and they place task scheduling within the context of the program parallelization process The author then reviews the basics of graph theory discussing the major graph models used to represent parallel programs Next the author introduces his task scheduling framework He carefully explains the theoretical background of this framework and provides several examples to enable readers to fully understand how it greatly simplifies and at the same time enhances the ability to schedule The second half of the text examines both basic and advanced scheduling techniques offering readers a thorough understanding of the principles underlying scheduling algorithms The final two chapters address communication contention in scheduling and processor involvement in communications Each chapter features exercises that help readers put their new skills into practice An extensive bibliography leads to additional information for further research Finally the use of figures and examples helps readers better visualize and understand complex concepts and processes Researchers and students in distributed and parallel computer systems will find that this text dramatically improves their ability to schedule tasks accurately and efficiently *Task Scheduling Problems for Parallel and Distributed Systems*, 1999 **Special Issue: Task Scheduling Problems for Parallel and Distributed Systems**

Evripidis Bampis, 1999 **Task Scheduling for Parallel Systems** Oliver Sinnen, 2007-05-18 A new model for task scheduling that dramatically improves the efficiency of parallel systems Task scheduling for parallel systems can become a quagmire of heuristics models and methods that have been developed over the past decades The author of this innovative

text cuts through the confusion and complexity by presenting a consistent and comprehensive theoretical framework along with realistic parallel system models. These new models based on an investigation of the concepts and principles underlying task scheduling take into account heterogeneity, contention for communication resources, and the involvement of the processor in communications. For readers who may be new to task scheduling, the first chapters are essential. They serve as an excellent introduction to programming parallel systems and they place task scheduling within the context of the program parallelization process. The author then reviews the basics of graph theory, discussing the major graph models used to represent parallel programs. Next, the author introduces his task scheduling framework. He carefully explains the theoretical background of this framework and provides several examples to enable readers to fully understand how it greatly simplifies and at the same time enhances the ability to schedule. The second half of the text examines both basic and advanced scheduling techniques, offering readers a thorough understanding of the principles underlying scheduling algorithms. The final two chapters address communication contention in scheduling and processor involvement in communications. Each chapter features exercises that help readers put their new skills into practice. An extensive bibliography leads to additional information for further research. Finally, the use of figures and examples helps readers better visualize and understand complex concepts and processes. Researchers and students in distributed and parallel computer systems will find that this text dramatically improves their ability to schedule tasks accurately and efficiently.

Parallel and Distributed Processing and Applications Minyi Guo, 2003. This book constitutes the refereed proceedings of the International Symposium on Parallel and Distributed Processing and Applications ISPA 2003 held in Aizu, Japan, in July 2003. The 30 revised full papers and 9 revised short papers presented together with abstracts of 4 keynotes were carefully reviewed and selected from numerous submissions. The papers are organized in topical sections on applications on Web-based and intranet systems, compiler and optimization techniques, network routing, performance evaluation of parallel systems, wireless communication and mobile computing, parallel topology, data mining and evolutionary computing, image processing and modeling, network security and database and multimedia systems.

Topics in Parallel and Distributed Computing Sushil K. Prasad, Anshul Gupta, Arnold Rosenberg, Alan Sussman, Charles Weems, 2018-09-29. This book introduces beginning undergraduate students of computing and computational disciplines to modern parallel and distributed programming languages and environments, including map-reduce, general-purpose graphics processing units (GPUs), and graphical user interfaces (GUI) for mobile applications. The book also guides instructors via selected essays on what and how to introduce parallel and distributed computing topics into the undergraduate curricula, including quality criteria for parallel algorithms and programs, scalability, parallel performance, fault tolerance, and energy efficiency analysis. The chapters designed for students serve as supplemental textual material for early computing core courses, which students can use for learning and exercises. The illustrations, examples, and sequences of smaller steps to build larger concepts are also tools that could be inserted into existing instructor

material The chapters intended for instructors are written at a teaching level and serve as a rigorous reference to include learning goals advice on presentation and use of the material within early and advanced undergraduate courses Since Parallel and Distributed Computing PDC now permeates most computing activities imparting a broad based skill set in PDC technology at various levels in the undergraduate educational fabric woven by Computer Science CS and Computer Engineering CE programs as well as related computational disciplines has become essential This book and others in this series aim to address the need for lack of suitable textbook support for integrating PDC related topics into undergraduate courses especially in the early curriculum The chapters are aligned with the curricular guidelines promulgated by the NSF IEEE TCPP Curriculum Initiative on Parallel and Distributed Computing for CS and CE students and with the CS2013 ACM IEEE Computer Science Curricula

Scheduling for Parallel Processing Maciej Drozdowski, 2010-03-14 Overview and Goals This book is dedicated to scheduling for parallel processing Presenting a research eld as broad as this one poses considerable dif culties Scheduling for parallel computing is an interdisciplinary subject joining many elds of science and te nology Thus to understand the scheduling problems and the methods of solving them it is necessary to know the limitations in related areas Another dif culty is that the subject of scheduling parallel computations is immense Even simple search in bibliographical databases reveals thousands of publications on this topic The versity in understanding scheduling problems is so great that it seems impossible to juxtapose them in one scheduling taxonomy Therefore most of the papers on scheduling for parallel processing refer to one scheduling problem resulting from one way of perceiving the reality Only a few publications attempt to arrange this eld of knowledge systematically In this book we will follow two guidelines One guideline is a distinction tween scheduling models which comprise a set of scheduling problems solved by dedicated algorithms Thus the aim of this book is to present scheduling models for parallel processing problems de ned on the grounds of certain scheduling models and algorithms solving the scheduling problems Most of the scheduling problems are combinatorial in nature Therefore the second guideline is the methodology of computational complexity theory

In this book we present four examples of scheduling models We will go deep into the models problems and algorithms so that after acquiring some understanding of them we will attempt to draw conclusions on their mutual relationships

Grid and Distributed Computing Tai-hoon Kim, Hojjat Adeli, Hyun-seob Cho, Osvaldo Gervasi, Stephen S. Yau, Byeong-Ho Kang, Javier Garcia Villalba, 2011-11-29 This book constitutes the refereed proceedings of the International Conference GDC 2011 held as Part of the Future Generation Information Technology Conference FGIT 2011 Jeju Island Korea in December 2011 The papers presented were carefully reviewed and selected from numerous submissions and focus on the various aspects of grid and distributed computing

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Table of Contents Task Scheduling In Parallel And Distributed Systems

1. Understanding the eBook Task Scheduling In Parallel And Distributed Systems
 - The Rise of Digital Reading Task Scheduling In Parallel And Distributed Systems
 - Advantages of eBooks Over Traditional Books
2. Identifying Task Scheduling In Parallel And Distributed Systems
 - Exploring Different Genres
 - Considering Fiction vs. Non-Fiction
 - Determining Your Reading Goals
3. Choosing the Right eBook Platform
 - Popular eBook Platforms
 - Features to Look for in an Task Scheduling In Parallel And Distributed Systems
 - User-Friendly Interface
4. Exploring eBook Recommendations from Task Scheduling In Parallel And Distributed Systems
 - Personalized Recommendations
 - Task Scheduling In Parallel And Distributed Systems User Reviews and Ratings
 - Task Scheduling In Parallel And Distributed Systems and Bestseller Lists
5. Accessing Task Scheduling In Parallel And Distributed Systems Free and Paid eBooks
 - Task Scheduling In Parallel And Distributed Systems Public Domain eBooks
 - Task Scheduling In Parallel And Distributed Systems eBook Subscription Services
 - Task Scheduling In Parallel And Distributed Systems Budget-Friendly Options

6. Navigating Task Scheduling In Parallel And Distributed Systems eBook Formats
 - ePub, PDF, MOBI, and More
 - Task Scheduling In Parallel And Distributed Systems Compatibility with Devices
 - Task Scheduling In Parallel And Distributed Systems Enhanced eBook Features
7. Enhancing Your Reading Experience
 - Adjustable Fonts and Text Sizes of Task Scheduling In Parallel And Distributed Systems
 - Highlighting and Note-Taking Task Scheduling In Parallel And Distributed Systems
 - Interactive Elements Task Scheduling In Parallel And Distributed Systems
8. Staying Engaged with Task Scheduling In Parallel And Distributed Systems
 - Joining Online Reading Communities
 - Participating in Virtual Book Clubs
 - Following Authors and Publishers Task Scheduling In Parallel And Distributed Systems
9. Balancing eBooks and Physical Books Task Scheduling In Parallel And Distributed Systems
 - Benefits of a Digital Library
 - Creating a Diverse Reading Collection Task Scheduling In Parallel And Distributed Systems
10. Overcoming Reading Challenges
 - Dealing with Digital Eye Strain
 - Minimizing Distractions
 - Managing Screen Time
11. Cultivating a Reading Routine Task Scheduling In Parallel And Distributed Systems
 - Setting Reading Goals Task Scheduling In Parallel And Distributed Systems
 - Carving Out Dedicated Reading Time
12. Sourcing Reliable Information of Task Scheduling In Parallel And Distributed Systems
 - Fact-Checking eBook Content of Task Scheduling In Parallel And Distributed Systems
 - Distinguishing Credible Sources
13. Promoting Lifelong Learning
 - Utilizing eBooks for Skill Development
 - Exploring Educational eBooks
14. Embracing eBook Trends
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