

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.

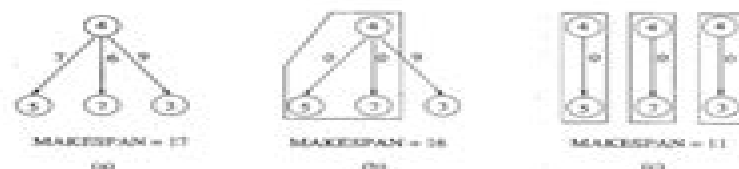


Fig. 1. (a) A fork DAG; (b) optimal clustering with no task duplication; (c) optimal clustering with task duplication.

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 For Parallel Systems

**Eitan Frachtenberg, Uwe
Schwiegelshohn**



Task Scheduling For Parallel Systems:

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

Optimal Task Scheduling for Parallel Systems Using State-space Search Michael Orr, 2020 It is of ever increasing importance that programs are able to take full advantage of the parallel systems on which they are run Task scheduling is the problem of producing a schedule for a program such that the tasks which make up the program are each allocated to a specific processor and in a specific order which minimises the overall run time This problem is NP hard so that the amount of work required grows exponentially as the number of tasks is increased Although the NP hardness of the problem usually discourages optimal solving an optimal schedule can give a significant advantage in time critical systems or applications where a single schedule is reused many times Previous research with branch and bound for optimal task scheduling has shown promise with small task graphs being competitive with other methods The state space model used in that work has an obvious drawback of allowing many duplicate states to occur in the state space which theoretically causes a large amount of additional time and memory to be required This thesis proposes a new state space model called Allocation Ordering AO which improves on older models through its carefully designed lack of duplicate states AO divides the task scheduling problem into two distinct sub problems allocation and ordering which are handled in

sequence within the state space Experimental evaluation confirms the benefits of the model The benefits of AO s lack of duplicate states for other branch and bound algorithms are then explored specifically variants with interesting properties such as parallelisation and low memory requirements We then investigate its applicability to more complex task scheduling models the model is first adapted to allow optimal task scheduling with related heterogeneous processors and then to allow optimal task scheduling with task duplication The success of the adaptation of AO shows its flexibility and suggests it may have wide applicability to variants of the task scheduling problem and potentially other problems

Task Scheduling for Multi-core and Parallel Architectures Quan Chen,Minyi Guo,2017-11-23 This book presents task scheduling techniques for emerging complex parallel architectures including heterogeneous multi core architectures warehouse scale datacenters and distributed big data processing systems The demand for high computational capacity has led to the growing popularity of multicore processors which have become the mainstream in both the research and real world settings Yet to date there is no book exploring the current task scheduling techniques for the emerging complex parallel architectures Addressing this gap the book discusses state of the art task scheduling techniques that are optimized for different architectures and which can be directly applied in real parallel systems Further the book provides an overview of the latest advances in task scheduling policies in parallel architectures and will help readers understand and overcome current and emerging issues in this field

Job Scheduling Strategies for Parallel Processing Eitan Frachtenberg,Uwe Schwiegelshohn,2009-10-05 This book constitutes the revised papers of the 14th International Workshop on Job Scheduling Strategies for Parallel Processing JSSPP 2009 which was held in Rome Italy in May 2009 The 15 revised papers presented were carefully reviewed and selected from 25 submissions The papers cover all current issues of job scheduling strategies for parallel processing this year the conference had an increasing trend towards heterogeneous and multi core architectures

Love for Association-Fodbold. Udg. af Dansk Boldspil-Union ,1899 Compiler Optimizations for Scalable Parallel Systems Santosh Pande,Dharma P. Agrawal,2003-06-29 Scalable parallel systems or more generally distributed memory systems offer a challenging model of computing and pose fascinating problems regarding compiler optimization ranging from language design to run time systems Research in this area is foundational to many challenges from memory hierarchy optimizations to communication optimization This unique handbook like monograph assesses the state of the art in the area in a systematic and comprehensive way The 21 coherent chapters by leading researchers provide complete and competent coverage of all relevant aspects of compiler optimization for scalable parallel systems The book is divided into five parts on languages analysis communication optimizations code generation and run time systems This book will serve as a landmark source for education information and reference to students practitioners professionals and researchers interested in updating their knowledge about or active in parallel computing

Advances in Grid and Pervasive Computing Paolo Bellavista,Ruay-Shiung Chang,Han-Chieh Chao,Shin-Feng Lin,Peter M.A. Sloot,2010-04-23 This book constitutes the

proceedings of the 5th International Conference CPC 2010 held in Hualien Taiwan in May 2010 The 67 full papers are carefully selected from 184 submissions and focus on topics such as cloud and Grid computing peer to peer and pervasive computing sensor and mobile networks service oriented computing resource management and scheduling Grid and pervasive applications semantic Grid and ontologies mobile commerce and services

Transputer Applications and Systems '94 A. De Gloria, M. R. Jane, D. Marini, 1994 Proceedings Parallel Computing

Scheduling for Parallel Processing Maciej Drozdowski, 2010-03-14 Overview and Goals This book is dedicated to scheduling for parallel processing Presenting a research field as broad as this one poses considerable difficulties Scheduling for parallel computing is an interdisciplinary subject joining many fields of science and technology Thus to understand the scheduling problems and the methods of solving them it is necessary to know the limitations in related areas Another difficulty is that the subject of scheduling parallel computations is immense Even simple search in bibliographical databases reveals thousands of publications on this topic The diversity 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 field of knowledge systematically In this book we will follow two guidelines One guideline is a distinction between 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 defined 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

Process-Aware Systems Jian Cao, Lijie Wen, Xiao Liu, 2015-02-02 This book constitutes the refereed proceedings of the First International Workshop on Process Aware Systems PAS 2014 held in Shanghai China in October 2014 The 5 revised full papers and 3 short papers were carefully reviewed and selected from 14 submissions The papers are organized in topical sections on process modeling and comparison workflow scheduling and resource allocation scientific workflow verification workflow applications

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