Distributed Constraint-Based Local Search

Laurent Michel[1], Andrew See[1], and Pascal Van Hentenryck[2]

[1] University of Connecticut, Storrs, CT 06269-2155
[2] Brown University, Box 1910, Providence, RI 02912

Abstract. Distributed computing is increasingly important at a time when the doubling of the number of transistors on a processor every 18 months no longer translates in a doubling of speed but instead a doubling of the number of cores. Unfortunately, it also places significant conceptual and implementation burden on programmers. This paper aims at addressing this challenge for constraint-based local search (CBLS), whose search procedures typically exhibit inherent parallelism stemming from multistart, restart, or population-based techniques whose benefits have been demonstrated both experimentally and theoretically. The paper presents abstractions that allows distributed CBLS programs to be close to their sequential and parallel counterparts, keeping the conceptual and implementation overhead of distributed computing minimal. A preliminary implementation in COMET exhibits significant speed-ups in constraint satisfaction and optimization applications. The implementation also scales well with the number of machines. Of particular interest is the observation that generic abstractions of CBLS and CP, such as models and solutions, and advanced control structures such as events and closures, play a fundamental role to keep the distance between sequential and distributed CBLS programs small. As a result, the abstractions directly apply to CP programs using multistarts or restarts procedures.

1 Introduction

Moore's law [13], i.e., the prediction that the number of transistors per square inch on integrated circuits would double every 18 months used to translate into a doubling of speed. While it marches on, these additional transistors are now devoted to doubling the number of cores and gave rise to commodity multiprocessors. As a result, parallel and distributed computing now offer reasonably cheap alternatives to speed up computationally intense applications. However, parallel and distributed computing also places significant conceptual and implementation burden on programmers. The computational model adds another dimension in conceptual complexity (i.e., the need to handle multiple threads of executions) and programming abstractions are often expressed at a lower level of abstraction than their sequential counterparts. This has slowed the use of distributed computing, even for applications that exhibit natural parallelism as is typically the case in constraint satisfaction and optimization.

The parallelism exhibited in constraint satisfaction and optimization is often coarse-grained, requires minimal synchronization and coordination, and may

Constraint Based Local Search

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Constraint Based Local Search:

   Constraint-based Local Search Pascal Van Hentenryck,Laurent Michel,2005 The ubiquity of combinatorial optimization problems in our society is illustrated by the novel application areas for optimization technology which range from supply chain management to sports tournament scheduling Over the last two decades constraint programming has emerged as a fundamental methodology to solve a variety of combinatorial problems and rich constraint programming languages have been developed for expressing and combining constraints and specifying search procedures at a high level of abstraction Local search approaches to combinatorial optimization are able to isolate optimal or near optimal solutions within reasonable time constraints This book introduces a method for solving combinatorial optimization problems that combines constraint programming and local search using constraints to describe and control local search and a programming language COMET that supports both modeling and search abstractions in the spirit of constraint programming After an overview of local search including neighborhoods heuristics and metaheuristics the book presents the architecture and modeling and search components of constraint based local search and describes how constraint based local search is supported in COMET The book describes a variety of applications arranged by meta heuristics It presents scheduling applications along with the background necessary to understand these challenging problems The book also includes a number of satisfiability problems illustrating the ability of constraint based local search approaches to cope with both satisfiability and optimization problems in a uniform fashion   *Extracting and Exploiting Interaction Information in Constraint-based Local Search* Alastair Neil Andrew,2014 Local Search is a simple and effective approach for solving complex constrained combinatorial problems To maximise performance Local Search can utilise problem specific information and be hybridised with other algorithms in an often intricate fashion This results in algorithms that are tightly coupled to a single problem and difficult to characterise experience gained whilst solving one problem may not be applicable in another Even if it is the translation can be a non trivial task offering little opportunity for code reuse Constraint Programming CP and Linear Programming LP can be applied to many of the same combinatorial problems as Local Search but do not exhibit these restrictions They use a different paradigm one where a problem is captured as a general model and then solved by a independent solver Improvements to the underlying solver can be harnessed by any model The CP community show signs of moving Local Search in this direction Constraint Based Local Search CBLS strives to achieve the CP ideal of Model Search CBLS provides access to the performance benefits of Local Search without paying the price of being specific to a single problem This thesis explores whether information to improve the performance of CBLS can be automatically extracted and exploited without compromising the independence of the search and model To achieve these goals we have created a framework built upon the CBLS language COMET This framework primarily focusses on the interface between two core components the constraint model and the search neighbourhoods Neighbourhoods define the behaviour of a Local Search and how it can traverse the

search space By separating the neighbourhoods from the model we are able to create an independent analysis component The first aspect of our work is to uncover information about the interactions between the constraint model and the search neighbourhoods The second goal is to look at how information about the behaviour of neighbourhoods with respect to a set of constraints can be used within the search process In particular we concentrate on enhancing a form of Local Search called Variable Neighbourhood Search VNS allowing it to make dynamic decisions based upon the current search state The resulting system retains the domain independence of model based solution technologies whilst being able to configure itself automatically to a given problem This reduces the level of expertise required to adopt CBLS and provides users with another potential tool for tackling their constraint problems **Principles and Practice of Constraint Programming -- CP 2011** Jimmy Lee,2011-09-01 This book constitutes the refereed proceedings of the 17th International Conference on Principles and Practice of Constraint Programming CP 2011 held in Perugia Italy September 12 16 2011 The 51 revised full papers and 7 short papers presented together with three invited talks were carefully reviewed and selected from 159 submissions The papers are organized in topical sections on algorithms environments languages models and systems applications such as decision making resource allocation and agreement technologies Principles and Practice of Constraint Programming - CP 2009 Ian P. Gent,2009-09-07 This volume contains the papers presented at CP 2009 The 15th International Conference on Principles and Practice of Constraint Programming It was held from September 20 24 2009 at the Rectory of the New University of Lisbon Portugal Everyone involved with the conference thanks our sponsors for their support There were 128 submissions to the research track of which 53 were accepted for a rate of 41 4% Each submission was reviewed by three reviewers with a small number of additional reviews obtained in exceptional cases Each review waseitherbyaProgrammeCommitteemember orbyacolleagueinvitedtohelp by a committee member thanks to their particular expertise Papers submitted as long papers were accepted at full length or not at all It is important to note that papers submitted as short papers were held to the same high standards of qualityas long papers There is thus no distinction in these proceedings between long and short papers except of course the number of pages they occupy As it happens the acceptancerates of short and long papers wereverysimilar indeed Therewere13submissionstotheapplicationtrack ofwhich8wereaccepted fora rateof61 5% Papersunderwentthe samereviewprocessasregularpapers and there was not a separate committee for reviewing application track papers However papers in the application track were not required to be original or novel research but to be original and novel as an application of constraints **Handbook of Heuristics** Rafael Martí,Panos M. Pardalos,Mauricio G.C. Resende,2025-11-17 The handbook of heuristics consists of five main parts search strategies local search metaheuristics analysis and implementations and applications They cover from search methods and methodological aspects such as matheuristics the exciting field in which mathematical programming is combined with heuristics to applications that provide the practitioner with a description of some relevant optimization issues in a number of

specific application areas such as scheduling vehicle routing or network optimization The first edition of the Handbook of Heuristics was published in 2018 and contained 47 chapters In this second edition the authors revised 30 of them to include new developments in the area that appeared in the last few years In particular the reader may find 14 chapters in search strategies including a new chapter on deep learning 4 in local search 14 in metaheuristics 5 in analysis and implementations and 24 in applications The inclusion of 14 new chapters makes this second edition even more comprehensive totaling 61 chapters **Springer Handbook of Computational Intelligence** Janusz Kacprzyk,Witold Pedrycz,2015-05-28 The Springer Handbook for Computational Intelligence is the first book covering the basics the state of the art and important applications of the dynamic and rapidly expanding discipline of computational intelligence This comprehensive handbook makes readers familiar with a broad spectrum of approaches to solve various problems in science and technology Possible approaches include for example those being inspired by biology living organisms and animate systems Content is organized in seven parts foundations fuzzy logic rough sets evolutionary computation neural networks swarm intelligence and hybrid computational intelligence systems Each Part is supervised by its own Part Editor s so that high quality content as well as completeness are assured *Integration of AI and OR Techniques in Constraint Programming* Laurent Michel,2015-04-15 This book constitutes the proceedings of the 12th International Conference on the Integration of Artificial Intelligence AI and Operations Research OR Techniques in Constraint Programming CPAIOR 2015 held in Barcelona Spain in May 2015 The 29 papers presented together with 8 short papers in this volume were carefully reviewed and selected from 90 submissions The purpose of the conference series is to bring together researchers in the fields of Constraint Programming Artificial Intelligence and Operations Research to explore ways of solving hard and large scale combinatorial optimization problems that emerge in various industrial domains Pooling the skills and strengths of this diverse group of researchers has proved extremely effective and valuable during the past decade leading to improvements and cross fertilization between the three fields as well as breakthrough for actual applications **Trends in Constraint Programming** Frédéric Benhamou,Narendra Jussien,Barry A. O'Sullivan,2013-05-06 This title brings together the best papers on a range of topics raised at the annual International Conference on Principles and Practice of Constraint Programming This conference provides papers and workshops which produce new insights concepts and results which can then be used by those involved in this area to develop their own work **Integration of Constraint Programming, Artificial Intelligence, and Operations Research** Bistra Dilkina,2024-05-27 This book constitutes the proceedings of the 21st International Conference on the Integration of Constraint Programming Artificial Intelligence and Operations Research CPAIOR 2024 held in Uppsala Sweden during May 28 31 2024 The 33 full papers and the 9 short papers presented in the proceedings were carefully reviewed and selected from a total of 104 submissions The content of the papers focus on new techniques or applications in the area and foster the integration of techniques from different fields dealing with large and complex problems

Proceedings of the Twenty-second AAAI Conference on Artificial Intelligence ,2007   *Principles and Practice of Constraint Programming* ,2005   Stochastic Algorithms ,2001   **Efficient and Expressive Extensions of Constraint-Based Temporal Reasoning** Michael David Moffitt,2007   INFORMS Annual Meeting Institute for Operations Research and the Management Sciences. National Meeting,2009   **Constraint-Based Agents** Alexander Nareyek,2001-05-30 Autonomous agents have become a vibrant research and development topic in recent years attracting activity and attention from various areas The basic agent concept incorporates proactive autonomous units with goal directed behaviour and communication capabilities The book focuses on autonomous agents that can act in a goal directed manner under real time constraints and incomplete knowledge being situated in a dynamic environment where resources may be restricted To satisfy such complex requirements the author improves combines and applies results from areas like planning constraint programming and local search The formal framework developed is evaluated by application to the field of computer games which fit the problem context very well since most of them are played in real time and provide a highly interactive environment where environmental situations are changing rapidly   **Integrating Constraint Programming, Artificial Intelligence, and Operations Research** Torsten Fahle,2002   **Proceedings** American Association for Artificial Intelligence,2006   *ACM SIGPLAN notices* ,1991   **INFORMS Conference Program** Institute for Operations Research and the Management Sciences. National Meeting,2000   PCK50 Dina Q. Goldin,2003

Whispering the Secrets of Language: An Psychological Journey through **Constraint Based Local Search**

In a digitally-driven world where screens reign supreme and immediate interaction drowns out the subtleties of language, the profound strategies and psychological nuances concealed within words frequently go unheard. Yet, set within the pages of **Constraint Based Local Search** a fascinating literary treasure blinking with organic emotions, lies an extraordinary journey waiting to be undertaken. Published by a skilled wordsmith, this charming opus attracts readers on an introspective trip, delicately unraveling the veiled truths and profound impact resonating within ab muscles fabric of every word. Within the psychological depths with this poignant review, we will embark upon a sincere exploration of the book is core subjects, dissect their charming writing type, and succumb to the powerful resonance it evokes heavy within the recesses of readers hearts.

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