THE UNIVERSITY OF ADELAIDE

DOCTORAL THESIS

Diversity Optimization and Parameterized Analysis of Heuristic Search Methods for Combinatorial Optimization Problems

Author:
Wanru Gao

Principle Supervisor:
Prof. Frank Neumann

Co-Supervisor:
Dr. Markus Wagner

A thesis submitted in fulfillment of the requirements for the degree of Doctor of Philosophy

in the

Optimisation and Logistics
School of Computer Science

December 8, 2016

Declaration of Authorship

I, Wanru Gao, declare that this thesis titled, "Diversity Optimization and Parameterized Analysis of Heuristic Search Methods for Combinatorial Optimization Problems" and the work presented in it are my own.

- I certify that this work contains no material which has been accepted for the award of any other degree or diploma in my name, in any university or other tertiary institution and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text. In addition, I certify that no part of this work will, in the future, be used in a submission in my name, for any other degree or diploma in any university or other tertiary institution without the prior approval of the University of Adelaide and where applicable, any partner institution responsible for the joint-award of this degree.
- I give consent to this copy of my thesis, when deposited in the University Library, being made available for loan and photocopying, subject to the provisions of the Copyright Act 1968.
- I also give permission for the digital version of my thesis to be made available on the web, via the University's digital research repository, the Library Search and also through web search engines, unless permission has been granted by the University to restrict access for a period of time.

Signed:

Date:

"Courage is not the absence of fear, but rather the assessment that something else is more important than fear."

Franklin D. Roosevelt

THE UNIVERSITY OF ADELAIDE

Abstract

Faculty of Engineering, Computer & Mathematical Science

School of Computer Science

Doctor of Philosophy

Diversity Optimization and Parameterized Analysis of Heuristic Search Methods for Combinatorial Optimization Problems

by Wanru Gao

Heuristic search algorithms belong to the most successful approaches for many combinatorial optimization problems which have wide real world applications in various areas. The heuristic algorithms usually provide solutions with acceptable quality in reasonable timeframe which is different from exact algorithms. Fixed-parameter approach provides a way for understanding how and why heuristic methods perform well for prominent combinatorial optimization problems. In this thesis, there are two main topics discussed.

Firstly, we integrate the well-known branching approach for the classical combinatorial optimization problem, namely minimum vertex cover problem, to a local search algorithm and compare its performance with the core component of the state-of-the-art algorithm. After that, we investigate how well-performing local search algorithms for small or medium size instances can be scaled up to solve massive input instances. A parallel kernelization technique is proposed which is motivated by the assumption that huge graphs are composed of several easy to solve components while the overall problem is hard to solve.

Using evolutionary algorithms to generate a diverse set of solutions where all of them meet certain quality criteria has gained increasing interests in recent years. As the second section, we put forward an evolutionary algorithm which allows us to maximize the diversity over a set of solutions with good quality and then focus on the theoretical analysis of the algorithm to provide understanding of how evolutionary algorithms maximize the diversity of a population and guarantee the quality of all solutions at the same time. Then the idea is extended to evolving hard/easy optimization problem instances with diverse feature values. The feature-based analysis of heuristic search algorithms plays an important role in understanding the behaviour of the algorithm and our results show good classification of the problem instances in terms of hardness based on different combinations of feature values.

Acknowledgements

I would like to express my special appreciation and thanks to many people who have encouraged, inspired and helped me in the PhD study. Without their generous help, it will be impossible for this thesis to be finished. I would like to thank

- First of all, to my supervisor Frank Neumann. It has been an honour to be one of his PhD students. He has provided me great support, guidance and inspiration in doing research. I appreciate all his contributions of time, ideas and funding to make my PhD study inspiring and productive.
- To my co-supervisor Markus Wagner for his kind advices and encouragement in both researching and teaching.
- To all of the co-authors of the papers, Mojgan Pourhassan, Samadhi Nallaperuma, Benjamin Doerr, Tobias Friedrich and Timo Kötzing. I learned a lot in collaborations with others.
- To all the researchers and practitioners whose work is referred in my study for their great efforts in previous research. None of the studies is able to be conducted without the foundations set by other researchers.
- To all reviewers of the papers and the examiners of this thesis for their valuable comments.
- To the past and present group members in our research group that I have had the pleasure to work with, Bradley Alexander, Mingyu Guo, Sergey Polyakovskiy, Samadhi Nallaperuma, Mojgan Pourhassan, Shayan Poursoltan, Junhua Wu, Feng Shi, Aneta Neumann and other fellow students in the HDR office. It has been a great experience to work in the research group of Optimisation and Logistics in School of Computer Science. Sharing ideas in both research and daily life helps me progress a lot.
- To the School of Computer Science, Genetic and Evolutionary Computation Conference (GECCO) and the International Conference on Parallel Problem Solving from Nature (PPSN) for supporting my conference travel and research visit.
- To everyone in the group of Algorithm Engineering in Hasso Plattner Institute, Potsdam, Germany for sharing research ideas and providing feedback on my research during my stay with them.
- To all of the teachers who have taught or directed me in different areas for encouraging me to keep studying.
- Lastly, to my beloved famliy, especially my mom Jing and my dad Mingli, my relatives and friends for supporting me all the time in both life and research.

Contents

List of Figures

List of Tables

List of Abbreviations

OMM	**O**ne **M**in **M**ax
RLS	**R**andomized **L**ocal **S**earch
EA	**E**volutionary **A**lgorithm
GA	**G**enetic **A**lgorithm
NP	**N**ondeterministic **P**olynomial
TSP	**T**raveling **S**alesman **P**roblem
MVC	**M**inimum **V**ertex **C**over
MOP	**M**ulti-objective **O**ptimization **P**roblem
MOEA	**M**ulti-**O**bjective **E**volutionary **A**lgorithm
w.l.o.g.	**w**ithout **l**oss **o**f **g**enerality
i.e.	**i**d **e**st (that is)
e.g.	**e**xempli **g**ratia (for example)

To my beloved parents. . .