



Universiteit  
Leiden  
The Netherlands

## Many objective optimization and complex network analysis

Maulana, A.

### Citation

Maulana, A. (2018, December 5). *Many objective optimization and complex network analysis*. Retrieved from <https://hdl.handle.net/1887/67537>

Version: Not Applicable (or Unknown)

License: [Licence agreement concerning inclusion of doctoral thesis in the Institutional Repository of the University of Leiden](#)

Downloaded from: <https://hdl.handle.net/1887/67537>

**Note:** To cite this publication please use the final published version (if applicable).

Cover Page



Universiteit Leiden



The handle <http://hdl.handle.net/1887/67537> holds various files of this Leiden University dissertation.

**Author:** Maulana, A.

**Title:** Many objective optimization and complex network analysis

**Issue Date:** 2018-12-05

# Many Objective Optimization and Complex Network Analysis

Asep Maulana



# Many Objective Optimization and Complex Network Analysis

Proefschrift

ter verkrijging van

de graad van Doctor aan de Universiteit Leiden,

op gezag van Rector Magnificus prof. mr. C.J.J.M. Stolker,

volgens besluit van het College voor Promoties

te verdedigen op Woensdag 5 December 2018

klokke 12.30 uur

door

Asep Maulana

geboren te Bandung, Indonesia, in 1974

Promotiecommissie

Promotoren	Prof. dr. T.H.W. Bäck	
	Dr. M.T.M.Emmerich	
Overige leden	Prof. dr. Aske Plaat	
	Dr. Frank Takes	
	Prof. dr. Fons Verbeek	
	Dr. Diego Garlaschelli	LION, Leiden University
	Prof. dr. Budi Ruchjana	Padjadjaran Univerity
	Prof. dr. Jing Liu	Xidian University

Copyright © 2018 Asep Maulana All Right Reserved

ISBN: 978-94-6375-227-5

Het onderzoek beschreven in dit proefschrift is uitgevoerd aan het Leiden Institute of Advanced Computer Science (LIACS), Universiteit Leiden.

This research is financially supported by the Indonesian Endowment Fund for Education (LPDP)

Printed by: Ridderprint BV | [www.ridderprint.nl](http://www.ridderprint.nl).

# Contents

1	Introduction	1
1.1	Background . . . . .	1
1.2	Research Goal and Contribution of this Thesis . . . . .	2
1.3	Thesis Outline . . . . .	3
2	Preliminaries	9
2.1	Multi-Objective and Many-Objective Optimization . . . . .	9
2.2	Networks . . . . .	10
2.2.1	Community Detection . . . . .	11
2.2.2	Network Centrality . . . . .	12
2.2.3	Multiplex Networks . . . . .	13
2.3	Matrix Correlation Analysis . . . . .	14
3	Community Detection for Reducing Complexity of Many Objective Optimization	19
3.1	Introduction . . . . .	19
3.2	Problem definition . . . . .	20
3.3	Related Work . . . . .	21
3.4	Workflow and Algorithms . . . . .	23
3.5	Experimental Analysis . . . . .	26
3.5.1	Problem with 10 Objectives . . . . .	27
3.5.2	Problem with 30 and 50 objectives . . . . .	29
3.5.3	Limitations of the Approach . . . . .	31
3.6	Summary . . . . .	32
4	Community Detection in NK-Landscapes -An Empirical Study of Complexity Transitions in Interactive Networks	37
4.1	Approach . . . . .	41
4.2	Results . . . . .	42
4.3	Summary . . . . .	45

5	Modularity Maximization in Multiplex Network Analysis Using Many-Objective Optimization	55
5.1	Introduction . . . . .	55
5.2	Related Work . . . . .	56
5.3	Many Objective Optimization Approach to Community Detection in Complex Networks . . . . .	56
5.4	Network Analysis Method . . . . .	57
5.5	Case Study and Analysis . . . . .	58
5.5.1	Analysis on Synthesized Multiplex Networks . . . . .	59
5.5.2	Economic Trade Multiplex Network Analysis . . . . .	60
5.6	Summary . . . . .	62
6	Towards Many-Objective Optimization of Eigenvector Centrality in Multiplex Networks	69
6.1	Introduction . . . . .	69
6.2	Related Work . . . . .	70
6.3	Many-Objective Optimization of Network Centrality in Multiplex Networks . . . . .	71
6.4	Case Study and Implementation . . . . .	72
6.4.1	Analysis on Artificial Multiplex Networks . . . . .	72
6.4.2	Analysis on Trade Economic Multiplex Networks . . . . .	73
6.5	Summary . . . . .	79
7	Immunization of Networks Using Genetic Algorithms and Multi-Objective Metaheuristics	83
7.1	Introduction . . . . .	83
7.2	Netshield Algorithm . . . . .	86
7.3	Problem Specific Genetic Algorithm . . . . .	86
7.3.1	Discussion of the method . . . . .	86
7.3.2	Comparison to Netshield Plus . . . . .	87
7.4	Multi-Objective Node Immunization . . . . .	90
7.4.1	Multi-objective Metaheuristics . . . . .	95
7.4.2	Empirical Results . . . . .	97
7.5	Summary . . . . .	98



8	Conclusions and Outlook	101
8.1	Conclusions . . . . .	101
8.1.1	Outlook . . . . .	104
	Bibliography	106
	Samenvatting	113
	Summary	117
	About the Author	121