

A New ACO Framework for Optimization with Application in Power System Problems

A THESIS

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by

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Dedicated to
My Mother

Declaration by the Research Scholar

I hereby declare that the entire work embodied in this Thesis is the result of investigations carried out by me in the School of Basic Science, Indian Institute of Technology Mandi, under the supervision of Dr. Manoj Thakur, and that it has not been submitted elsewhere for any degree or diploma. In keeping with the general practice, due acknowledgments have been made wherever the work described is based on the finding of other investigators.

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Declaration by the Research Advisor

I hereby certify that the entire work in this Thesis has been carried out by Anand Kumar, under my supervision in the School of Basic Science, Indian Institute of Technology Mandi, and that no part of it has been submitted elsewhere for any Degree or Diploma

Signature:

Name of the Guide: **Dr. Manoj Thakur**

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Abstract

Ant colony optimization (ACO) is a nature inspired population-based strategy widely used to solve optimization problems. ACO algorithms have been applied to solve many real-life problems from a wide area of applications. The performance of ACO algorithms shows their competitiveness and applicability in solving real-world optimization problems. ACO algorithms were originally developed to solve combinatorial optimization problems. Combinatorial optimization problems belong to the category of problems where each decision variables assume its state from a finite set of states. In the last decade, many attempts have been made to apply ACO algorithms for solving continuous optimization problems. Continuous optimization problems are problems where the decision variables assume a real value within the predefined limits. However, all the available ACO algorithms have a tendency to converge at suboptimal points. Also, minimal effort has been made to explore the ability of ACO algorithms in solving constrained optimization problems, that is, optimization problems where the feasible region is reduced and even may be broken into feasible subregions due to certain restrictions are known as constraints. In this work, a novel strategy is proposed to extend ACO algorithm, so that it can be applied to solve large scale continuous optimization problems, constrained optimization problems, and complex real-life problems. Firstly, we demonstrate the extension of ACO to solve unconstrained continuous optimization problems. We explain the proposed algorithm, discuss and analyze the different design components. Along with that, we show various testing and simulations results. We check the performance of the proposed algorithm by comparing its results on standard benchmark problems with other state-of-the-art algorithms available in the literature applied to solve considered benchmark problems. Finally, we investigate how our algorithm performs on eight unconstrained real-life problems, coming from the various fields of applications. On the basis of the outcome of performance analysis of proposed ACO on unconstrained continuous optimization problems, we discuss the design choices made to make the proposed algorithm capable of tackling constrained optimization problems. We incorporate various constrained handling techniques available in the literature with the proposed ACO and analyze and compare their performances. Finally, the performance of the proposed algorithm is investigated on complex constrained real-life problems coming from the engineering design. The first real-life problem is model

order reduction problem in which the complexity of the complex dynamical system is reduced in such a way that their input-output behavior is as much preserved as possible. The next application is the problem of most economical generation of demanded power, known as Economic Load Dispatch (ELD) problem. The third and last application is the problem of secure power distribution in the presence of distributed generators (DGs) using overcurrent relay. In this application directional overcurrent relays (DOCRs) are coordinated in such a way that the time taken by relays to isolate the fault line from the rest of the system as soon as possible.

Original Contributions

The following is a summary of contributions of the present work:

- **ACO based framework for unconstrained continuous optimization problems:** One of the most remarkable contributions of this work is an extension of ACO to continuous domains with the novel ant's interaction model. We present the fundamental ideas, discuss the proposed ACO based framework and analyze and compare its performance on standard benchmark functions.
- **Application of the framework on real-life problems:** We analyze the performance of the framework on some small as well as high dimensional unconstrained real-life problems. The performance of the framework is compared with various other algorithms applied to solve these problems. We show that the proposed framework outperforms all the other algorithms considered for the performance comparison for all the included problems.
- **Extension of proposed framework for constrained optimization problems**
Extending the general idea of the framework, we further incorporate various constraint handling strategies so that the extended version of the framework is capable of handling constrained problems. We scrutinize its performance using standard benchmark problems from literature.
- **Application of the modified framework on real-life optimization problems from engineering:** We apply an extended version of the framework to solve three real-life constrained optimization problems from electrical engineering. We analyze the performance and applicability of the framework by comparing its results with the results of various methods available in the literature.

Contents

Declaration by the Research Scholar	iv
Declaration by the Research Advisor	v
Acknowledgements	vi
Abstract	viii
Original Contributions	x
1 Introduction	1
1.1 Optimization problems	1
1.2 Global optimization algorithm	2
1.3 Nature Inspired Algorithm (NIA) for optimization	4
1.3.1 Evolutionary algorithm (EA)	4
1.3.2 Swarm Intelligence algorithm (SIA)	5
1.4 Ant Colony Optimization (ACO) algorithms	5
1.5 Ant colony based algorithms for combinatorial optimization problems	6
1.5.1 Ant system	6
1.5.2 Ant colony system (ACS)	8
1.5.3 Rank based ant system	9
1.5.4 Max-min ant system	10
1.5.5 Population based ant colony optimization (PB-ACO)	10
1.5.6 EigenAnt	11
1.6 Ant colony algorithms for continuous domain	12
1.6.1 CACO	12

1.6.2	CACS	12
1.6.3	ACO_R	13
1.6.4	$DACO_R$	14
1.6.5	Incremental ACO_R with local search ($IACO_R - LS$)	15
1.6.6	Unified ACO_R (UACOR)	16
1.7	Motivation and objectives of the thesis	16
1.7.1	Motivation behind the real-life problems considered to solve	17
1.8	Assumptions	17
1.9	Organization of the thesis	18
2	An ACO Framework for Solving Unconstrained Continuous Optimization Problems	20
2.1	Proposed algorithmic framework for continuous ACO	21
2.1.1	Population initialization	21
2.1.2	New tour construction	21
2.1.3	Selection of tours (population) for next iteration	25
2.1.4	Termination conditions	26
2.2	ACO algorithms with double Pareto and Laplace distribution based interaction schemes	26
2.2.1	Double Pareto distribution based ant's interaction (ACO-DPD)	29
2.2.2	Laplace distribution based ants interaction (ACO-LD)	31
2.3	Illustration of ACO-LD algorithm using Himmelblau's function	34
2.4	Performance analysis of ACO-DPD and ACO-LD on test suite I	40
2.4.1	Pairwise performance comparison	41
2.4.2	Performance comparison using performance index	46
2.4.3	Overall performance of the ACO-DPD and ACO-LD algorithms on test suite I	47
2.5	Performance analysis of ACO-DPD and ACO-LD on test suite II	49
2.5.1	Performance Analysis	50
2.5.2	Overall Performance of ACO-DPD and ACO-LD algorithms on test suite II	58
2.5.3	Convergence behavior of the ACO-DPD and ACO-LD on test suite II	61

2.6	Conclusions	64
3	Strategies for performance improvement of proposed ACO framework	69
3.1	Introducing additional diversity mechanisms	70
3.1.1	First approach	70
3.1.2	Second approach	71
3.2	Experimental setup and performance analysis	72
3.2.1	Performance analysis of mACO-LD on test suite I	72
3.2.2	Performance analysis of mACO-LD on test suite II	74
3.2.3	Overall Performance	82
3.2.4	Effect of introducing diversity mechanisms	84
3.3	Application of mACO-LD on real-life problems	90
3.3.1	Performance analysis of mACO-LD on real-life problems	93
3.4	Conclusions	96
4	Model order reduction using mACO-LD	97
4.1	Problem Formulation of MOR problem	99
4.1.1	ISE	99
4.1.2	IRE	100
4.1.3	Objective Function	100
4.1.4	Method to derive a reduced second order system of a given higher order system	100
4.2	Results And Discussion	102
4.2.1	Experimental Settings	102
4.3	Conclusion and Future Direction	113
5	Ant colony algorithm for constrained optimization problems	114
5.1	Constraint handling techniques	115
5.1.1	Adaptive penalty method	119
5.1.2	Parameter free penalty method	120
5.2	Experimental Setup	121
5.2.1	Analysis of results on test functions	122

5.2.2	Overall performance comparison	134
5.3	Conclusions	135
6	Planning optimal power dispatch schedule using CACO-LD-AP	137
6.1	Mathematical Formulation	142
6.1.1	Objective function	142
6.1.2	Constraints	143
6.2	Experimental setup and performance study	146
6.2.1	Test case I - ELD problems considering only valve-points effect . . .	147
6.2.2	Test case II - ELD problems considering valve-points effect and multiple fuel options	154
6.2.3	Test case III - ELD problems considering only line loss	157
6.2.4	Test case IV - ELD problems considering line loss, ramp-rate limits and prohibited operating zones	159
6.3	Conclusion	165
6.4	Line loss coefficients for 20 generating-unit system	165
6.5	Line loss coefficients for 6 generating-unit system	166
6.6	Line loss coefficients for 15 generating-unit system	166
7	Optimal coordination of DOCRs using CACO-LD-AP	169
7.1	Problem Formulation	172
7.1.1	Objective Function (OF)	172
7.1.2	Constraints	173
7.2	Results And Discussion	177
7.2.1	Experimental Settings	177
7.3	Conclusions	195
8	Conclusions and Future Scope	196
8.1	Conclusions	196
8.1.1	Salient features of the algorithms developed in the thesis	199
8.1.2	Future Scope	200
	Bibliography	203