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.

Place: Indian Institute of Technology Mandi

Date:

Signature:

Name: **Anand Kumar**

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.

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