IITB-Monash Research Academy

Indian Institute of Technology Bombay | MONASH University

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Project Title:	Convex optimization approaches to structured global optimization problems
Project Number	**IMURA0692**
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Research Clusters:

Research Themes:

Highlight which of the Academy's CLUSTERS this project will address? *(Please nominate JUST **one.** For more information, see www.iitbmonash.org)*		**Highlight which of the Academy's Theme(s) this project will address?** *(Feel free to nominate more than one. For more information, see www.iitbmonash.org)*	
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3	*Math, CFD, Modelling, Manufacturing*	3	*Clean Energy*
4	*CSE, IT, Optimisation, Data, Sensors, Systems, Signal Processing, Control*	4	*Water*
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The research problem

Global optimization is a natural tool to solve problems arising in diverse engineering applications, such as AC Power Flow, Chemical Process Control, Water Network Design, Protein Structure Prediction, etc. Large scale global optimization problems are difficult to solve, due to high nonlinearity and possibility of a large number of local optima.

Semidefinite programming, a natural extension of linear programming, is a powerful technique used for constructing convex relaxations for global optimization problems. It has been particularly successful in situations in which the problem's nonlinearities have algebraic structure. Semidefinite programs are typically solved by interior point algorithms. While these algorithms are fast for small- to medium-scale semidefinite programs, large-scale semidefinite programming problems are typically not tractable.

In several applications, the problem has additional sparsity structure, often coming from an underlying network, such as in power flow problems. In these cases, semidefinite relaxations that have been developed (in an ad hoc fashion) are also highly structured and sparse. This sometimes leads to simpler formulations, in terms of *second-order cone programs*, that can be solved quickly. Nevertheless, it remains poorly understood what problem features, in addition to and in combination with sparsity, lead to such simplified formulations.

The goal of this project is to investigate the structure of feasible regions of such global optimization problems and develop systematic approaches to generating these simpler convex relaxations. This is expected to lead to faster solutions to a range of challenging global optimization problems with a combination of network structure and nonlinearity and nonconvexity.

Project aims

This project aims to

1. Study semidefinite programming (SDP) relaxations of structured global optimization problems and understand the difficulty in their solution.
2. Understand the sparsity structure of the semidefinite relaxations and develop necessary and sufficient conditions under which the SDPs can be solved as second-order cone programming problems (SOCPs).
3. Implement and apply the methods developed above to realistic large--scale global optimization problems.

Expected outcomes

1. Development of new theory and insight into the difficulty of several structured global optimization problems arising in several engineering applications.
2. Development and implementation of faster solution techniques for the abovementioned global optimization problems.

3. Publications in flagship journals.

How will the project address the Goals of the above Themes?

Engineering problems mentioned above, such as optimal power flow, need to be solved multiple times in a day. Fast and accurate solutions to these problems will definitely help in more efficient use of resources and infrastructure.

Capabilities and Degrees Required

Candidates should

1. have a strong mathematical background and the aptitude to pick up new algebraic/analytical/optimization techniques.
2. be familiar with at least one programming language.

Knowledge of Power Systems or other engineering applications listed above is ***not*** necessary.

Potential Collaborators

James Saunderson, Electrical Engineering, Monash University

Select up to **(4)** keywords from the Academy's approved keyword list **(available at www.iitbmonash.org)** relating to this project to make it easier for the students to apply.

Mathematics, Optimization