IITB-Monash Research Academy

Indian Institute of Technology Bombay | MONASH University

An Indian-Australian research partnership

Project Title:	**Deep Learning Techniques for solving Combinatorial Optimization Problems**	
Project Number	**IMURA0976**	
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Research Clusters:

Highlight which of the Academy's CLUSTERS this project will address? *(Please nominate JUST **one.** For more information, see www.iitbmonash.org)*	
1	*Material Science/Engineering (including Nano, Metallurgy)*
2	*Energy, Green Chem, Chemistry, Catalysis, Reaction Eng*
3	*Math, CFD, Modelling, Manufacturing*
4	***CSE, IT, Optimisation, Data, Sensors, Systems, Signal Processing, Control***
5	*Earth Sciences and Civil Engineering (Geo, Water, Climate)*
6	*Bio, Stem Cells, Bio Chem, Pharma, Food*
7	*Semi-Conductors, Optics, Photonics, Networks, Telecomm, Power Eng*
8	*HSS, Design, Management*

Research Themes:

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)*	
1	***Advanced computational engineering, simulation and manufacture***
2	*Infrastructure Engineering*
3	*Clean Energy*
4	*Water*
5	*Nanotechnology*
6	*Biotechnology and Stem Cell Research*
7	*Humanities and social sciences*
8	Design

The research problem

Define the problem

Deep Neural Networks have become useful tools in several scientific fields. Recently deep neural networks have been explored for solving combinatorial optimization problems. The methods developed so far rely heavily on training data generated by solving real combinatorial optimization problems which might be too slow in practice. Hence efficient generation of training data is an important goal in using deep learning methods to solve combinatorial optimization problems. A related issue is about generating labeled training data useful for combinatorial optimization problems. Hence semi-supervised methods and transfer learning methods become useful in such contexts. The project aims to investigate the use of semi-supervised, weakly supervised and transfer learning methods in using deep learning for solving combinatorial optimization problems.

Further, deep learning methods involve tuning several hyperparameters to achieve the best performance metric on specific tasks. These hyperparameters include but are not limited to the number and structure of layers in deep neural network architectures, the types of activation functions and weight normalization used in each layer and the types of algorithms used in training. A thorough investigation of these aspects is missing in the existing literature. Hence one of the major aims of the project is to initiate an intensive study of impact of deep neural network hyperparameters in solving combinatorial optimization problems.

Training methodologies used for Deep learning have some limitations due to potential noise in data, which might be naturally occuring or might be induced by an adversary. The impact of naturally occuring or adversary induced noise in training data and in the associated labels used in deep learning methods for solving combinatorial optimization problem has also not been carefully explored in the literature. Hence the aim of the project also involves investigating the effect of noise in training data which might be natural or adversary induced.

Project aims

Define the aims of the project

1. To understand and analyze the state-of-the-art in deep learning tools for specific combinatorial optimization problems.
2. Develop novel deep learning methods for solving specific combinatorial optimization problems.
3. Understand the effect of noise in training data, adversaries and limited data in using deep learning techniques for solving combinatorial optimization problems
4. Develop rigorous deep learning theoretical tools for the proposed techniques.

Expected outcomes

Highlight the expected outcomes of the project

1. The project will result in the development of novel deep learning methods to be used in solving combinatorial optimization problems.
2. The project will advance the understanding of the importance of hyperparameters, types of activation functions, layer functionality in deep learning architectures used for solving specific combinatorial optimization problems.
3. The project will address the important issue of noise in training data, limited size of training data and the lack of labeled training data used for solving combinatorial optimization problems, and about the role of adversaries in the training process.
4. The project will also lead to development of novel learning theoretic tools to understand the nature of proposed tools.
5. Codes for the newly developed tools will be made available for further research purposes.

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

Describe how the project will address the goals of one or more of the 6 Themes listed above.

The development of sophisticated deep learning models for solving combinatorial optimization problems will help in advancing the state-of-the-art in computational methods and engineering. The methods developed will be general-purpose and will be useful for other related combinatorial optimization problems.

Potential RPCs from IITB and Monash

Provide names of the potential research progress committee members (RPCs) and describe why they are most suited for the proposed project

IITB RPC members:

1. Prof. Vishnu Narayanan (IEOR)
2. Prof. Ashutosh Mahajan (IEOR)
3. Prof. Biplab Banerjee (CSRE)

The proposed RPC members have expertise in mathematical optimization and deep learning and hence would be most suited for the proposed project.

Capabilities and Degrees Required

List the ideal set of capabilities that a student should have for this project. Feel free to be as specific or as general as you like. These capabilities will be input into the online application form and students who opt for this project will be required to show that they can demonstrate these capabilities.

1. Proficiency in Deep Learning.
2. Sound knowledge in Machine Learning
3. Exposure to Mathematical Optimization
4. Proficiency in programming.
5. Good knowledge of Python programming language

Necessary Courses

Name three tentative courses relevant to the project that the student should complete during his/her coursework at IITB (the student will require to secure 8 point in these courses)

1. Mathematical Optimization Tehniques
2. Integer Programming
3. Deep Learning – Theory and Practice

Potential Collaborators

Please visit the IITB website www.iitb.ac.in OR Monash Website www.monash.edu to highlight some potential collaborators that would be best suited for the area of research you are intending to float.

Select up to **(4)** keywords from the Academy's approved keyword list **(available at http://www.iitbmonash.org/becoming-a-research-supervisor/)** relating to this project to make it easier for the students to apply.

Data Science,optimisation,algorithms