IITB-Monash Research Academy

An Indian-Australian research partnership

Indian Institute of Technology Bombay | MONASH University

Project Title:	**Data driven model for real-time overall networkwide predictions**	
Project Number	**IMURA1016**	
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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	***Artificial Intelligence and Advanced Computational Modelling***
2	*Circular Economy*
3	*Clean Energy*
4	*Health Sciences*
5	*Smart Materials*
6	***Sustainable Societies***

The research problem

Define the problem

The traditional dynamic traffic assignment (DTA) method captures complex traffic dynamics in a realistic way. DTA model aims to describe the time-varying network and demand interaction more precisely which makes it more complex, thus requires more computational time. In a smaller model with less complexity, the DTA process works well in converging to a point of equilibrium. As the scale of a model grows in size, complexity and congestion, the DTA process becomes more difficult and time-consuming, rendering it unrealistic for real-time deployment. To fill this gap, this task proposes an alternative approach, which relies on a data driven approach to estimate the route choices using real-time data. This is formulated as an adaptive data-driven learning model without assuming the travel behaviour (i.e. user equilibrium). However, one of the major challenges in developing data-driven network model is to implement a framework that can learn the relationship between OD demand and link flows from real-world data. This will be tackled in this project as below.

In a transportation network, all nodes are connected, and each link is associated with information such as distance, speed limit, capacity etc. Here, we consider the transportation network as a weighted directed graph ***G(N,L,W)*** where ***N*** denotes the set of nodes and ***L*** denotes the set of links between nodes (i,j). ***W*** represents the connectivity between nodes as a weighted adjacency matrix, where weights are based on free flow travel time between any two nodes (i,j). The proposed data-driven formulation of the traffic assignment problem aims to *learn* the flow patterns of a transportation network based on the network structure and the instances available on origin to destination (OD) travel demand. Let **D** be the demand matrix for the transportation network ***G***, where each element of a row indicates the travel demand between origin node (i) and the destination node (j). The traffic assignment problem aims to learn a function $\boldsymbol{\mathcal{F}}$**(.)** that maps *M* instances of OD demand matrix $[\boldsymbol{D_1}, \boldsymbol{D_2}, \dots, \boldsymbol{D_M}]$ to *M* instances of link outflow $[\boldsymbol{Q_1}, \boldsymbol{Q_2}, \dots, \boldsymbol{Q_M}]$ as defined as follows:

$$\boldsymbol{\mathcal{F}}\big([\boldsymbol{D_1}, \boldsymbol{D_2}, \dots, \boldsymbol{D_M}]; \boldsymbol{G}(\boldsymbol{N}, \boldsymbol{L}, \boldsymbol{W})\big) = [\boldsymbol{Q_1}, \boldsymbol{Q_2}, \dots, \boldsymbol{Q_M}]$$

The vector $\boldsymbol{Q_m}$ **(**$\boldsymbol{m} \in \boldsymbol{M}$**)** contains the link outflow vector from a node for a given OD demand $\boldsymbol{D_m}$. In this formulation, OD demands, and network properties are input variables, while link outflows are the target variables. To let the data-driven predictive model work closely to current traffic situation, the learned mapping function of $\boldsymbol{\mathcal{F}}$(.) will be regularly updated based on the newly collected (and limited) real-time data. This challenging task will be investigated in this project.

Project aims

Define the aims of the project

The aims of this project are to

1) Investigate data-driven alternatives of traditional DTA
2) Estimate a function that outputs link flows on a network given its OD matrices by utilizing machine learning algorithms
3) To develop simulation based DTA for Mumbai (or Navi Mumbai) and Melbourne
3) Validate the data-driven link flow prediction framework

How skills/experience of the IITB and the Monash supervisor(s) support the proposed project

Highlight the purpose of the collaboration and/or the complementary skills/experience that you bring to the project. Do you have any joint or independent publications in the area of the proposed project?

We are aiming to develop a data-driven framework as an alternative to the conventional DTA.
To train the machine learning algorithm, we need to use the DTA models from Melbourne and Mumbai/Navi Mumbai cities. The IIT Bombay supervisors have experience with Mumbai/Navi Mumbai demand model, and the Monash supervisor has experience with the Melbourne demand model.

Monash supervisor has expertise in traffic flow modelling, data fusion, simulation and network optimization. The IIT Bombay supervisor has a background in network optimization, Transportation demand models, and data analytics. Thus the skills of IIT Bombay and Monash supervisors support the tasks that needs to be performed for the proposal.

What is expected of the student when at IITB and when at Monash?

Highlight how the project will gain from the students stay at IITB and at Monash

The tasks that is expected when the student is at IIT Bombay include i) Study the existing demand models and OD-matrices for both Mumbai/Navi Mumbai and Melbourne, ii) Obtaining real-time link data either from the field observations or through simulation, iii) developing simulations based conventional DTA models, and iv) develop initial data-driven network prediction framework that gives link flows using network characteristics and OD matrix. The student will spend one or two semesters at Monash. During the stay at Monash, the student is expected to refine the framework and perform validation using field data or simulation data.

Expected outcomes

Highlight the expected outcomes of the project

The expected outcome is the data-driven framework that can predict link flows in real-time. This can be an alternative to the conventional DTA models.

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 project develops novel mathematical models based on which new, advanced computational methods and simulation will be developed to estimate link flows of a complex and realistic network in real-time. The final framework predicts the network flow conditions, which can be used to initiate measures to improve mobility and reduce negative externalities such as emissions and fuel consumption.

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

1. Prof. Tom Mathew, Department of Civil Engineering, IIT Bombay, IIT Bombay
2. Prof. Nagendra Velaga, Department of Civil Engineering, IIT Bombay
3. Prof. Hai Vu, Monash University

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.

The candidate should have good analytical skills and should be comfortable in writing computer programs. The background in one or more of the following areas is desired:

- Dynamic Traffic Assignment
- Network optimization
- Machine learning algorithms
- Traffic simulation

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)

- Urban Transportation Systems Planning
- Probability and Statistics
- Engineering Optimization

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.

- Transportation and Traffic Engineering and Logistics
- Data Science,optimisation,algorithms