IITB-Monash Research Academy

Indian Institute of Technology Bombay | MONASH University

An Indian-Australian research partnership

Project Title:	**Multi-agent modelling and inverse optimal control theory for autonomous and connected vehicles**	
Project Number	**IMURA0881**	
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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)*	
1	*Material Science/Engineering (including Nano, Metallurgy)*	***1***	*Advanced computational engineering, simulation and manufacture*
2	*Energy, Green Chem, Chemistry, Catalysis, Reaction Eng*	2	*Infrastructure Engineering*
3	*Math, CFD, Modelling, Manufacturing*	3	*Clean Energy*
4	*CSE, IT, Optimisation, Data, Sensors, Systems, Signal Processing, Control*	4	*Water*
5	*Earth Sciences and Civil Engineering (Geo, Water, Climate)*	5	*Nanotechnology*
6	*Bio, Stem Cells, Bio Chem, Pharma, Food*	6	*Biotechnology and Stem Cell Research*
7	*Semi-Conductors, Optics, Photonics, Networks, Telecomm, Power Eng*	7	*Humanities and social sciences*
8	*HSS, Design, Management*	8	Design

The research problem

Recent technological advances have seen autonomous vehicles become a reality on roads. The efficiency and safety of these vehicles is the highest priority in developing the autonomous driving capability, and they can only be achieved by collaborating with other autonomous vehicles and the road infrastructure through real-time connectivity. Although a wide range of information is expected to be exchanged between autonomous vehicles on the road, the ability of predicting future behaviours of surrounding agents such as pedestrians, bicycles, mopeds, and other vehicles is important but challenging problem. In this project, we will attempt to solve this problem using networked multi-agent theory and inverse optimal control techniques.

We assume that the behaviours of road agents can be modelled as a multiphase cost function that is a weighted sum of specified intentions with phase-dependent weights that switch at some unknown phase transition points. The cost weights and motion phase transitions will be estimated by a newly developed inverse optimal control approach that uses a length-adapted window moving along the observed agent trajectories, where the window length is determined by finding the minimal observation length that suffices for a successful cost weight recovery. To date, the proposed approach has been applied to single agent modelling, the inverse optimal control approach will be expanded to handle multi-agent scenarios and derive conditions for observability.

Once the model is established, it will be first validated in a virtual road simulator with a mixture of simulated vehicles and other agents. Next, recorded road data will be used for final validation of the proposed approach and the recorded movements will be used to measure the performance of the model.

The proposed approach can also be applied to modelling of lane-free traffic flow. In many developing countries, traffic includes a much larger variety of participants, drivers do not obey lane markings or traffic signals and traffic conditions are rather chaotic as a result. As most of those countries are facing rapid urbanisation, the accurate estimation and control of traffic flow around their ever-expanding cities is an important but very challenging problem. However, the current traffic flow estimation in those countries is still done using models developed in lane-based road conditions from western countries, which inevitably causes large prediction errors. We believe that our approach will also be able to provide a solution to this problem, which enables a large-scale traffic simulation for road traffic estimation.

Project aims

The primary objective of the project is to develop a set of heterogeneous models and a model estimation framework that can describe road behaviours of various agents on the road. The model will then be used for predicting future trajectories of the agents in real-time path planning for connected autonomous vehicles. In order to validate the model, a road simulator will be developed, which will be run in an immersive virtual reality environment. Final validation will be done on recordings of agent trajectories in real road conditions. The lane-free traffic scenario will also be considered, which will lead to a larger-scale traffic simulations to estimate traffic flow and congestions.

Expected outcomes

Highlight the expected outcomes of the project including likelihood of patents

The project will develop a methodology for modelling, estimating and predicting multi-agent behaviour and interactions in challenging traffic settings. This will include algorithm development and characterisation, and validation in simulation and realistic traffic conditions. We expect that the work will be published in high quality control and automation journals.

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.

Motion prediction of surrounding agents is one of the primary problems that the autonomous driverless vehicles face. Also, accurate traffic modelling in urban, lane-free conditions is an important and challenging problem. This project will contribute fundamental algorithms, modelling and simulation approaches to address these challenges, in line with the "Advanced computational engineering, simulation and manufacture" theme.

Capabilities and Degrees Required

List the ideal set of capabilities that a student should have for this project. 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. Control theory (optimal control and multi-agent consensus)
2. Virtual environment (immersive simulation)
3. Mathematics

Degrees: Btech, Mtech, MS, BSc/MSc in Electrical, Electronics, Mechanical Instrumentation Engineering, Control Systems, Robotics

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.

Dr Hai Vu at Civil Eng at Monash University

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
Computer Simulation
Systems Analysis and Control