IITB-Monash Research Academy

An Indian-Australian research partnership

Indian Institute of Technology Bombay | MONASH University

Project Title:	**Reasoning about Resource-Bounded Multi-Agent Systems**	
Project Number	**IMURA1003**	
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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***	***Artificial Intelligence and Advanced Computational Modelling***
2	*Energy, Green Chem, Chemistry, Catalysis, Reaction Eng*	2	*Circular Economy*
3	***Math**, CFD, **Modelling**, Manufacturing*	3	*Clean Energy*
4	*CSE, IT, Optimisation, Data, Sensors, Systems, Signal Processing, Control*	4	*Health Sciences*
5	*Earth Sciences and Civil Engineering (Geo, Water, Climate)*	5	*Smart Materials*
6	*Bio, Stem Cells, Bio Chem, Pharma, Food*	6	*Sustainable Societies*
7	*Semi-Conductors, Optics, Photonics, Networks, Telecomm, Power Eng*		
8	*HSS, Design, Management*		

The research problem

Real-world systems have limited resources: tasks must be accomplished in a limited time, they may incur costs, and their execution might require necessary, but not always available, additional resources. A big challenge in modern AI is the development of models and techniques to compute optimal, yet resource-aware, strategies of behaviour for a collection of agents having to make decisions, both collectively and individually, in furtherance of globally optimal desired outcomes and individual goals, respectively, especially when there is uncertainty about the dynamics, and possibly conflicting goals, of other agents in the system -- their environment. In this PhD project, the aim is to address this problem, and to produce novel technologies to formally and automatically reason about both collective and individual behaviour in complex systems consisting of multiple resource-bounded AI agents operating in unknown environments, which may exhibit probabilistic behaviour.

To address this problem, we plan to use a novel combination of modelling and reasoning techniques coming from game theory, automated verification, formal modelling methods, and multi-agent systems (MAS) analysis. We will consider scenarios in which only limited resources and observable data are available, and based on that information produce both a probabilistic MAS model of the unknown environment and a collection of strategies -- one for each agent in the MAS -- such that, globally, they are optimal with respect to both a desired outcome of the system and their consumption of resources. To ensure optimality, we will develop novel game-theoretic techniques to find strategy profiles that together should form a game-theoretic equilibrium -- and thus, are individually stable and locally optimal with respect to the goals of the agents in the system.

Project aims

- To develop a model of multi-agent behaviour, formally informed by game-theoretic ideas, that can be used to reason about optimal decision-making processes with resource-bounded AI agents.
- To provide new decision procedures to answer questions about performance and optimal behaviour, while constraints given by the existence of limited resources are satisfied.
- To better understand how the behaviour of multiple intelligent agents in an interacting complex system is affected by factors such as limited resources, uncertainty, and stochastic behaviour.

Expected outcomes

Highlight the expected outcomes of the project

- A novel **modelling framework** for resource-bounded multi-agent systems (MAS).
- A toolkit of powerful **reasoning techniques** for the analysis of resource-bounded MAS.
- A collection of **mathematical results** relating resources and optimal decision making in MAS.

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.

AI and Advanced Computational Modelling: the project specifically aims to provide a *novel modelling framework* for systems consisting of several autonomous and interacting AI agents. As such, the project deals directly with multi-agent systems, a well-known subarea of *distributed AI*. The project focuses on issues arising due to the presence of limited resources, uncertainty, and stochastic behaviour, making the proposed outcomes of the project closer to what is found in nowadays real-world AI systems.

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.

Applicants are expected to:

- have a background in Computer Science, AI, Logic, or Mathematics;
- have excellent written and verbal communication skills in English;
- be creative, organised, and have strong mathematical and critical thinking skills.

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)

CS 771 : Foundations of Verification and Automated Reasoning
CS 738 : Concepts, Algorithms and Tools for Model-Checking
CS 713 : Special Topics in Automata and Logics

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.

At Monash, collaborations with various other members of the Department of Data Science and AI are very likely. For instance, with other experts in Game theory (Julian Garcia and David Dowe), Multi-Agent Systems (Daniel Harabor), and Logic (David Ripley at the Department of Philosophy). We also currently work with researchers at the University of Oxford (Michael Wooldridge) precisely on similar topics and associated applications in AI, formal verification, and multi-agent systems. **At IITB**, we can have potential collaborations with Ashutosh Gupta (AI, Logic), Paritosh Pandya and Akshay (Timed systems).

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.

Maths, Optimisation, Algorithms, Modelling