IITB-Monash Research Academy

An Indian-Australian research partnership

Indian Institute of Technology Bombay | MONASH University

Project Title:	Dynamic Mechanisms for Skill Elicitation Using Reputation	
Project Number	**IMURA1152**	
Monash Main Supervisor (Name, Email Id, Phone)	A/Prof Julian Garcia, julian.garcia@monash.edu	*Full name, Email*
Monash Co-supervisor(s) (Name, Email Id, Phone)		
Monash Head of Dept/Centre (Name, Email)	Jianfei Cai, jianfei.cai@monash.edu	*Full name, email*
Monash Department:	Department of Data Science and AI	
Monash ADGR (Name, Email)	Guido Tack, Guido.Tack@monash.edu	*Full name, email*
IITB Main Supervisor (Name, Email Id, Phone)	Prof. Swaprava Nath, swaprava@cse.iitb.ac.in	*Full name, Email*
IITB Co-supervisor(s) (Name, Email Id, Phone)		*Full name, Email*
IITB Head of Dept (Name, Email, Phone)	Prof. Varsha Apte, head@cse.iitb.ac.in	*Full name, email*
IITB Department:	Computer Science and Engineering	

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*	7	*Infrastructure*
8	*HSS, Design, Management*		

The research problem

The modern world depends on AI-based decision-making tools that impact every aspect of our lives. Some of these tools influence how we deal, as consumers, with service providers. There are several platforms where a typical user finds out certain specialized service providers, e.g., household tasks (https://www.airtasker.com/, https://jobrabbits.com/, https://hometriangle.com/, https://dashonduty.in/, https://www.click.in, etc.), or ridesharing services (Uber, Ola, Ryde, DiDi, Bolt, etc.), and picks one of them that not only suits their needs but also ensures a good quality of service. For instance, a user interested in getting carpentry work done would like to hire a carpenter that has a certain *minimum* skill level. Given that the 'skill' information is private and only revealed once the job is done, it is very difficult for an individual using the service only once to ascertain the quality of a service provider ex-ante. An arbitrary service provider on a platform may have poor quality and if they are matched with a consumer, the performance of the work could be poor, reducing the platform's reliability.

Our project involves designing mechanisms where the consumers can be informed about the 'true' quality/skill of the service provider; thereby increasing the reliability of the platform service. Typically, the quality of a service provider is displayed on such platforms as the user-based ratings and the consumers are allowed to choose the provider based on the rating information provided (e.g., products on Amazon/Flipkart have user ratings against them which helps users to make decisions). However, when the numbers of such providers are large, and the ratings are not enough for each of them, a typical user may find it overwhelming to search for the 'right' provider. The aim of the project is to apply mechanism design to address this allocation and reward protocol for such a setup. The design goal is to decide (a) which provider is assigned to which consumer based on their posted requirements, and (b) the prices to pay for this service. Typically, prices are set before the task is executed in every platform, so the 'reputation' of the provider can act as an alternative way to reward/penalize performance for the provider. It is possible that a 'reputed' provider did not perform according to its reputation (voluntarily or otherwise), and the mechanism will penalize that in the next iteration of the provider by reducing its reputation score. This is how systems work in practice. Our objective is to design mechanisms that will ensure that the payoff of a service provider increases with their service quality/skill and therefore, a 'rational' and 'intelligent' service provider should perform the task with their best skill level. Despite the prevalence of reputation systems, formal models that leverage the power of mechanism design to guarantee efficient outcomes are not common and that is what we aim to achieve in this project.

There is a sizable literature in the area of crowdsourcing on skill elicitation for tasks. This survey [1] gives a holistic view of the task assignment problem in crowdsourcing. Online coalitional skill formation is also an active area of research [7]. Likewise, the study of reputation dynamics is common for games in which equilibria are inefficient, allowing for reputation to stabilise outcomes that maximise social welfare [5, 9].

In our approach, we will leverage tools from the areas of dynamic mechanisms [2, 3] and reputation mechanisms [4]. We would like to model the service providers as game theoretic agents who derive payoffs both from the payments they receive in the mechanism and the reputation (e.g., the stars people rate them with) they receive after performing the task. Agents aim to maximize the long-term rewards (e.g., the expected discounted payoff over a finite or infinite horizon) and pick their actions accordingly. The actions available to them is to report their skills (overselling their skills might get them a specific job, e.g., someone who is not skilled in carpentry may bid for it and get a job, but poor performance will earn a negative reputation) for the available jobs and the objective is to reveal this information in a 'truthful' manner. Naturally, this falls in the class of dynamic mechanism design [2] and when the jobs are done as a group, the problem has another dimension of value interdependence [6, 8]. The reputation update is an integral part of the mechanism [5]; previous approaches where reputation assignments are modelled as Markovian processes [9] provide an opportunity to link the idea of reputation dynamics to models and results in the area of dynamic mechanism design.

The research in this project will efficiently use the techniques of dynamic mechanism design and reputation mechanisms and use skills of algorithms, game theory, mechanism design, reinforcement learning to obtain the desired objectives.

[1] Danula Hettiachchi, Vassilis Kostakos, and Jorge Goncalves. 2022. A Survey on Task Assignment in Crowdsourcing. ACM Comput. Surv. 55, 3, Article 49 (March 2023), 35 pages. https://doi.org/10.1145/3494522
[2] Bergemann, D. and Välimäki, J., 2019. Dynamic mechanism design: An introduction. *Journal of Economic Literature*, *57*(2), pp.235-274.
[3] Pavan, A., Segal, I. and Toikka, J., 2014. Dynamic mechanism design: A Myersonian approach. *Econometrica*, *82*(2), pp.601-653.
[4] Dellarocas, C., 2006. Reputation mechanisms. *Handbook on economics and information systems*, pp.629-660.
[5] Anastassacos, N., García, J., Hailes, S. and Musolesi, M., 2021, May. Cooperation and Reputation Dynamics with Reinforcement Learning. In *Proceedings of the 20th International Conference on Autonomous Agents and MultiAgent Systems* (pp. 115-123).
[6] Nath, S. and Zoeter, O., 2013. A strict ex-post incentive compatible mechanism for interdependent valuations. *Economics Letters*, *121*(2), pp.321-325.
[7] Cohen, S. and Agmon, N., 2023, May. Online Coalitional Skill Formation. In *Proceedings of the 2023 International Conference on Autonomous Agents and Multiagent Systems* (pp. 494-503).
[8] Nath, S., Zoeter, O., Narahari, Y. and Dance, C., 2011, July. Dynamic Mechanism Design for Markets with Strategic Resources. In *Conference on Uncertainty in Artificial Intelligence*.
[9] Xu, J., García, J. and Handfield, T.,2019, May. Cooperation with bottom-up reputation dynamics. In *Proceedings of the 2019 International Conference on Autonomous Agents and Multiagent Systems* (pp. 269-276).

Project aims

- Development of mathematical models to represent platform-based task assignments.
- Development of mechanisms that satisfy a set of desirable properties in this setting.
- Conducting real and synthetic data experiments to test the efficacy of these methods.
- Publishing our work in leading conferences and journals.
- Providing a good exposure of game theory, mechanism design, and reinforcement learning to the students and improving the scope of inter-institute collaborations.

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

The student is expected to learn mechanism design, learning theory (in particular reinforcement learning), research on them to get publications while at IIT Bombay with inputs from the PI at Monash. This research will be extended during his/her stay at Monash and will get an international exposure. The interdisciplinary nature of the project requires the student to spend time with each group and therefore, their stay at both places is necessary. Both PIs are also expected to visit for a short time the partnering institution to maximize collaboration and productivity.

Expected outcomes

- A **formal mechanism design framework** for skill elicitation in platform-based services.
- A set of multi-agent **algorithms/mechanisms** that achieve several desirable properties.
- Extensive experiments with real and synthetic dataset to test these methods in real-world scenarios.
- An implementation of these mechanisms into a **demo tool** to show its efficacy.

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 modeling and implementation 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 conflicting and stochastic behavior, making the proposed outcomes of the project closer to what is found in nowadays real-world AI systems. We note that the project squarely fits within the CSE, IT, and Optimization cluster because of our focus of study centered around Mechanism design, a subfield of game theory, where solutions are, essentially, locally/globally optimal outcomes of a game. From an optimization perspective, solving a game is solving a multi-agent, multi-objective optimization problem.

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

RPCs from Monash and IITB: To be decided when a particular student is selected.

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, Quantitative Economics, or Mathematics;
- have excellent written and verbal communication skills in English;
- be creative, organized, 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 218 (Design and analysis of algorithms)
CS 6001 (Introduction to game theory and mechanism design)
CS 6002 (Selected areas of mechanism design)
CS 747 (Foundations of intelligent and learning agents)

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 Gutierrez and David Dowe), Multi-Agent Systems (Daniel Harabor) and the adjacent Optimisation group. We also currently work with researchers at UCL (Mirco Musolessi and Steve Hailes) precisely on similar topics and associated applications in AI. **At IITB**, there is a set of experts in algorithms (Rohit Gurjar), multi-agent systems (Shivaram Kalyanakrishnan), and learning theory (Avishek Ghosh) who may be potential collaborators. In addition, the Centre for Machine Intelligence and Data Sciences (CMInDS) has several domain experts in AI and data science who will be easy to collaborate with.

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, optimization, algorithms (6)
Maths (8)

Research cluster: CSE, IT, Optimisation, Data, Sensors, Systems, Signal Processing, Control