Prashant Trivedi

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POSITION

ML Scientist, **One Network Enterprises India** — May 2023 – Present

EDUCATION

Indian Institute of Technology Bombay, India

Ph.D. at Industrial Engineering and Operations Research (IE&OR) — Jul 2018 – Aug 2023
Thesis Title: Multi-Agent Reinforcement Learning and Decision Making
Supervisor: Prof. N. Hemachandra and Prof. J. Venkateswaran

Master of Science (M.Sc.) in **Operations Research** at IE&OR — Jul 2016 – Jun 2018
- Cumulative GPA: 8.5/10

Banaras Hindu University Varanasi, India

B.Sc. (Honors) Mathematics at Institute of Science — Jul 2013 – Jun 2016
- Cumulative GPA: 8.43/10

RESEARCH INTERESTS

Theoretical and practical aspects of various decision making and related models such as *reinforcement learning*. Specifically, my research interests are
Machine Learning: Reinforcement learning, multi-agent reinforcement learning, deep reinforcement learning, multi-armed bandits, supervised learning, unsupervised learning.
Sequential Decision Making: Markov decision process, dynamic programming, stochastic dynamic programming.
Optimization: Linear and non-linear optimization, multi-objective optimization, Discrete optimization, integer programming, network flow models.
Game Theory: Non-cooperative games, cooperative games, mechanism design, stackelberg games.

PUBLICATIONS

Trivedi, P., Hemachandra, N. (2023) *Multi-Agent Congestion Cost Minimization With Linear Function Approximation. In 26th International Conference on Artificial Intelligence and Statistics (AISTATS) 2023. https://proceedings.mlr.press/v206/trivedi23a.html.*

Trivedi, P., Hemachandra, N. (2022) *Multi-Agent Natural Actor-critic Reinforcement Learning Algorithms. In Special Issue on Multi-Agent Dynamic Decision Making and Learning, Dynamic Games and Applications, 2022. https://doi.org/10.1007/s13235-022-00449-9.*

Trivedi, P., Hemachandra, N. (2022) *Noise Robust Core-stable Coalitions of Hedonic Games. In 14th Asian Conference on Machine Learning (ACML) 2022. https://proceedings.mlr.press/v189/trivedi23a.html*.

Trivedi, P., Hemachandra, N. (2023) *Local Differential Privacy Preserving Mechanisms for Multi-Agent Reinforcement Learning.* Under Review.

Tripathi, S., Hemachandra, N. and Trivedi, P. (2020) *Interpretable Feature Subset Selection: A Shapley Value Based Approach. In IEEE 2020 International Conference on Big Data (Big Data). https://ieeexplore.ieee.org/abstract/document/9378102.*

RESEARCH WORK

Multi-Agent Congestion Cost Minimization With Linear Function Approximation

In this work, we consider the multi-agent path planning problem, where all the agents starts at a common initial state and ends at the goal state. However, cost of traversing a link by agent depends on a private factor and the congestion on the link. Moreover, the agents do not communicate the actions they take but can share some parameters associated with the cost function. We use the linear function approximation of the transition probability and the global cost function. With these approximations, we propose a multi-agent reinforcement learning algorithm that gives the sub-linear regret. We prove this theoretically, and provide the computational evidences for the same on a given network.

Multi-Agent Natural Actor-critic Reinforcement Learning Algorithms

Both single and multi-agent natural actor-critic methods are an important class of Reinforcement Learning algorithms. In this work, we provide three *fully decentralized* multi-agent natural actor-critic (MAN) algorithms and prove their asymptotic convergence. To capture the intrinsic curvature in the state space, we use the natural gradients that are more useful in non-Euclidean setup. We observe that the minimum singular value of the Fisher information matrix is well within the reciprocal of the policy parameter dimension. Using this we theoretically show that a deterministic variants of these MAN algorithms gives a better local minima than the corresponding variant of the standard gradient based algorithm. We validate our results on a traffic network model, compared to the standard gradient based algorithms the congestion is reduced by 25% via MAN algorithms.

Local Differential Privacy Preserving Mechanisms for Multi-Agent Reinforcement Learning

This work considers the local differential privacy (LDP) aspects of multi-agent reinforcement learning (MARL). We design a fully decentralized and generic multi-agent locally differential private (MA-LDP) algorithm that can handle any noise adding mechanisms. We prove that the MA-LDP algorithm preserves the user's data privacy and attains the sub-linear regret for four noise mechanisms with different noise supports. Further, we compare the noise adding mechanisms with unbounded support to those with bounded support. A key observation is that for a suitably chosen bounded noise support, the regret of the MA-LDP algorithms is on-par or lower than the noise mechanism with unbounded support. We validate our theoretical findings on an network MDP with a large state and action spaces.

Noise Robust Core-Stable Coalitions of Hedonic Games

We consider the coalition formation games with an additional component, 'noisy preferences'. Moreover, such noisy preferences are available only for a sample of coalitions. We first propose a multiplicative noise model equivalent to an additive noise model and then find the prediction probability that the estimated PAC core-stable partition of the *noisy* game is also PAC core-stable for the *unknown noise-free* game. We also identify the noise regimes for which an estimated partition is noise robust; that is, it is PAC core-stable in both the noisy and noise-free games. Further, in a two agent model with full information on the noisy preferences we obtain a safety value below which the noise-robust regime is the entire probability simplex.

Interpretable Feature Subset Selection: A Shapley Value Based Approach

To interpret the influence of a single feature or their interactions on the label/class, we use the framework of transferable utility cooperative games and introduce a classification game with features like players and hinge loss based characteristic function (computed as LPs). Using the Shapley value based error apportioning (SVEA) of the features contribution we give a subset of the features whose test error accuracy is almost the same when all the features are used. To address the computational complexity of the Shapley value we provide an approximation algorithm that yields with high confidence the same SVEA values.

INTERNSHIP

Summer research intern on *"Data Valuation in Federated Setting"* at Indian Research Lab, IBM Bangalore with Ruhi Sharma Mittal May 2020 – Aug 2020

- We provide a stackelberg game based framework to give the valuation to dataset sample in federated setting when sharing the data with server is not possible.

INVITED TALKS/WORKSHOP

1) Invited talk on "Multi-Agent Natural Actor-Critic Reinforcement Learning Algorithms" at the *Department of Computer Science and Automation*, IISc Bangalore.
2) Paper presentation on "Learning Noisy Hedonic Games" at *GAMES 2020, the 6th World Congress of the Game Theory Society*, Online.
3) Paper presentation on "Noise Robust Core Stable Coalition of Hedonic Games" at *Asian Conference on Machine Learning 2022*, Dec 12-14, ISB Hyderabad.
4) Two days workshop on "Markov Decision Processes, Reinforcement Learning and Multi-Agent Reinforcement Learning" at IIM Bangalore, India.

POSTER PRESENTATIONS

1) "Shapley Value For Multichoice Cooperative Games: A New Approach" at *International workshop on game theory*, Dibrugarh University Assam, India, Sep 2018.
2) "Noise Robust Core Stable Coalitions of Hedonic Games"at *Asian Conference on Machine Learning 2022*, ISB Hyderabad, India, Dec 2022.
3) "Multi-Agent congestion cost minimization with linear function approximations" at *International Conference on Artificial Intelligence and Statistics (AISTATS) 2023*, Valencia, Spain, Apr 2023.

WORKSHOPS AND SCHOOLS

1) Workshops and Tutorials in ACML 2022 at *ISB Hyderabad*. Dec 2022
2) Online Asian Machine Learning School (OAMLS). Nov 2021, Dec 2022
3) Learning Theory 1 and 2 Workshop at *TIFR, Bombay*. Jan 2019, Jan 2020
4) Advance in Applied Probability II (Online). Jan 2021, Jan 2021
5) The 'Indo-French Center for Applied Mathematics (IFCAM) summer school on Mathematics for Data Science' at *IISc, Bangalore*. Jul 2019

ACADEMIC SERVICES

Reviewer: AISTATS 2023.

Volunteer: 51st Annual Convention of the Operations Research Society of India (ORSI) and International Conference on "Emerging Trends in Operations Research and Management Science (OR/MS)" held at IIT Bombay.

TECHNICAL SKILLS

Programming Skills: Python.

Statistical and Simulation Tools: MS Excel, Salabim.

Optimization Solvers: AMPL, Gurobi, Cplex, Baron, Snopt, PuLP.

Machine Learning Tools and Libraries: NumPy, Scikit-learn, Tensorflow, Pandas.

Other Skills: LaTeX, Beamer, MS Office.

OTHER PROJECTS

***"Algorithms for Multi-Class Perceptron"* with Prof. P. Balamurugan and Prof. M. Hanawal** Jan 2018 – Apr 2018

- We proposed two new update rules for the multi-class perceptron algorithm with K classes. We implemented these update rules in Python on five real data sets. An average reduction of 5 mistakes is observed using the proposed rules.

***"Simulating Risk and Security of Departing Passengers at Airport"* with Prof. Ashutosh Mahajan and Prof. K.S. Mallikarjuna Rao** Jul 2018 – Nov 2018

- Simulated the airport security system and proposed a new algorithm with two fold objectives: maximizing the efficiency which helped in reducing the risk and minimizing the cost of setting up the security system.

***"Facility Location and Oil-seed Procurement Network Design Problem"* with Prof. Narayan Rangaraj and Prof. K.S. Mallikarjuna Rao** Jul 2018 – Nov 2018

- Gave an optimal solution for locating the refineries that have limited technology plants to extract the oil from oil-seeds in the oil refinery such that the overall transportation cost of oil to the refinery minimize.

***"Shapley Value for Multi-Choice Cooperative Games"* with Prof. K.S. Mallikarjuna Rao** Jan 2018 – May 2018

- We obtain the Shapley value for the multi-choice cooperative games by reducing it to the simple cooperative game. This Shapley value exactly coincides with the existing valuation to each player.

***"Random Fixed Points and Polya's Urn Model with Normal and Non-Normal Limits"* with Prof. V. Kavitha** Jul 2017 – Nov 2017

- Explored random fixed point theorems for special case of Polya's urn model. The asymptotic convergence was derived for Normal and Non-Normal limits.

MAJOR COURSES

Foundations of Machine learning, Online Learning, Introduction to Stochastic Models, Optimization Models, Optimization Techniques, Advanced Topics in Discrete Optimization, Topics in IE&OR, Integer Programming: Theory and Computations, Discrete Event System Simulations, Quantitative Models for Supply Chain Management, Decision Analysis and Game Theory, IE&OR for Health Care, Service and Infrastructure Systems.

TEACHING ASSISTANT

Topics in Learning Algorithms, Data Analytics in Operations Research, Operations Analysis, Engineering Statistics, Naval Operations Analysis, Decision Analysis and Game Theory, Markov Decision Processes, Introduction to Financial Engineering, Web TA.

REFERENCES

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Prof. P. Balamurugan
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More references can be provided on request.