Karan Chadha | Electrical Engineering

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Research Interests: Applied Probability, Learning Theory, Optimization, Game Theory, Social Networks

EDUCATION

Indian Institute of Technology, Bombay *2014 - 2019*
Dual Degree (B.Tech +M. Tech), Electrical Engineering
Specialization: Communication and Signal Processing
GPA: 9.67 /10 (**1st** among 46 students)

PUBLICATIONS

- Vivek Borkar, **Karan Chadha**, "A reinforcement learning algorithm for restless bandits", Indian Control Conference, 2018. (https://ieeexplore.ieee.org/abstract/document/8307959)
- **Karan N Chadha**, Ankur A Kulkarni, "On independent Cliques and Linear Complementarity Problems", to be submitted to SIAM Journal of Discrete Mathematics. (https://arxiv.org/abs/1811.09798)
- **Karan N Chadha**, Ankur A Kulkarni, "Effort Maximizing Play in Strategic Interaction on Networks", to be submitted to Journal of Mathematical Economics.

RESEARCH PROJECTS

Strategic Interaction on Networks with Imperfect Substitutability | Master's Thesis
Advisor: Prof. Ankur Kulkarni, Systems and Control, IIT Bombay *May '18 - Present*

· *Introduction:* We study a public goods game on networks with imperfect substitutability, wherein each node is an agent and the action performed is the effort put in the game. The benefit function of each player is dependent on the sum of their own effort and a substitutability factor times the sum of effort of each of their neighbours. The cost is dependent on only one's own effort.

- Proved that the Nash equilibria of a public goods game on a network are given by suitably scaled solutions to a Linear Complementarity Problem defined using the adjacency matrix of the underlying graph.
- Characterized the effort maximizing solutions of public goods game using special structures on the graph which are generalizations of independent sets.
- Derived absolute upper bounds for the aggregate effort of any equilibria when the underlying graphs are trees.

On independent Cliques and Linear Complementarity Problems | Master's Thesis
Advisor: Prof. Ankur Kulkarni, Systems and Control, IIT Bombay *Fall '18*

· *Introduction:* Linear Complementarity Problem (LCP(M, q)) is an optimization problem defined as "Find x such that $x \geq 0,\ y = Mx + q \geq 0,\ y^T x = 0$". We study the ℓ_1 norm maximizing solutions of LCP$(I + \delta A, -\mathbf{e})$, where A is the adjacency matrix of a graph, $\delta \in (0, \infty)$ and $\mathbf{e}$ is the vector of 1's.

- Generalized the concept of independent sets to a union of independent cliques and defined solutions of the LCP$(I + \delta A, -\mathbf{e})$ with support as union of independent cliques as Independent Clique Solutions (ICS).
- Derived an algorithm which constructs an ICS of the LCP$(I + \delta A, -\mathbf{e})$ for suitable δ.
- Proved that the maximum ℓ_1 norm amongst all the LCP$(I + \delta A, -\mathbf{e})$ solutions is achieved by an ICS.
- For $\delta \geq 1$, proved that the maximum weighted ℓ_1 norm is achieved at the characteristic vector of a maximum weighted independent set.

A Reinforcement Learning Algorithm for Restless Bandits
Advisor: Prof. Vivek Borkar, EE Department, IIT Bombay *Spring '17*

· *Introduction:* The restless bandit problem is to find optimal policies which choose to keep each bandit active or passive at every time step. They use a heuristic called Whittle Index which gives a threshold based near optimal policy. However, computing the Whittle Index is intractable in general and we provide an algorithm to find it.

- Proposed and analyzed a two timescale learning algorithm to learn the Whittle index for indexable restless bandits which uses the LSPE(Least Squares Policy Evaluation) and Gradient Descent schemes.
- Used Linear Function Approximation and Approximate Dynamic Programming to learn the previously intractable Whittle Index Heuristic to solve the restless bandits problem.

[1] Use URL kc1729.github.io if hyperlinks don't work

- Conducted simulations to test our algorithm in scheduling of web crawlers for ephemeral content.

Estimation of edge resistances using MCMC
Advisor: Prof. Vivek Borkar, EE Department, IIT Bombay *Fall '17*

· *Introduction:* The effective resistance of an edge is the resistance assuming all edges are of resistance 1 unit, which is an important metric in social networks and useful for graph sparsification. We provide a fast ($\sim O(n \log n)$) algorithm for estimating edge resistances of a graph.

- Derived an Markov Chain Monte Carlo (MCMC) based algorithm in a Probably Approximately Correct(PAC) Learning framework to estimate effective edge resistances of a graph.
- Provided the complexity analysis and achieved faster convergent rates than existing MCMC algorithms by using Aldous' and Wilson's Algorithm to generate uniform random spanning trees.
- Illustrated using simulations that the estimates give the correct order (ranking) of resistances much faster than the time each estimate takes to converge to the true resistance value.

Risk Aware Economic Dispatch | Summer Internship, USC
Advisor: Prof. Rahul Jain, EE Department, University of Southern California *Summer '17*

· *Introduction:* Economic dispatch solves the optimal output of electricity generation facilities, to meet the system load, at the lowest possible cost, subject to transmission and operational constraints. We consider the risk averse version of this problem and solve it.

- Surveyed the literature of Stochastic Programming and algorithms to solve multistage stochastic programs.
- Studied various type of Risk Measures applicable to Power Markets and reformulated the economic dispatch problem to make it solvable under the risk aware and stochastic regime.
- Simplified the problem involving CVaR risk measure into a risk neutral stochastic program which can be solved using standard algorithms like Stochastic Decomposition.

SCHOLASTIC ACHIEVEMENTS

- Scored a Semester Point Index of **10/10** in the 4^{th}, 5^{th}, 7^{th} & 8^{th} semester in IIT Bombay
- Awarded the **Institute Academic Prize** for standing 1^{st}(out of 66) in 2017 and 2018.
- Secured **AP** grade (awarded to less than top 1 % of a class) in 4 courses: Digital Communications, Internet Economics, Science of Information Statistics and Learning & Topics in Topology
- Recipient of the **Honda YES Award** awarded 2016 to 14 students in India which recognizes meritorious students in the field of Science and Technology and sponsors higher studies in Japan
- Secured an **All India Rank of 125** in **JEE Advanced '14** out of **126000** short listed candidates in 2014
- Stood **14^{th}** in the state for Round 1 of the **Regional Mathematics Olympiad** (RMO) & among **top 300** of the nation to compete in **INMO** (Indian National Mathematics Olympiad) in 2013
- Ranked **4^{th}** in the **35^{th}** Mathematics Olympiad, Mathematics Association, IIT Bombay, 2016

WORKSHOPS AND CONFERENCES ATTENDED

- Workshop on Learning Theory, Tata Institute of Fundamental Research, January 2019*
- Workshop on Games on Networks and Queueing Theory, IIT Bombay, January 2019*
- Workshop on Stochastic Optimization over Networks and related topics, IIT Bombay, February 2018
- Probability Day, Tata Institute of Fundamental Research, January 2018
- Bombay Information Theory Seminar, IIT Bombay, January 2018
- Indian Control Conference, IIT Kanpur, January 2018
- Workshop on Applied Probability, Tata Institute of Fundamental Research, April 2017

OTHER SELECT PROJECTS

Deep Reinforcement Learning for Atari games | Summer Internship, SYSU-CMU JIE
Guide: Prof. Paul Weng, UM-SJTU Joint Institute *Summer '16*

· Reviewed the code of Google DeepMind for choosing optimal actions while playing Atari Games and ran experiments on variants of its Deep Q-Network (DQN) by incorporating ideas like Double DQN and Duelling network architectures. Binarized the neural network estimating the Q-function to speed up learning and save on memory, leading to a 3-fold decrease in memory usage compared to original code.

Mathematics of Deep Learning
Guide: Prof. Vivek Borkar, EE, IIT Bombay *Spring '18*

· Surveyed the recent literature on the mathematics underlying regularization in deep neural networks and how stochastic gradient descent (SGD) performs variational inference. Reviewed theoretical analysis of Entropy-SGD which provably outperforms the classical SGD algorithm by converging to wider valleys.

Pyraminx Utility Kit
Guide: Prof. Kavi Arya, CSE, IIT Bombay *Spring '15*

· Implemented the BFS algorithm and AVL trees to derive the optimal solutions of a Pyraminx, a tetrahedron Rubiks Cube style puzzle. Used Allegro, a C++ framework, to design an interface to help solve pyraminx optimally, find cube algorithms and generate solve analysis. Designed an Android app implementing image processing techniques to read pyraminx configurations and send it to a Java server.

MENTORSHIP AND TEACHING EXPERIENCE

Head, Department Academic Mentorship Programme March '18 - Present

· Spearheading a team of 22 handpicked mentors counseling over 150 students on academic and personal issues.
· Mentored 26 students over 2 years to help them overcome academic and personal difficulties.
· Awarded a Special Mention (4 out of 210 students) for exhibiting excellent mentorship skills

Institute Student Mentor April '17 - April '18

· Selected on the basis of peer-review and inter-personal skills to mentor and guide a batch of 12 freshmen in their academic and extra-curricular endeavors.

Institute Teaching Assistant
Undergraduate: Partial Differential Equations (MA 207, Fall '16), Linear Algebra (MA 106, Spring '17)
Graduate: Optimization (EE 659, Fall '18)

· Conducted weekly 90 min tutorials for a class of about 60 students, involving problem solving and concept discussion sessions; involved in the setting of question papers and correction of answer scripts for the exams.
· In MA 207, helped the section achieve the best performance among 8 other similar sized sections.

RELEVANT COURSEWORK & PROGRAMMING SKILLS

Optimization	Mathematics	Electrical Engineering
Intro. to Optimization	Basic Algebra	Advanced Network Theory
Stochastic Optimization	Partial Differential Equations	Advanced Concentration Inequalities
Combinatorial Optimization	Real & Complex Analysis	Information Theory & Coding
Games & Information	Measure Theory	Internet Economics
Science of Information, Statistics	Stochastic Processes	Optimal Control Systems
and Learning	Topics in Topology	Error Correcting Codes

Computer Science: Data Structures and Algorithms, Computer Networks
Programming: C/C++ (with Allegro), Python(with NetworkX), MATLAB/Octave, VHDL, Assembly

EXTRA-CURRICULAR ACTIVITIES

- Completed 80 hours of social service in NSS(National Service Scheme), IIT Bombay
- Learning A1 Level french Language under International Relations Office, IIT Bombay
- Convenor of the Robotics Club, IIT Bombay enabling freshmen to take up robotics as a hobby
- Achieved 1st position in the Intra Hostel Football Championship in 2015 and 2017
- Secured 2nd position in the Inter-school Free-Style Relay Swimming competition

REFERENCES

Prof. Vivek Borkar
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Systems & Control Engineering
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Prof. Rahul Jain
Electrical & Computer Engineering
University of Southern California
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