Karan Chadha | Electrical Engineering

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Research Interests: Applied Probability, Learning Theory, Optimization, Control, Game Theory

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

1. Vivek Borkar, **Karan Chadha**, "A reinforcement learning algorithm for restless bandits", *Indian Control Conference*, 2018. (https://ieeexplore.ieee.org/abstract/document/8307959)
2. **Karan N Chadha**, Ankur A Kulkarni, "On independent cliques and linear complementarity problems", submitted to *Mathematics of Operations Research.* (https://arxiv.org/abs/1811.09798)
3. **Karan N Chadha**, Ankur A Kulkarni, "Aggregate play and welfare in strategic interaction on networks", in preparation, *Journal of Mathematical Economics.* (https://kc1729.github.io/files/aggeffort.pdf)

RESEARCH PROJECTS

Aggregate Play and Welfare in Strategic Interaction on Networks| Master's Thesis [3]
Advisor: Prof. Ankur Kulkarni, Systems and Control, IIT Bombay *May '18 - Present*

· *Introduction:* We study a strategic interactions game on networks, 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 strategic interactions game on a network are given by scaled solutions to a Linear Complementarity Problem defined using the adjacency matrix of the network.
- Characterized the effort maximizing equilibria of this game using union of independent cliques.
- Derived tight upper and lower bounds for the total effort of any equilibria and provided approximations for the social welfare in terms of the total effort.

On Independent Cliques and Linear Complementarity Problems | Master's Thesis [2]
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 related solutions of the LCP$(I + \delta A, -\mathbf{e})$ 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 among 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.

[1] Use URL https://kc1729.github.io/ if hyperlinks don't work
[2] All project reports available on website

A Reinforcement Learning Algorithm for Restless Bandits [1]
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. To solve this, a well-known heuristic called Whittle Index gives a threshold based near optimal policy, but computing it is intractable in general.

- Proposed and analyzed a two timescale learning algorithm to learn the Whittle index for indexable restless bandits which uses LSPE (Least Squares Policy Evaluation) and gradient descent schemes.
- Used linear function approximation to overcome the problem of continuous state spaces.
- 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 in a graph is the equivalent resistance assuming all edges are of resistance 1 unit. We provide a fast ($\sim O(n \log n)$) algorithm for estimating edge resistances.

- Derived a 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:* The aim is to find the optimal power each generator should pump into a power system with renewable sources and random demand, so that a risk measure of the cost of generation is minimized.

- Reformulated the economic dispatch to make it solvable under the risk aware and stochastic regime.
- Proposed a method to convert a risk-aware problem with CVaR risk into a risk neutral problem.
- Proved that the Vickery Clarkes Grove (VCG) pricing mechanism is both incentive compatible and individually rational.

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
- **All India Rank 125** in JEE Advanced '14 out of 126000 short listed candidates in 2014
- Stood **14^{th}** in the state in the **Regional Mathematics Olympiad** (RMO) in 2013
- Ranked **4^{th}** in the **35^{th}** Mathematics Olympiad, Mathematics Association, IIT Bombay, 2016

WORKSHOPS 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
- 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.

Mathematics of Deep Learning
Guide: Prof. Vivek Borkar, EE 763 Course Project, 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.

Johnson-Lindenstrauss Lemma and its Applications
Guide: Prof. Sharayu Moharir, EE 761 Course Project, IIT Bombay *Fall '17*

· Studied and presented various probabilistic proofs and applications of Johnson-Lindenstrauss lemma which uses random projections to find low-distortion embeddings of points into a low-dimensional space.

Risk Constrained Markov Decision Processes
Guide: Prof. Vivek Borkar, EE 736 Course Project, IIT Bombay *Spring '17*

· Surveyed the literature on risk aware markov decision processes and corresponding reinforcement learning algorithms, namely risk-aware versions of value iteration, policy gradient and actor-critic algorithms.

MENTORSHIP AND TEACHING EXPERIENCE

Head, Department Academic Mentorship Programme March '18 - Present

· Leading a team of 22 handpicked mentors counselling over 150 students on academic & 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 (MA207, Fall '16), Linear Algebra (MA106, 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 design and correction of exams.

RELEVANT COURSEWORK & PROGRAMMING SKILLS

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

Computer Science: Data Structures & Algorithms, Computer Networks, Machine Learning(coursera)
Programming: C/C++ (with Allegro), Python(with NetworkX), MATLAB/Octave, LaTeX

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

REFERENCES

Prof. Vivek Borkar
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Prof. Rahul Jain
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