Statement of Purpose

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(Application for Ph.D. in Computer Science)

I want to pursue a career in academic research and teaching. I am interested in theoretical computer science and applied mathematics, particularly algorithms, optimization, learning theory, and their application to problems in economics.

I completed my undergraduate education in 2018 from the Dept. of Mathematics at IIT-Guwahati and was awarded the President of India Gold Medal[1]. My major was a blend of courses in mathematics, computer science, and their applications. My undergraduate thesis was on *welfare maximizing cardinal voting mechanisms*. Currently, I am completing my MS in computer science at UT-Austin.

I got my most extensive research experience working with Prof. Umang Bhaskar (TIFR-Mumbai). In my undergraduate junior year, I got interested in algorithmic game theory and mechanism design. After completing a few online graduate courses in those areas and reading some recent research papers, I reached out to Prof. Bhaskar at TIFR-Mumbai and following his recommendation applied to TIFR's Visiting Students Research Programme (VSRP). Prof. Bhaskar and I collaborated over the next year. We worked on randomized truthful voting mechanisms. The problem was to design mechanisms that give voters the incentive to vote truthfully while ensuring that the candidate chosen by the mechanism maximizes the social welfare as much as possible. We captured optimality using distortion, the worst-case ratio between the welfare of the optimal candidate and the candidate selected by our mechanism, in expectation. We studied the two main categories of voting mechanisms: ordinal, where voters reveal a ranking of the candidates, and cardinal, where voters reveal their utility for each candidate.[2]

For truthful ordinal mechanisms, Prof. Bhaskar designed a mechanism with distortion $O(\sqrt{n \log n})$, where n is the number of candidates, and a gave corresponding lower bound of $\Omega(\sqrt{n \log n})$ with some additional restrictions. I contributed by generalizing the lower-bound to all truthful ordinal mechanisms and making the bounds tight. For our distortion lower-bound, characterizations of randomized truthful ordinal mechanisms by Gibbard (1975) [3] was crucial. In an effort to find similar characterizations for cardinal mechanisms, we gave a class of truthful cardinal mechanisms that violated properties of localization and non-perversity essential to truthful ordinal mechanisms, establishing a separation between the two categories. These mechanisms also maintained the same distortion of $\Theta(\sqrt{n \log n})$. We also gave a near-tight lower bound of $\Omega(\sqrt{n})$ for all truthful cardinal mechanisms [2]. This result showed us that truthfulness is too strong a restriction for welfare-maximizing voting mechanisms.

To circumvent the strong lower bounds for truthful mechanisms, we then studied approximately truthful mechanisms and gave one that has distortion close to 1. Finally, we considered the simple mechanism that selects the candidate that maximizes social welfare. This mech-

[1] Awarded for the best academic performance among students graduating in 2018 across all majors (1/650 students)

[2] We assumed that for each voter, the sum of the utility for the candidates is 1.

anism is not truthful, and we studied the distortion at equilibria (equivalent to the Price of Anarchy, PoA). While in general, the PoA is unbounded, we showed that for equilibria obtained from iterative voting dynamics, the PoA is close to 1. We also showed that iterative voting converges. Thus, relaxing the notion of truthfulness in both cases allowed us to obtain near-optimal distortion. Overall, I got valuable research experience working with Prof. Bhaskar, and our work led to my undergraduate thesis and two papers [1, 2].

In my master's program, I wanted to explore areas of artificial intelligence. I experienced over the past year that despite the boom in AI research, there are underlying theoretical problems that need to be solved to make significant progress. This has further strengthened my interest in giving strong theoretical foundations to problems in AI. For some of the course projects, I combined ideas from my previous research with the new approaches that I learned, for example, in the Deep Probabilistic Modeling course I designed an adversarial network to approximately solve the optimal truthful voting mechanism problem.

Currently, I am working as a research assistant with Prof. Ufuk Topcu (UT-Austin) on problems involving online learning and Markov Decision Processes (MDPs). In one problem, an agent has to interact and classify a randomly sampled MDP from an underlying set of MDPs, incurring a loss for misclassification. Also, the agent has to estimate the model using the data from previous episodes and increase its classification accuracy over time. We gave a sample efficient PAC learning algorithm for this problem.

For my future research, some specific directions that I find interesting are: beyond worst-case analysis of algorithms; study markets for information; design relatively simple mechanisms (revenue-maximizing auctions, contracts) that provably approximate the theoretical optimum; design algorithms to learn near-optimal auctions from data considering algorithmic and strategic issues; contribute to the progress in P vs NP by studying problems related to economics in TFNP; mechanism design considering designer's credibility and multi-party communication complexity. My major motivation for pursuing a Ph.D. is to have the freedom to target such fundamental and practical problems with rigor and depth. My previous research exposure has made me confident about my desire to pursue theoretical computer science and applied mathematics, and I hope to devote my career to academic research in the field.

References

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[2] U. Bhaskar and A. Ghosh. On the welfare of cardinal voting mechanisms. In *Proceedings of the 38th IARCS Annual Conference on Foundations of Software Technology and Theoretical Computer Science (FSTTCS)*, pages 27:1–27:22, 2018.

[3] A. Gibbard. Manipulation of schemes that mix voting with chance. In *Econometrica: Journal of the Econometric Society*, pages 665–681, 1977.