Statement of Purpose

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1 Background

I grew up in a college campus in India. I have always been interested in Mathematics and making things. My introduction to computer science started following a week long workshop in 8^{th} grade, where I was introduced to C programing. That one could build powerful solutions to problems immediately resonated with me. My interest led me to explore more and to compete for the National Informatics Olympiad in my 9th grade. Subsequently I represented India thrice in the International Informatics Olympiad and got medals twice. The training sessions and our instructors in the training camp introduced me to the wonderful world of algorithms and data structures.

When I started college at MIT, I was drawn towards theoretical Computer Science, and I have had the opportunity to take several upper level graduate courses in this domain starting from my freshman year. I have also had a keen interest in Physics, and have completed a variety of courses including quantum mechanics, particle physics, statistical mechanics, and experimental physics. In conjunction with my mathematics coursework, this has helped me develop a strong mathematical background which has been invaluable in my research.

At MIT, I have actively pursued some exciting research topics, under the guidance of Ronitt Rubinfeld and Erik Demaine (Section 2), resulting in two publications, and two additional papers in review.

I have also sought out many teaching related activities at MIT, including a TA position for the second level undergraduate algorithms course three times, starting from my sophomore year. I also organized and taught a month long independent algorithms crash course for MIT students. I completely conceived and organized a programming, simulation and robotics workshop for high school students in my hometown in India, as a joint venture between MIT and IIT Kharagpur.

I am interested in a career in academia that will allow me to pursue my interests in research and teaching. Completiong a PhD will enable me to delve more intensely in research in theoretical computer science, and prepare me for my academic career.

2 Research

During my time at MIT, I have conducted research in a number of different topicsincluding sublinear algorithms, local algorithms, computational geometry and origami theory.

Sublinear Algorithms

My first exposure to research was in freshman year through a graduate course titled "Randomness and Computation". Our instructor was Ronitt Rubinfeld, and being the only undergraduate student in a small class, I got to know her quite well. I was invited to join in group meetings with her PhD students, who were working on graph property testing. Having considered $\mathcal{O}(n)$ to be the gold standard of complexity all my life, I was very excited to learn more about sublinear algorithms.

Counting Subgraphs. Our work (published in Algorithmica [1]) was focused on estimating the number of star subgraphs in a given graph. We introduced a new model in graph property testing, which allowed for a random edge to be sampled. Most prior research had only considered random vertex, and random neighbor queries. However, the ability to sample a uniformly random edge is very natural, since it is equivalent to sampling a random element from an adjacency list representation of a graph. We were able to show that this model is more powerful than the old vertex sampling models, by improving the bounds presented in [2].

Local Access Implementations. More recently, I have started working on a new research project concerning *local-access implementations* of huge random objects, a field that was pioneered in [3, 4], and further developed in [5, 6]. This model considers huge random objects such as exponentially sized random graphs. Classically, such objects are fully generated, before being studied. However, in the context of sub-linear query complexity, it is wasteful to generate the entire object. Local-access implementations aim to provide oracle access to these random objects, while avoiding a large pre-processing overhead.

We have obtained some new and interesting results in this area – particularly for undirected random graphs with independent edge probabilities. We provide the first implementations of RANDOM-NEIGHBOR queries. Our implementation also introduces support dense graphs, and unlike many past results, we can generate the entire graph without introducing inconsistencies. Specifically, we show that our algorithm can be used to efficiently implement $G(n,p)$ graphs, and the Stochastic Block Model. We also design generators for graphs in Kleinberg's small world model, where edge probabilities depend on a 2-dimensional distance metric.

Currently, I am working on implementations of Geometric and Hyperbolic Random Graphs. We have also investigated the local generation of uniformly random domino tilings (which has applications in the dimer model), and uniform samples from Dyck languages.

Computational Geometry

I have also worked on several problems in origami and computational geometry with Erik Demaine.

Origami. One of the results from this class was a result on common unfoldings; 2D shapes that can fold into multiple different polyhedra. Our paper [7], published in CCCG, outlines the construction of a development that can fold into twelve different convex polyhedra. Most of the past results in the field [8, 9, 10, 11, 12] only result in a small number of unfoldings. Our construction also presents the first non-trivial *uncountable family* of unfoldings.

I have also worked on computational origami design, introducing a novel design framework which uses time-evolving cross-sections. This results in a construction for arbitrary orthogonal terrains, with 2-optimal paper usage. We also formulate a technique for constructing arbitrary extruded polygons, where convex polygons can be made with $1 + \mathcal{O}(1/n)$ optimal paper usage.

Auxetic Linkages. One of my ongoing projects is on the design of 2-dimensional auxetic linkages. These are periodic linkages with an expansive deformation [13, 14]. Specifically, I am interested in inhomogeneous bistable auxetic linkages; linkages with exactly two configurations, that are isolated in state space. While existing literature focuses on periodic linkages with *continuous homogenous expansion*, I am investigating *aperiodic* linkages that have *position dependent* expansion coefficients. This results in a non-Euclidean final state, and allows us to approximate any desired 3D surface. I have constructed physical models that start out as a flat sheet, and unfold into a 3D surface.

3 Teaching

I enjoy teaching, and greatly appreciate its importance for being academically active and doing research. In addition to solidifying my own understanding of the material, teaching a topic is also a wonderful exercise in communication. After all, the most novel of ideas is useless one can communicate it effectively.

Teaching Assistant My first teaching experience was in sophomore year, when I was a TA for the second level algorithms course at MIT. This happened to be the semester when the course was being recorded for MIT Open Courseware. So, the videos of my recitation were recorded, and posted on the OCW website (recitations $\{2, 6, 8, 9\}$ available online [1]).

This was my also first teaching experience, and I found that I thoroughly enjoyed the process of preparing material, and teaching a class. I have since been a TA for this class three times, and every offering has contributed to further my understanding of the material.

Independent Teaching I have also undertaken several independent teaching related activities. During my Junior year, I designed and taught a month-long algorithms course at MIT, with 40 students. Last summer, I started a workshop for high school students in my hometown in India. During this three-week intensive workshop, the participants learned C programming, basic simulations, and completed a hands-on robotics project.

4 Conclusion

I hope to continue my research as a PhD student. In the meanwhile, I will pursue the aforementioned research topics, but I am eager to tackle other interesting problems. I am very excited to formulate new ideas through interactions with students and faculty at your institute, which will allow me to broaden my research horizons. I look forward to an enriching learning experience that will help me pursue my academic career.

[1] https://goo.gl/G1vsMB

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