Statement of Purpose

Ray Tsai

I am applying to the Master's program in Operations Research at MIT to translate my mathematical foundation, particularly in combinatorics, to abilities that can address real-world problems. My primary interests lie in combinatorial optimization, and I envision myself contributing to fields like transportation systems and resource allocation in the industry.

As a mathematics-computer science major at UC San Diego, I placed most of my attention to mathematics in my undergraduate studies, primarily through honors and graduate-level coursework. While I appreciate the beauty of pure mathematics, I wasn't satisfied pursuing abstract mathematics for its own sake. I instead looked for a field in mathematics with a closer connection to the real world and turned to graph theory, the study of relationships that can model a wide range of practical problems effectively.

During my sophomore year, I began my research journey by directly reading under Professor Jacques Verstraete, exploring the vast literature on extremal graph theory. Through the readings, I was exposed to a variety of powerful techniques for tackling extremal graph problems, such as probabilistic methods, stability, and finite geometric constructions, which laid the groundwork for my honors thesis centered on the Double Turán problem. The problem asks for the maximum possible number of edges across n subgraphs of a complete graph K_n such that no pairwise intersection of these subgraphs contain a specified forbidden structure. After dedicating my summer to studying the triangle-free case, I established a tight upper bound on the number of edges under the stricter condition that each subgraph is induced. Specifically, I showed that the extremal condition is uniquely achieved when all subgraphs are complete bipartite graphs, by recursively expanding the intersection of all subgraphs. This case serves as a stepping stone for the project, and I am currently working on the general triangle-free case.

Expanding my interests to include the computational aspects of combinatorial problems, I had the opportunity to learn about computational complexity theory directly from Professor Russell Impagliazzo, studying Arora and Barak's text, Computational Complexity: A Modern Approach [1]. With this foundation, I then joined Professor Impagliazzo's research group, studying Multicalibration to mitigate unintended biases to certain subpopulations in learning models from the perspective of complexity theory. This research opened my eyes to the surprising connections between abstract mathematical concepts and the practical applications of machine learning. Specifically, the project brought the application of extremal combinatorics and complexity theory to a new level by modeling the fairness of algorithms with the random-like structures yielded by Szemeredi's Regularity Lemma, further strengthening my commitment to applying theoretical results to practical problems.

Operations Research program at MIT provides rigorous theoretical training while emphasizing on practical implementations, which perfectly aligns with my goal of translating my mathematical expertise into a career focused on developing practical algorithms and solutions. I aim to contributing to fields related to transportation networks, where combinatorial tools are applied extensively, and taking courses like Combinatorial Optimization (18.433), Network Optimization (15.082J), Logistics Systems (15.770J), and Air Transportation Operations Research (16.763J) would provide me the necessary background of combinatorial applications and challenges in transportation.

I am particularly drawn to the research conducted at the MIT Operations Research Center, especially in network optimization and air transportation. One research topic I am eager to explore is the optimization of medical evacuation (MEDEVAC) helicopter routing — a critical issue with significant implications for emergency response scenarios. Born and raised in Taiwan, I am particularly invested in this topic due to the potential military conflict between China and Taiwan. Optimizing MEDEVAC helicopter routing could play a vital role in saving lives during such crises, and I hope to contribute to this area by leveraging Professor James Orlin's expertise in network optimization and my background in combinatorics.

Furthermore, I am inspired by Professor Alexandre Jacquillat's extensive work on aircraft routing and scheduling, particularly his research on vertiport planning for urban aerial mobility [2]. This work is highly relevant to optimizing MEDEVAC helicopter routing in urban environments like Taipei during a conflict. By applying these methodologies, I aim to develop solutions that not only address potential conflicts but also offer a general framework for MEDEVAC routing in diverse emergency contexts. I believe my research in this area could provide a blueprint for enhancing emergency medical response capabilities worldwide.

I have only begun to scratch the surface of operations research, and there are still a lot of topics to explore. I am excited about the prospect of joining MIT's Master's in Operations Research program to expose me to a broader range of topics in operations research through rigorous coursework and extensive research opportunities. With the mathematical foundation I built during my undergraduate studies, I am confident in my ability to excel in the program and evolve into a capable problem-solver. I look forward to contributing to the vibrant academic community at MIT and bridging the worlds of mathematics and real-world problems.

References

[1] Sanjeev Arora and Boaz Barak. *Computational complexity: a modern approach*. Cambridge University Press, 2009.

[2] Wang Kai, Alexandre Jacquillat, and Vikrant Vaze. Vertiport planning for urban aerial mobility: An adaptive discretization approach. *Manufacturing & Service Operations Management*, 24(6):3215–3235, November 2022.