Statement of Academic Purpose

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My research interests lie in uncovering the mathematics that drives Machine Learning and deep learning and their theoretical nature. What are the theoretical foundations explaining the success of deep networks? Are there inherent limits to their expressiveness? What are the potential applications of learned representations in various domains, such as computer vision, natural language processing, and speech recognition? How do we address the challenges of interpretability and explainability in these learned representations? I aim to explore these problems to develop an understanding of the theoretical limits of Machine Learning. I am particularly interested in understanding and applying these algorithms across engineering and natural sciences to build intelligent systems and conduct research in physics and mathematics to solve problems such as approximating numerical computations using neural networks, astronomical simulations, assisted theorem proving, etc. My unwavering passion for engineering and research is evident in my academic achievements during my undergraduate years, reflected in my transcripts and my active involvement in extracurricular activities. My journey has underscored the importance of further specialization and enrichment, which I believe a master's program can provide, laying the foundation for a future Ph.D. pursuit. In this regard, I am convinced that Cornell University is the ideal place to nurture my potential.

During my bachelor's I was extremely fascinated by astrophysics and its intersection with computer science. In my junior year, I led a team of three and delved into the research on neural network applications in galaxy morphology classification. Identifying galaxy morphologies has important implications in many astronomical tasks, e.g., studying galaxy evolution. The recent data influx in astronomy necessitates a robust and automated system for processing large amounts of images. We aimed to set up a 7-class classification system that classified galaxy images using CNNs, which can surpass existing benchmarks. I was responsible for establishing a robust training pipeline and optimizing various neural network architectures from the ground up. Our collective efforts outperformed the second-best submission on the Kaggle Public Leaderboard. I gained a profound understanding of the intricacies of applying deep learning to various tasks and explored aspects such as hyperparameter tuning, debugging, troubleshooting, and custom model design—each underscored by a need for a profound grasp of the underlying theory. Consequently, I eagerly anticipate the advanced topics in coursework such as "Deep Learning" offering a more in-depth exploration of the core principles of deep learning and practical implementations compared to my prior senior-year coursework. I am extremely interested in working with Prof. Alex Townsend because of his interest in the theoretical aspects of deep learning. I believe all of this will equip me with the mathematical principles necessary to succeed in my research pursuits.

The Galaxy Morphology Classification project proved to be a stepping stone in connecting astrophysics to computer science. Soon after that project, I began contributing to EinsteinPy, an open-source Python package designed to address issues in General Relativity and gravitational physics. My work specifically involved incorporating various symbolic computations, such as the Reissner–Nordström metric and calculations for the event horizon and ergosphere of a Kerr-Newman black hole. While symbolic computations are valuable in controlled environments, real-world problems often necessitate approximate rather than exact solutions. The potential for deep learning in simulating complex system behaviors is vast, e.g., in surrogate modeling where we can use deep learning to approximate behaviors in complex systems allowing for faster evaluations when original simulation using numerical methods is computationally expensive. I wish to leverage deep learning for such tasks, accelerating scientific discovery in the future. I am highly interested in research of Scientific Computing group. I am eager to learn various concepts of physical simulations from Prof. David Bindel. His interests in mathematical analysis and numerical methods for data science overlap with my own. On top of that, Prof. Anil Damle's interest in development of fast algorithms is intriguing. Working with him on such techniques could potentially help me develop algorithms for large scale simulations, which are also compute efficient. I would enjoy working with them in this area and learn more about numerical linear algebra, numerical methods and physical & mathematical modeling.

For my bachelor's thesis, I worked on utilizing Conditional GANs for astronomical image colorization. Space archives are filled with large amounts of low-quality, greyscale images, many of which go unnoticed. I was interested in utilizing generative models for creating aesthetically pleasing representations of celestial scenes. Generative models are attractive because they enable us to better understand, create, and work with data, having many practical and theoretical implications. In my work, I focused on tasks like image-to-image translation and style transfer, where I realized the need for distributional robustness in my application to maintain quality in my output images, even in varying conditions. GANs often deal with high-dimensional data and are used for various conditional image generation tasks, hence, it is

important to study their optimization landscape and convergence guarantees. In my ongoing academic journey, I'm equally interested in gaining a theoretical understanding of how various neural network models generalize, especially in complex, high-dimensional spaces when provided with different conditions or inputs. Prof. Florentina Bunea's interests in high-dimensional statistics and ML theory would tremendously help me navigate these concepts. Undergraduate studies seldom comprehensively cover advanced machine learning theory. In this regard, I see coursework such as "Advanced Machine Learning" by Prof. Thorsten Joachims as well as working with Prof. Karthik Sridharan on theoretical ML for understanding the underlying foundation as exhilarating opportunities to immerse myself in these concepts more formally than ever and create ML algorithms in the future with provable guarantees.

For the past two years, I have been working as an ML consultant at Relfor Labs, an AI startup. My professional experience in Machine Learning has further motivated me to pursue graduate studies to kick-start a research career. The scientific landscape has been consistently evolving, but many longstanding problems have eluded complete solutions for many years. Looking into the future, I wish to make a difference in this significant era. My determination to pursue a research career is unwavering, and I eventually aspire to work in an academic setting as a professor. The vibrant community of students and researchers at Cornell is the perfect place for me to nurture myself and further my commitment to help expedite this scientific advancement. Thank you for considering me as a prospective student at your university.