Personal, Relevant Background, and Future Goals Statement

Summary of Personal, Relevant Background, and Future Goals Statement:

I was first introduced to computer science during my freshman year at Bowdoin College out of curiosity, after initially planning to study economics for practical reasons. I believed it would offer the best chance to succeed as a low-income student. My entry to research was similarly pragmatic. It was a work-study job that paid my way through college. Yet in that intersection of necessity and opportunity, I discovered something unexpected: a genuine passion for research that has fundamentally shaped my intellectual identity and future. Three years later, that "job" has become my purpose and the vision guiding my graduate studies.

My first research experience, with Professor Abhilasha Kumar at Bowdoin, focused on computational modeling of lexical processes in deaf populations using cochlear implants. I developed methods to process semantic word embeddings for Forager, a Python package modeling memory search from verbal fluency tasks, and combined semantic representations (word2vec, speech2vec) with optimal foraging theory to model within- and between-cluster transitions during categorical fluency tasks. Our analysis revealed that cochlear implant participants emphasized speech-derived representations more than hearing participants, challenging our initial hypothesis. This work was published in the Proceedings of the 46th Annual Meeting of the Cognitive Science Society (2024), and presenting our findings at the conference in Rotterdam transformed my understanding of what research could mean. It was not just an academic exercise, but a pathway to help people better understand how the world works for those whose experiences differ from the majority.

This experience solidified my conviction that computer science is uniquely powerful for addressing real-world problems. I began seeking research that would let me operate at both theoretical and applied levels to understand the principles underlying modern deep learning while also ensuring those principles translate into practical solutions that matter. This led me to work with Professor Jeova Farias on developing Convolutional Nearest Neighbors (ConvNN), a novel framework that generalizes standard convolution by allowing each pixel to aggregate information not only from spatial neighbors, but also from its k most similar features in feature space, regardless of spatial distance. This hybrid approach enables networks to capture both local structural patterns and long-range semantic dependencies. Our work also revealed a connection to self-attention mechanisms, demonstrating that ConvNN can be interpreted as a computationally efficient alternative to softmax-based attention. We have achieved significant improvements in image classification accuracy on benchmark datasets (CIFAR-10/100) and are preparing this work for submission to IEEE/CVF CVPR 2026.

Complementing this theoretical work, I pursued supervised learning for accelerated MRI reconstruction with Professor Ulugbek Kamilov at Washington University in St. Louis. Working directly with clinical patient data from Washington University School of Medicine, I investigated how undersampled k-space MRI data can be effectively reconstructed using deep learning—a problem critical for making clinical MRI more accessible and reducing scan times. I developed a U-Net architecture with data consistency layers enforcing k-space fidelity, and solved the technical challenge of preserving phase information in complex-valued MRI data by treating complex values as pairs of real values. This work achieved 37 dB PSNR and 0.923 SSIM on 4x accelerated reconstructions, and demonstrated to me how theoretical advances in deep learning can have immediate relevance in clinical settings.

These research experiences have taught me that I thrive at the intersection of theory and application, and that I am genuinely motivated by problems where both dimensions matter. I have developed the ability to learn quickly across domains, implement sophisticated architectures, and translate mathematical principles into working systems that address real problems.

Intellectual Merit

My graduate research will focus on advancing efficient neural architectures at the intersection of computer vision and computational imaging, with particular emphasis on medical imaging applications.

Specifically, I plan to deepen the theoretical understanding of ConvNN and extend it to computational imaging problems where efficiency is crucial both computationally and environmentally.

The core intellectual problem I want to address is: how can we design neural architectures that are theoretically principled (unified through geometric properties of feature space), computationally efficient (reducing energy consumption, memory requirements, and computational costs), and practically applicable to medical imaging (maintaining clinical-grade image quality with minimal artifacts)? ConvNN represents a promising direction as it unifies convolution and attention through k-nearest neighbor selection, which enables networks to achieve comparable performance to standard attention while dramatically reducing computational overhead (25% reduction in GFLOPS in preliminary work).

In my PhD, I will extend ConvNN to medical imaging domains beyond MRI: accelerated CT reconstruction, limited-angle tomography, and other inverse problems where undersampled acquisition is necessary. I will investigate how ConvNN's efficiency properties scale to clinical problem sizes, and whether the local-global feature aggregation inherent to ConvNN can improve reconstruction quality and robustness to noise compared to standard approaches. I am also interested in the fundamental question: what properties of feature space geometry make certain architectures more sample-efficient and generalizable? This work will contribute both to theoretical understanding of modern deep architectures and to practical advances in making medical imaging faster, more accessible, and less resource-intensive.

Broader Impacts

Now, as a senior reflecting on my undergraduate years, I recognize that my path has not been straightforward. I have navigated family instability, mental health challenges, and periods of housing insecurity during college breaks. For a long time, I believed these struggles had no place in my academic or professional life; success meant compartmentalizing pain and presenting only the "scholar" version of myself. But Bowdoin changed that. Professors who believed in me demonstrated that my lived experiences were not liabilities to overcome, but rather assets that informed how I saw the world and the problems I wanted to solve.

Research became my anchor during these difficult moments. On days when personal challenges felt overwhelming, the work was constant. On days when experiments failed, there was always something to learn. Research taught me resilience, not as an abstract concept, but as a practice. Some days bring meaningful results, while others require starting over completely. Through it all, research became more than passion—it became my source of stability and purpose.

As a peer tutor and teaching assistant in my senior year, I am determined to be for others what my professors were for me. I work with students from diverse backgrounds who face similar challenges of financial insecurity and low-income status. I don't view these roles merely as work; I view them as opportunities to connect with and uplift my community. I may never know the full scope of what my students face outside the classroom, but I can offer support, perspective, and the knowledge that research can become a source of purpose and stability, just as it has for me.

In graduate school, I plan to continue this commitment to mentoring and community while pursuing my doctorate in computer science. I want to work in an environment where rigorous research and genuine care for people are both valued. Beyond my own research contributions, I am committed to creating pathways for students from underrepresented backgrounds and immigrant communities to see themselves in computer science research.

I envision my career as both a researcher and a mentor, someone who advances the theoretical and practical frontiers of efficient neural architectures, and who uses that platform to open doors for others who, like me, discovered their passion in an unexpected place. I want to show students from my community that excellence in STEM is built by people who have learned to solve problems with limited resources, who understand the value of efficiency out of necessity, and who see technology as a tool for making the world more accessible to everyone.

References:

[1] Kumar, A.A., Kang, M., Kronenberger W.G., Jones M.N., Pisoni D. (2024). Structures and

process-level lexical interactions in memory search: A case study of individuals with cochlear implants and normal hearing. *Proceedings of the 46th Annual Meeting of the Cognitive Science Society (Vol. 46)*.