Personal Statement

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My fascination with machine learning methods used to accelerate progress in biomedical fields was fostered by my experiences as an undergraduate working on projects ranging from predicting rib cage structures to mapping out blood vessel networks. Looking ahead, I believe that pursuing a **PhD in Computer and Information Science at the University of Pennsylvania** will prepare me for a research career focused on developing **deep learning techniques with broad relevance in neuroscience and computer vision**.

A few weeks into my freshman year at Boston College, I applied to work at Prof. Donglai Wei's Computer Vision Lab. Having prior experience with computer vision techniques in interdisciplinary settings, I was intrigued by the lab's specialization in **connectomics**—a field focused on **reconstructing the brain's wiring diagram from small samples of tissue imaged at nanometer resolutions**. Over the course of a few months navigating the literature, acquainting myself with the PyTorch Connectomics codebase, and figuring out how to submit SLURM jobs on the Boston College Linux Cluster, connectomics was demystified ever so slightly.

Through my first research project at the lab, I was introduced to Shixuan Gu, who was then a master's student at Carnegie Mellon. He hypothesized that the Frenet-Serret formulas from differential geometry could be used to improve the detection of aneurysms and synaptic connections by "straightening" blood vessel and dendrite geometries before they are fed into machine learning models. After I implemented and ran experiments for dendritic spine segmentation, we hastily prepared a manuscript detailing how enforcing this **equivariance** allowed our **point cloud models** to maintain high performance with **significantly less data and fewer augmentations** on our datasets. Despite my eagerness to land my first deep learning publication, our submission was rejected at MICCAI 2023.

Taking feedback from the rebuttal to heart, I evaluated the performance of modern point cloud architectures, implemented 5-fold cross-validation across our benchmarks, and manually inspected our annotations for the 4,476 dendritic spines we had. I performed detailed analyses studying how our transform induced cross-domain generalization—allowing models trained on the dendrites in the mouse somatosensory cortex to demonstrate **strong zero-shot performance on structures in the mouse visual cortex and human frontal lobe**. We submitted the manuscript to IEEE Transactions on Medical Imaging last month [D]. While I hope to do work that accelerates scientific progress, this project taught me that proper science is "slow," requiring meticulous attention to detail and the humility to recognize mistakes.

During the summer of 2023, I was awarded a $4,800 stipend by the Boston College Eagle Intern Fellowship, which gave me the opportunity to branch out into **biomedical imaging** as an intern at the EPFL CVLab in Switzerland. Under the guidance of Dr. Jiancheng Yang and Prof. Pascal Fua, I contributed to the **Heart Augmented Reality Training System**, which aimed to develop a **surgery simulator for practicing catheter insertion**. The setup involved a simple box equipped with cameras to track catheter movements, which were mapped onto a 3D heart model displayed on screen, providing a more interactive training experience.

Sitting across from two PhD students, I gained valuable insights into their work on applying neural fields to novel view synthesis and implicit surface representation problems. Incorporating what I had learned, I was tasked with integrating models pretrained on the TotalSegmentator organ segmentation dataset with Dr. Yang's prior work on **latent-conditioned shape templates**—in order to **generate anatomically correct heart models from patients' MRI scans**. This work was published at the International Conference on Medical Image Computing and Computer Assisted Intervention 2024 [G]. Besides showing me how integral the exchange of ideas is to the research process, the internship allowed me to see that machine learning tools were not merely academic, having real promise in improving patient outcomes.

Presently, my research spans three projects: enhancing the PyTorch Connectomics framework using segmentation guided contrastive learning foundation models, clustering neurons in fresh-water polyps using translation and rotation equivariant autoencoders, and adapting cell tracking solutions to extract whole-brain neural dynamics in roundworms.

Neuroscience research has led me to develop segmentation models for dendrites [D], synaptic vesicles [A, B, F], and cerebral vasculature [D, E]. Last summer, I expanded on this work by developing benchmarks for neural activity trace extraction from calcium imaging [C], aiming to advance efforts in reverse-engineering the *C. elegans* nervous system. Going forward, I hope to study how machine learning can be leveraged to better understand cognition while also investigating neuro-inspired architectures. I am drawn to **Prof. Konrad Kording's** line of research on the nematode's connectome and methods for neural decoding. I am also keen on exploring the connection between deep neural networks and brain activity through fMRI under the guidance of **Prof. Jianbo Shi**.

Central to all my past work has been **computer vision**. I have extensive experience training point cloud architectures to process dendrites in 3D microscopy [D] and rib cage structures in CT scans [H], which aligns with Prof. Shi's efforts in point cloud analysis. In terms of equivariance, my projects have involved using E(2) equivariant autoencoders to cluster vesicles in *Hydra vulgaris* neurons [A, B] and adapting the Frenet-Serret formulas to induce invariance to deformations in anatomical structures [D]. I would be open on studying how geometric priors can empower data-efficient models under **Prof. Kostas Daniilidis**.

I am applying to the NSF Graduate Research Fellowship Program, DOD National Defense Science and Engineering Graduate Fellowship Program, DOE Computational Science Graduate Fellowship, Paul & Daisy Soros Fellowships for New Americans, and Graduate Fellowships for STEM Diversity to seek additional funding.

I believe that my interdisciplinary background, spanning vision foundation models, imaging modalities, and biomedical applications, has uniquely prepared me to contribute to rigorous research at Penn.

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