Statement of Purpose

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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 Computing and Mathematical Sciences at the California Institute of Technology** will prepare me for a research career focused on developing **deep learning techniques with broad relevance to science, with an emphasis on neuroscience and clinical applications**.

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.

Longer term, **I aspire to become a professor to follow my passions for both research and mentoring**. My commitment to making education more accessible has been shaped by my experiences dealing with **financial constraints as a first-generation American** of Indonesian descent—I am grateful for the full-tuition scholarship and need-based aid that made my undergraduate studies possible. To pay it forward, I have taken on teaching roles in Boston and Indonesia and I intend to continue working on science outreach in Pasadena.

Presently, my research spans three projects: enhancing the PyTorch Connectomics framework using seg-

mentation guided contrastive learning foundation models, clustering neurons in fresh-water polyps [B] using translation and rotation equivariant autoencoders [A], and adapting cell tracking solutions to extract whole-brain neural dynamics in roundworms [C].

Neuroscience research has led me to develop segmentation models for dendrites [D], synaptic vesicles [A, B, F], and cerebral vasculature [D, E]. **Prof. Yisong Yue's** recent work using transformers to improve neural activity decoding aligns with my interest in advancing neural data analysis. Last summer, I tackled a related but lower-level challenge by developing benchmarks for neural activity trace extraction from calcium imaging [C]. This was an effort to scale up the data collection pipelines needed to train models of the *C. elegans* nervous system. I am eager to continue this research direction, crafting machine learning solutions to decipher large-scale neural data.

My previous work on multi-seed tracking schemes—which adapt the Segment Anything Model (SAM) for segmenting blood vessels in volumetric microscopy images [E]—parallel's **Prof. Georgia Gkioxari's** approach of adapting SAM for cell segmentation through prompt engineering. In addition, I have extensive experience training point cloud architectures to process dendrites in electron microscopy [D] and rib cage structures in CT scans [H], which relates with Prof. Gkioxari's recent paper on 3D part segmentation. This background has fostered a strong focus on **3D computer vision**.

My experience with **symmetry** includes using E(2) equivariant autoencoders [A] to cluster vesicles in *Hydra vulgaris* neurons [B] and adapting the Frenet-Serret formulas to make point cloud networks invariant to deformations in dendrites and blood vessels [D]. I am eager to explore how equivariant transforms can enable data-efficient models for the natural sciences under **Prof. Anima Anandkumar**. Additionally, I would be interested in branching out into Prof. Anandkumar's work on vision models for surgical procedures.

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 Caltech.

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