

## Statement of Purpose

The COVID-19 pandemic induced a significant strain between the demand for and relatively fixed supply of available physician labor, thereby threatening its ability to function properly in the future. As such, and in memory of my grandfather who died due to insufficient medical resources, I resolved to develop intelligent healthcare solutions to help more people avoid the misery of disease and premature death. Witnessing the development of artificial intelligence has reinforced my belief that machine learning can help medical professionals better use their expertise to make decisions and mitigate the labor shortage, especially for medical imaging for screenings, precision medicine, and risk assessment. However, the community has had difficulty building unified diagnosis models for several common diseases. Therefore, I am pursuing the M.S. in Electrical and Computer Engineering at the Georgia Institute of Technology where I will refine the skills needed to contribute to machine learning and medical imaging by developing a multi-modal multi-task unified model for diagnosing disease.

My academic trajectory is like a gradient descent algorithm  $\theta_{n+1} = \theta_n - \eta \nabla F(\theta_n)$ , where  $\theta$  is my life goal,  $\eta$  is the step length,  $\nabla F(\theta)$  is my research interest (descent direction), and the most important thing is my resolution to keep moving to the next point in the curve. In this regard, my undergraduate studies in Electronic Science and Technology at Southeast University exposed me to several promising machine learning projects for medical diagnosis, including medical imaging and signal processing. For example, under the supervision of Professor Hao Liu at the National ASIC Engineering Research Center, I led the “Arrhythmia Detection” project which aimed to design and deploy an efficient arrhythmia detection algorithm on resource-constrained devices. After noticing quantization methods suffered from accuracy degradation, I suggested pruning useless parameters and emphasizing essential network layers. Inspired by existing methods that quantize weights and activations of deep neural networks into multiple binary bases, I proposed a 1D adaptive loss-aware multi-bit networks quantization method to allocate different bitwidth for respective layers, balancing high performance (95.84% accuracy) and low resource consumption ( $23.36\times$  compression rate). This experience confirmed the prospect of deployment on wearable devices to realize a real-time arrhythmia diagnosis, prompting me to investigate the difficulty of deploying more sophisticated models to support 2D medical images.

To extend my domain expertise in this area, I joined the PAttern Learning and Mining Lab to focus on medical imaging, especially fundus and chest X-ray images. Previous models mainly focused on a specific task and modality, meaning information was restricted from a single source. To address this issue, our team set out to develop a multi-modal multi-task model for massive datasets from different disease domains. Initially, I found the model suffered greatly from medical label uncertainty and inconsistency. Taking chest X-rays as an example, most datasets have employed rule-based natural language processing to radiology reports to extract labels automatically which frequently results in label noise. Therefore, I introduced inter- and intra-instance consistency regularization to provide consistent predictions for images with similar medical findings to combat noisy labels. Next, I trained models on multi-datasets with data imbalance to take advantage of the attention mechanism and correlation between tasks. One finding showed that a unified model trained under such settings could outperform single-task models even when downstream task domains lacked similarity; however, executing the development still posed challenges.

Leveraging my exposure to medical imaging, I joined the University of Alberta as a Research Intern where I was tasked with designing a model lacking prior abnormality information to identify

and localize anomalies in optical coherence tomography (OCT) images. Initially, I wanted to build a hybrid architecture incorporating many models to improve detection performance, as it is the easiest way to balance respective outputs simultaneously. However, my professor proceeded to exclaim: *“What is the motivation of the method? Research is not piling others’ ideas and pursuing model accuracy without a big picture. Hanshi, you should think critically about whether it makes sense and keep striving to become a scientist.”* After comprehensively investigating pathological features, I discovered the uniqueness of the OCT images, different from natural images, have notable regular structure features (e.g., structured anatomy). Stimulated by this finding, I presented an architecture to integrate segmentation knowledge as privileged features, incorporating privileged features distillation and reverse distillation methods with the help of structure extraction networks. The result exceeded my expectations, outperforming state-of-the-art methods such as STFPM by 5.76%. Ultimately, I realized that medical images have high similarity in overall structure and diversity in details; however, encoding the uniqueness of medical images precisely into the model is a challenging task.

Currently, I am working as an R&D iPad System Intern at Apple. One of my assignments is to capture and reduce the camera noise for coexistence testing. My work and research experiences have shown it is typical to find noise in images. For some use cases, noise is not disruptive; however, for medical imaging, one small noise spot can significantly impact a diagnosis. Conscious of this issue, my time at Apple has empowered me to define my future research direction and gain a sense of image noise problems which can be challenging to research.

I am drawn to the program at Georgia Tech due to its leading position in machine learning and medical imaging research. I dream of joining Professor Vince Calhoun’s group, whose research interests in machine learning align perfectly with my focus. I admire Professor Vince’s recent work, “Machine Learning Over Encrypted Distributed Neuroimaging Data,” which demonstrated a method that leverages the potential of datasets spread among some data-collecting organizations when only encrypted data is shared and manipulated, inspiring me when I was doing research related to patients’ privacy-preserving. I aspire to explore similar approaches to further protect data privacy via distributedly storing medical data and only sharing the model updates. I am interested in Professor David V Anderson’s projects on sparse network architecture, which is a promising way to increase model robustness. Beyond research, Georgia Tech’s customizable curriculum will enable me to acquire the knowledge needed to build my ideal diagnosis model, including security and networking, given the need to protect patients’ private data. Upon completing the program, I plan to pursue a Ph.D. before progressing to a career in R&D or academia.