STATEMENT OF PURPOSE

While pursuing my master's degree in Biomedical Engineering (BME) at Duke University, I had the privilege of exploring a range of research domains in Machine Learning (ML) such as Digital Image Processing, Generative Modeling, Robustness and Bias in Artificial Intelligence (AI) and Signal Processing. Based on this experience, an intersection of biomedical signal processing and multimodal machine learning has emerged as a focal point for my PhD aspirations.

ML research in BME has predominantly focused on unimodal learning tasks, usually using one type of modality (biomedical images, medical records, wearable sensor data, etc.) but real-world biomedical data is often a combination of multiple modalities in conjunction with abstract concepts (disease progression, treatment response, patient outcomes, etc.). Human learning is usually multimodal involving interpretation of complex entity relationships and interdependencies between variables and concepts from different modalities. To make machine learning models capable of such inference, we need to capture these complex interdependencies with multimodal learning into one model. With that in mind, I am interested in focusing my Ph.D. research on developing machine learning models for such multimodal learning with special emphasis on biomedical applications.

During my first semester, I got captivated by the role of generative models in drug discovery, leading to my research project on "Reinforcement Learning for Generation of Novel Non-toxic Molecules" under the guidance of **Prof. Daniel Reker**. I used a generative model trained with the Chembl dataset and compared classifiers (Random Forest, SVM, MLP) on the Tox21 dataset, optimizing the network for non-toxic structure generation. SVM, with the highest recall, was integrated into a reinforcement learning pipeline, resulting in a bias towards non-toxic molecules in the generated compounds. This research project kindled my interest in generative modeling.

Robustness in AI, is a new paradigm in machine learning that aims to develop AI systems that are resilient to noise, uncertainty, and unexpected changes in their environment. I was introduced to this concept while working on a research project to build ML models using microscopic image data that had spherical aberrations, which often hampers the precision of segmentation tasks under **Prof. Roarke Horstmeyer**. As a team, we developed a solution that involved integrating a trainable physical layer into the UNET network architecture. We evaluated three different versions of this solution and found that employing Zernike polynomials for correction demonstrated superior segmentation accuracy. It would be highly advantageous for healthcare AI models to possess the capability to autonomously correct themselves and maintain consistent, reliable performance, even when confronted with inherently aberrant or inconsistent datasets.

Fairness and Bias in AI, especially in healthcare, is of paramount importance. I explored bias in clinical prediction models to study the effect of race on model performance under **Prof. Jessilyn Dunn**. I evaluated the predictive capabilities of machine learning algorithms for 30-day hospital readmission after hip fracture repair surgery, specifically examining potential performance disparities by race. I employed random forest with lasso regression for this work. However, underrepresentation of minority classes in the existing datasets underscores the need for more diverse healthcare datasets for future research, a fact that I would like to be mindful of in my future research activities.

I have been fortunate to be involved as a Research Assistant (RA) in two of Duke's Biomedical Engineering laboratories. My experience as an RA in the Computational Optics Lab under **Prof.**

Roarke Horstmeyer has reinforced my interest to pursue further research in the vision and image processing domain for my PhD. I gained hands-on experience in cell image data acquisition, processing, and annotation. I acquired and processed this data using a microscopic system at various magnifications, and developed code to annotate cells in low-magnification images and transfer annotations to higher-magnification counterparts. My work to transfer annotations between images of different resolutions could be used to develop new methods for multimodal learning that can handle data from different modalities with different resolutions.

Since last summer, I have been actively working as an RA on building ML models using temporal biomedical signals for assessing Traumatic Brain Injuries (TBI) in mice models. This work is being done at Duke's Applied Machine Learning Lab under the guidance of **Prof. Leslie Collins**, **Prof. Boyla Mainsah**, and **Dr. Bradley Kolls**. Our research introduced an automated approach for feature extraction from EEG data. We developed a convolutional autoencoder to condense EEG signals, preserving vital information while reducing dimensionality. These encoded features were then used in clustering and topic modeling techniques, including Latent Dirichlet Allocation (LDA), to reveal hidden patterns in TBI data. This methodology streamlines analysis and uncovers complex relationships, offering valuable insights for TBI research and assessment. We are further exploring modern clustering methods like BertTopic to investigate TBI severity and recovery patterns in mice models. This work aims to develop machine learning tools that can be used to improve the diagnosis and prognosis of TBI, and to identify new therapeutic targets.

During my undergraduate years, I have been fortunate to get an opportunity to do research under the guidance of many eminent researchers from University of Pennsylvania, Stony Brook University and MIT-ADT University Pune. One project that stands out is a project on transfer learning for oral cancer detection, a collaboration with Stony Brook University and a dental hospital[1]. With real patient data, I worked to use pre-trained image classification models (InceptionNet, MobileNet and ResNet) and applied transfer learning strategies to oral cancer data, achieving a 10-15% accuracy improvement. We summarized this work as a research paper uploaded on arXiv, and I was very delighted to learn that my first paper has been cited by various research groups several times.

I have also been a **Teaching Assistant** for two courses while at Duke and I have thoroughly enjoyed my teaching experience. Each experience thus far has proven to be a great source of motivation leading me to decide to pursue a career in academic research. I strongly believe academia is one of the most impactful careers that provides an avenue to drive research and push the boundaries of knowledge. I would like to continue in academic research after my PhD.

To embark upon an academic research career path, Ph.D. at Columbia University is undoubtedly the appropriate next step for me. Columbia is one of the esteemed research institutions in the world where Biomedical AI research is already underway. I want to be part of such research efforts that will certainly define the course of tomorrow's AI research in healthcare going forward. I would be honored to have an opportunity to do research work under the guidance of **Prof. Elham Azizi**, **Prof. Andrew Laine**, **Prof. Nima Mesgarani**, **Prof. Kaveri Thakoor**, and **Prof. Sanja Vickovic**, as their work is highly synergistic to my PhD research interests as outlined above. I am confident that with my relevant research experience, intellectual curiosity and team spirit, I will be able to contribute effectively to Biomedical AI research and my research group.

[1] https://arxiv.org/abs/2011.11610