RESEARCH STATEMENT

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My research interests are to work on optimization of AI models, the integration of reliable and explainable AI methods into computer graphics, robotics and computer vision applications to accelerate their performance and improve accuracy. Broadly put, I want to answer two important research questions – "How can we make AI more explainable and trustworthy?" and "How can we apply AI to solve problems that are difficult to solve using conventional methods?"

MY RESEARCH GOALS AT IDEAS LAB

IDEAS lab works on human motion and behavior learning and the interactions between robotics and computer graphics/vision with humans through human-in-the-loop analysis. I believe that my background in ML will help me analyze motion synthesis problems from an AI perspective. There is a lot of work going on in rendering realistic motions, such as realistic rendering of human facial expressions, realistic robot movements. I am interested in applying AI techniques to achieve realistic movements in the field of robotics and computer graphics. I am further interested in building models that are faster and more efficient than conventional graphics rendering models.

PHYSICS INFORMED MACHINE LEARNING

In the summer of 2022, I worked at ResconAI, a research startup, where I collaborated with Dr. Suhas Prameela Eswarappa from MIT and Dr. Burigede Liu from Cambridge university, who are working on designing AI based solutions to solve partial differential equations (PDE). The reason for exploring AI solutions stemmed from the fact that methods such as Finite Element Method are computationally expensive. My contribution was to understand a new type of architecture - Fourier Neural Operator (FNO), designed by Dr. Liu's team at Caltech, and adapt it to solve generalized PDEs. In the past, FNOs were used to solve specific types of PDEs but not a general elliptic PDE. The project helped me realize that FNOs have extremely fast training times, they are comparable to conventional methods in terms of accuracy and I came across research that showed that they perform better than the state-of-the-art weather prediction models, which led me to consider the potential that FNOs have in solving time-series prediction problems. I authored an article summarizing the study analyzing neural operators against other conventional methods. This article will be published in *Nature Physics Communications*.

I see a lot of potential in physics informed neural architectures and would be interested to work on applying them to solve research problems. I identify quite a few areas where FNO might outperform traditional models, such as generating missing frames from video footage, predicting faults/failures from time series data, object motion prediction (robotics – crash prediction from trajectory), recovering lossy audio or recovering lost packets in an unreliable network, optimizing for storage by dropping data points (Frames, bits etc.) from time series data and using FNO to recover these data points.

NATURAL LANGUAGE PROCESSING AND INTERPRETABILITY

I am currently working with Dr. Tianyi Zhang at Purdue university, as part of CS59000 independent study to identify fairness and trust issues with large pretrained language models in an effort to make NLP systems more unbiased and trustworthy. My research involves building a python toolkit, similar to Cafy or Scikit Learn, to make bias detection metrics (WEAT, HONEST, StereoSet, CrowS, WinoBias etc.) and mitigation techniques (counterfactual data augmentation, self-debiasing etc.) accessible to end users. Through my research, I have inferred that these metrics have been evaluated in very specific settings (against one specific model or with one specific dataset) and a lot of work is required in making them plug-and-play. I have worked on decoupling such mathematical techniques from specific social constructs such as gender and race, to ensure that these methods can be applied to other social groups. Apart from designing application interfaces, my research also includes determining where these metrics are applicable, where they fail and how they can be improved. A lot of my work has involved understanding these metrics from a mathematical perspective and understanding how other researchers have implemented these metrics. My contribution was to go through large codebases and decouple various bias detection metrics from language models and template datasets to make them more generic and adaptable. I built wrapper classes and generic interfaces that would allow users to use these mathematical tools in more flexible settings, such as against their own dataset or their own custom language models. My work is going to be sent to *ACL findings* as a research paper.

This project led me to define some new research questions which interest me, such as applying Language model techniques in other domains such as speech to vision or speech to motion conversion etc.

MACHINE LEARNING IN IMAGE PROCESSING AND 3D GEOMETRY

Another research project I worked on during my undergraduate studies was exploring the applications of AI in generating 3D models from 2D images, which had potential in creating real world replicas for virtual environment, an area that has potential due to Metaverse. My team and I experimented with Capsule Networks, GANs and Autoencoders to generate depth maps from images. A breakthrough idea I had was to remove color from images because that was unnecessary information which was confusing the neural network. I inferred that color had no impact on the depth of an object, but shade due to light did. My inference proved correct because color was indeed affecting the model's predictions and converting the images to grayscale allowed the network to focus on shade instead, improving the prediction of the model. Furthermore, my team and I also worked on conventional methods such as Epipolar geometry, where we captured images from two viewpoints to calculate the corresponding points (coordinates of the object from 2 different angles) and use those points to calculate the depth.

An interesting problem I worked on was interpolation of video frames to increase the frame rate using GAN architectures. The novelty was splitting the frames into slow moving and fast moving regions and train the network to learn to interpolate fast moving regions. The reason for doing this was to preserve the chromatic features of the background and prevent flickering. This work was published in a conference proceedings journal by *Springer (Singapore).*

This project allowed me to define research areas where we could apply this technique – reducing video size on servers and generating the intermediate frames, improving the resolution of the videos using the same technique (An idea I verified by testing), Improving the streaming speed by upscaling videos on the client side.

MACHINE LEARNING ON THE WEB

During my time as an intern at Cisco Systems, I helped automate the processing of router testbed logs by building an NLP based chatbot. I Improved efficiency and reduced man hours of the team by having approximately 60% of the runs successfully auto analyzed. This project helped me identify another area where AI could be applied to improve productivity. The model had to be optimized to be run on a server, which meant it had to be fast and light-weight. The primary objective of the model was to optimize for speed over accuracy because the fallback in case of failure was manual analysis. Since the goal was to not replace manual error analysis, but to reduce the workload, this was an acceptable tradeoff. Another requirement was to ensure that user interface was smooth and easy to use since it was important to ensure that the task of accessing the model did not become a bottleneck in the performance analysis pipeline.