Keshav Anand — RSI Application

1. Why did you choose these research fields?

Prompt: Articulate why the research fields chosen on the previous page are intriguing and exciting to you. For each sub-field, state what you perceive as the one or two most interesting questions or problems in this area. Explain why these sorts of questions interest you. Your responses are shared with mentors. Please respond with clarity and specificity, including what specific prior research/coursework/etc experiences have prepared you to "hit the ground running" in these fields at RSI.

- Field 1: Computer Science — Machine Learning for Signal Processing
- Field 2: Robotics/Mechatronics — Autonomous Motion Planning

Limit: 5000 Characters

It was during a COVID-19 YouTube binge where I was first introduced to the art of modern computer. After stumbling into a rabbit hole of videos explaining the inner-workings of a machine, I immediately fell in love with Computer Science. Over the years, I have also developed a specialized interest in signal processing and its applications. My curiousity in this topic stems from my first Math Club meeting in 9th grade, where a senior officer had explained the fascinating science of how radio signals are transmitted and received using Fourier transforms. These concepts overlapped with my learning of fascinating Calculus concepts, and I was amazed at how signals can be analyzed and processed. Today, the major question that excites me within the field of Signal Processing is how to effectively adapt digital signal processing and machine learning for real-time resource-constrained embedded systems. As a hardcore robotics enthusiast, I have always been not just interested in the theoretical software, but also the practical hardware embedding of these algorithms. This really sparked my interest in the field of signal processing for embedded systems, prompting me to start a 2 year research project that would become the focus of my life. My ISEF-winning research project from 2024 - 2025, GaitGuardian, was my first major experience with signal processing, as I had worked on a project to predict Freezing of Gait (FoG) episodes in Parkinson's Disease patients using a belt-mounted IMU sensor and machine learning algorithms. My novel pipeline involved using fourier transforms, z-score normalization, and wavelet denoising to filter out noise from the raw IMU data. Unlike existing approachs that used time-domain features, I fed the cleaned time-series data into a 1D CNN, acting as an automatic feature extractor (with no flattening). This was passed into a hybrid biLISTM with temporal and spatial attention mechanisms, allowing for segmented windows to be read both forwards and backwards, and a final dense layer would output the boolean state of whether a FoG episode was occuring in real time. The learning I gained from this research led me to pursue other related signal processing tasks to boost the final product for Parkinson's patients. Researching other Parkinsonian symptoms led me to explore tremor detection (uncontrolled shaking of the hands), and I implemented a real-time tremor detection model that involved a bandpass butterworth filter to isolate tremor frequencies between 4-6 Hz, followed by an FFT to extract frequency-domain features. These features were then fed into a lightweight 1D CNN, resulting in state-of-the-art 99% accuracy while limiting false positives. I also looked into signal processing within my FTC robotics team, realizing that IMU data could be used to improve odometry and localization. I implemented a custom Kalman filter to fuse IMU data with wheel encoder reading, significantly reducing drift during autonomous navigation and reducing error buildup over time. My second major interest has been in the field of Robotics, springing from a lucky acceptance into my Middle School's robotics team in 6th grade. Due to COVID-19, out team had to start from scratch, and as a completely inexperienced 7th grader, it took me 7 months to simply learn to spin a motor. The same fascination I had with computers was now being applied to physical hardware, and I have been a loyal participant in the First Tech Challenge (FTC) robotics competition. As the software lead of my globally ranked team, Technical Turbulence FTC, I have learned a lot about the algorithms that empower robots during the 30-second autonomous period of the competition. Today, I am intrigued by two major research questions within the field of autonomous motion planning. First, I wonder how multiple autonomous agents can effectively coordinate in real-time to achieve a common goal while avoiding collisions. This question fascinates me because it combines elements of path planning, communication protocols, and decision-making under uncertainty. Secondly, I am fascinated by the question of whether autonomous robots and vehicles can learn optimal paths from experience rather than relying on pre-programmed maps. This idea of reinforcement learning for motion planning excites me because it provides a pathway for devices to improve performance over time in dynamic environments. My experience with robotics has provided me with a strong foundation to tackle these questions, as I have designed and implemented a custom pathing algorithm for my FTC robot. The motion profiling algorithm I developed uses cubic and quintic splines to generate smooth trajectories between points, using inverse kinematics and a PID controller to accurate follow the path. By prioritizing endpoint accuracy over time and path accuracy, our robot's pathing is extermely precise, resulting in a top-30 autonomous ranking globally. Outside FTC, I worked on a passion project to allow for pathing of two vaccuum robots in a shared environment. Using A* for initial pathfinding and a custom potential fields algorithm for real-time obstacle avoidance, I made a software system that allowed for efficient cleaning of a dynamic space. (5239)