

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

During the antisocial years of the COVID-19 pandemic, my endless YouTube bingeing led me into accidentally discovering how computers work at a low level. The moment I learned the fascinating marvel of engineering that is a computer, 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 curiosity 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 (as an application of calculus). 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 approaches 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 biLSTM 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 occurring 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. (3101)