FACULTY MENTOR
Dinesh Bharadia

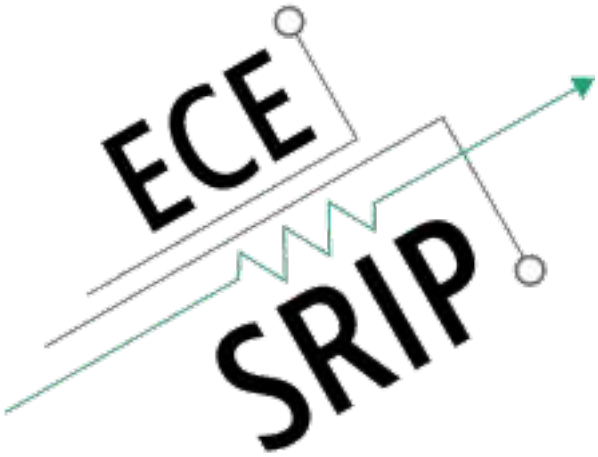
PROJECT TITLE
Smartphone Enabled Ubiquitous Indoor Navigation and Mapping

PROJECT DESCRIPTION
Description: Localization in GPS-denied environments has been a long-researched problem, falling under the broader field of Simultaneous Localization and Mapping (SLAM). Aided by multiple sensors' fusion (cameras, lidars, inertial measurement sensors), computer-vision based feature detection and graph-based optimization, significant progress has enabled robots to autonomously navigate alien environments. Unfortunately, these techniques cannot easily be applied with smartphones to localize users due to the lack of sophisticated sensors and compute power. An attractive alternative to vision-based localization is to use of WiFi signals. In simple terms, the WiFi signals which are propagating in the environment create unique signatures that can be used to localize the user. But the current state of the art systems, which provide up to 50 cm error in localization, either require extensive mapping of the environment or perform well only in the absence of multiple propagation paths.

The aim of this project is to overcome the above challenges and develop a robust smartphone application to enable the mapping and localization of an environment. Mapping will consist of developing algorithms to generate 2D floor-plans or 3D point-clouds using an RGB-D camera. Localization will involve developing a data-collection pipeline and methods to perform centimeter-level reverse localization of deployed WiFi access points and decimeter-level forward localization of user.

INTERNS NEEDED
2 - 3 Students

PREREQUISITES
1. MS or Rising junior/senior BS students with strong experience in python programming, basic data processing and Android/iOS programming
2. Preferred qualifications are background knowledge in SLAM, wireless communications or image/signal processing



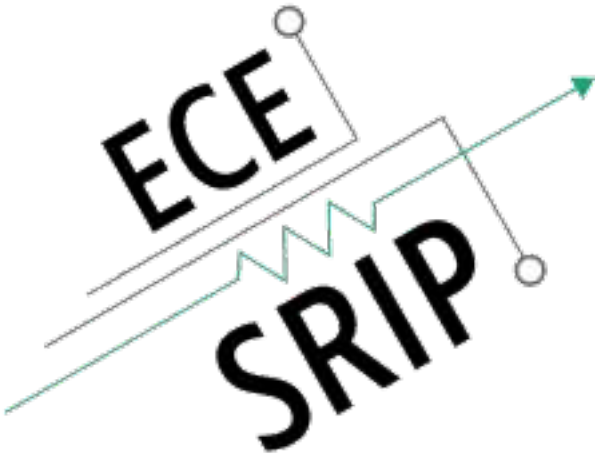
FACULTY MENTOR
Dinesh Bharadia

PROJECT TITLE
Robust SLAM for Autonomous System by combining light-based sensing (Lidar, Camera) and RF-based sensing

PROJECT DESCRIPTION
Description: Automated vehicles, robots or mobile devices largely rely on the sensor fusion of Inertial measurement units (IMU's), GPS, Lidar, Radar or Vision-based technologies to map and localize themselves within an environment using SLAM frameworks. They track landmarks in the environment and predict their relative position to these landmarks. Unfortunately, despite vast improvements in sensor technologies, they still suffer from major drawbacks from incorrect landmark detection in vision-based sensors to poor visibility of Lidars under harsh weather conditions. Furthermore, there is no way to predict when these sensors might fail. The objective of this project is to address these issues and incorporate WiFi based localization for both mapping the environment and localization of the device in a SLAM framework.

INTERNS NEEDED
1 - 2 Students

PREREQUISITES
1. MS or Rising junior/senior BS students with strong experience in python programming, background knowledge in SLAM, wireless communications or image/signal processing



FACULTY MENTOR
Dinesh Bharadia

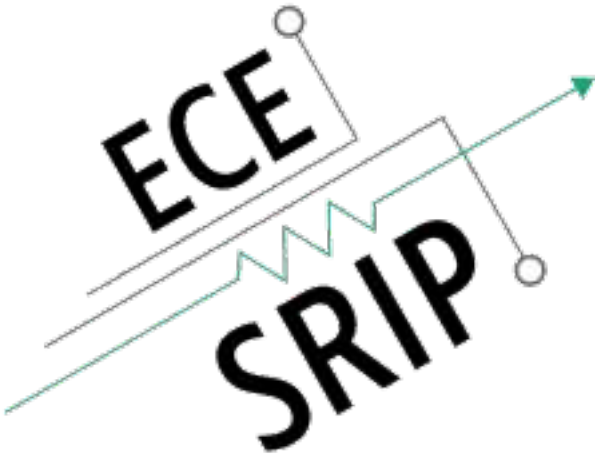
PROJECT TITLE
Automotive radar perception in bad weather

PROJECT DESCRIPTION
Description: Radio sensing has been an old and vital science but the use of radars has been limited to specialized applications like terrain mapping and surveillance systems. Recently, with the advent of mmWave based radars, high quality and super-resolution radars with a smaller form factor have started to hit the market. These devices find their applications in health monitoring, factory automation, and many other areas. One of the major applications of mmWave radars is in self-driving cars. Conventionally used sensors like LiDAR and cameras have made remarkable progress in this field but are known to fail miserably in adverse conditions. Radars, on the other hand, provide an all-weather resistant reliable automotive sensing solution.

This project aims at developing specialized algorithms for achieving vehicular sensing tasks like scene understanding, object detection, and tracking. We use state-of-the-art mmWave radar sensors and develop end-to-end solutions from signal processing to optimal data representation and deep learning-based post-processing algorithms. We also work on multi-sensor fusion that includes both radar-radar fusion and radar-camera/LiDAR fusion.

INTERNS NEEDED
2 -3 Students

PREREQUISITES
1. Knowledge about digital signal processing techniques and embedded system development (preferably experience with ROS)
2. Strong command of python language and prior knowledge of working with ML algorithms and frameworks like PyTorch is a plus



FACULTY MENTOR
Dinesh Bharadia

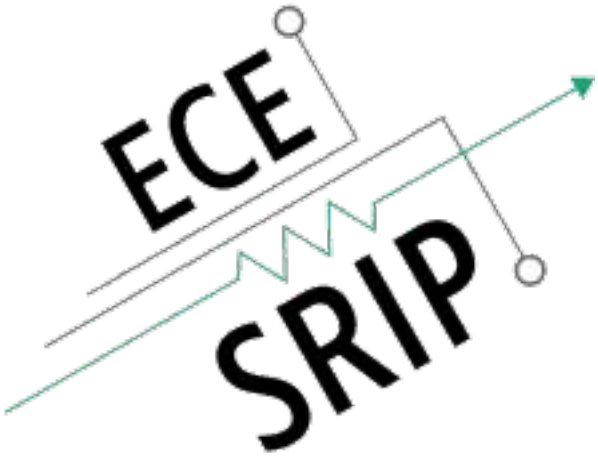
PROJECT TITLE
Intelligent Nonlinear Communications

PROJECT DESCRIPTION
Description: Most of the modern communications rely on the assumption of linearity. This poses restrictions on performance as power amplifiers and other active components act very nonlinearly when operating at high efficiencies. This is largely addressed by power back-off, operating power amplifiers and components in a linear region at the cost of efficiency.

We seek to create novel methods to address these issues. Through the use of neural networks and intelligent function approximation techniques, we are attempting to correct these nonlinearities. Further, we are exploring the prospect of encoding information within these nonlinearities to boost performance and eventually design more efficient communications that work with these nonlinearities rather than around them.

INTERNS NEEDED
1 Student

PREREQUISITES
1. Knowledge of communications, digital signal processing and machine learning techniques
2. Strong command of python and experience with machine learning frameworks like PyTorch



FACULTY MENTOR
Dinesh Bharadia

PROJECT TITLE
In-Body Localization

PROJECT DESCRIPTION
Description: There has been a lot of interest recently on localization using RF signals. However, most of the existing literature considers localization problems in free space (i.e. over the air). Most of these algorithms rely on utilizing phase information to estimate distance traveled by the signal and angle of arrival, in order to localize. To estimate distance travelled by the signal from phase information, it is generally assumed in these algorithms that signal travels completely over the air (i.e. in a completely homogeneous medium). Furthermore, to perform localization from this distance estimates, it is assumed that signal travels in a straight line between transmitter and receiver.

Both these assumptions become invalid if one wants to localize inside the human body, which is composed of various layers (i.e. skin, muscle, fat, etc). The signal travels over different mediums, undergoing various refractions. Starting point of this project is to understand the signal propagation models inside the human body, and utilizing these to relax the assumptions made by the previous localization algorithms. Furthermore, the project involves experimenting with SDRs and artificial phantoms designed to emulate body tissues.

INTERNS NEEDED
1 - 2 Students

PREREQUISITES
1. Knowledge of communications, signal processing & optimization techniques and understanding of EM Wave propagation basics
2. Experience with Python/MATLAB

FACULTY MENTOR
Dinesh Bharadia

PROJECT TITLE
Sensing Driven Communication

PROJECT DESCRIPTION
Description: Efficient usage of the wireless spectrum is a foundational problem in the field. Decades of research has produced a wide range of solutions to tackle this: from new waveforms, modulation and coding schemes to complex multi-antenna techniques. Even advances in networking and orchestration have all had the same goal: get more bits to more users in the least time possible. In recent years, the diversity and number of devices that operate wireless has increased manyfold; serving a variety of applications ranging from cellular to IoT. Simultaneously, with the advent of LTE, 5G-NR and other state-of-the-art technologies, there's been an explosion in the complexity of spectrum usage, access and management.

Amidst all of this complexity, the answer to "are we using the spectrum as efficiently as we can?" is proving to be extremely important. Enabling new applications while keeping costs low to improve adoption hinges on this answer. This project proposes a sensing and data driven approach to improve spectrum usage. Given a scenario with multiple low-cost sensors scattered across an area of interest, what are the variables that need to be sensed? Now, assuming we have sensor data (signal strength, band occupancy, location etc.), what is the best way to inject this data into existing communication infrastructure to drastically improve functioning? Building on this, machine learning techniques may be employed to bridge the sensor data with useful inferences for spectrum usage. From fundamentals of wireless systems to real-life data acquisition and inferencing, this multi-faceted project is poised to answer some important questions in the field!

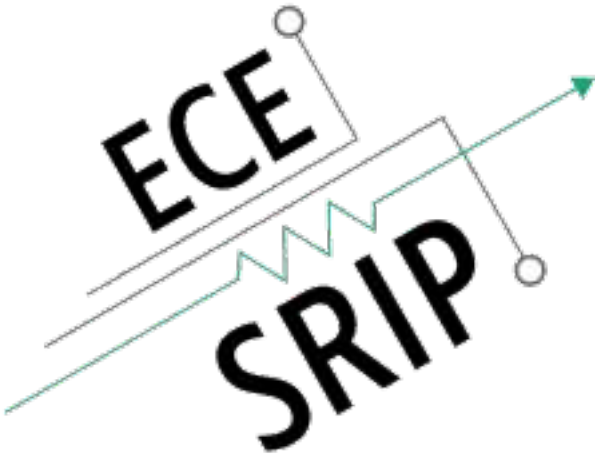
INTERNS NEEDED
1 - 2 Students

PREREQUISITES
Required:

1. Exposure to some wireless communication systems and protocols (Wi-Fi, LTE etc.)
2. Experience with Python/Matlab

Suggested:

1. In depth knowledge of infrastructure network protocols and layers
2. Exposure to machine learning techniques
3. Experience with some open source communication tools (GNURadio, SRS-LTE, OpenAirInterface etc.)
4. C/C++ proficiency



FACULTY MENTOR
Dinesh Bharadia

PROJECT TITLE
SweepSense 2.0

PROJECT DESCRIPTION
Description: With the increase in demand for spectrum, underutilized bands like CBRS (3.5 -3.7 Ghz), ISM band (5-5.8 GHz), TV white spaces (sub 1GHz) etc.., are set to be shared with secondary users. To avoid collisions and enable efficient spectrum usage, these wide-bands of spectrum must be rapidly sensed and transmissions identified as incumbent or secondary.

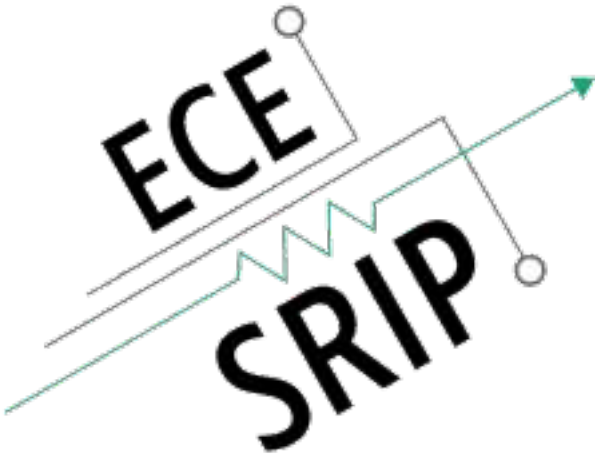
Sweepsense is a spectrum sensor that we have developed on a USRP radio that continuously scans the whole of sub-6Ghz spectrum in the span of milliseconds and collects complex I/Q data. Our goal is to create a distributed network of sweepsense nodes to enable applications like Dynamic spectrum sharing, Spectrum mapping, localizing wireless bugs, Network health monitoring and many more.

To realize these applications, students are expected to:

1. To create a data-base for collecting real world spectrum data (with labels) from multiple USRP radios.
2. Create a scalable backend framework that enables implementing real-time algorithms like signal detection, spectrum anomaly detection and distributed algorithms like localization, protocol detection etc.

INTERNS NEEDED
1 - 2 Students

PREREQUISITES
1. Experience working with SQL, Python
2. Familiarity with Signal processing, Software Defined Radio (SDR) is preferred



FACULTY MENTOR
Dinesh Bharadia

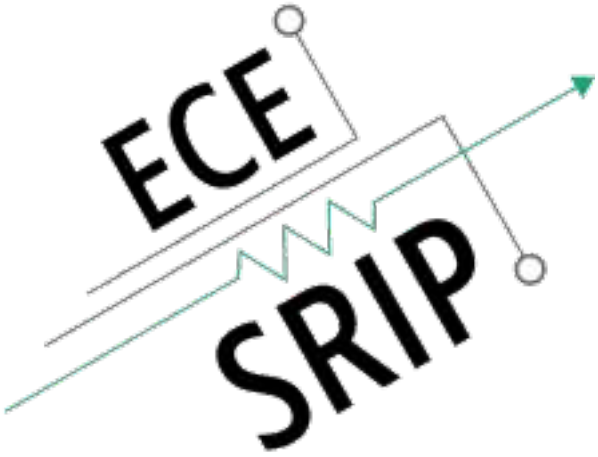
PROJECT TITLE
Securing Your Communication with IoT Devices Using Device Identification

PROJECT DESCRIPTION
Description: As the applications of IoT grow every day and the use of IoT devices becomes pervasive, the security and privacy challenges behind that is grabbing more attention. While security and privacy in higher layers are heavily researched, physical layer security and privacy have remained an open problem. The unique and interesting property of physical layer security compared with other layers is that, it is almost impossible to mimic physical layer signatures (an opportunity to build more secure systems) and also it is hard to hide these signatures with the current hardware implementation (a privacy concern). These “signatures” or “fingerprints” are made by the imperfections in the underlying hardware of devices which simply means the difference between the generated signal by the device (Smartphone, Smartwatch, etc.) and the ideal signal that the device intended to generate. These fingerprints are different even for the devices of the same type and manufacturer. Therefore, they can be used to identify a device even if it is trying to hide or fake its MAC address.

In this project, we aim to develop and use deep learning models and signal processing algorithms to extract these fingerprints from the physical layer signals, in order to enable robust device identification. Then we build an authentication and tracking system based on this device identification method.

INTERNS NEEDED
1 - 2 Students

PREREQUISITES
1. Experience in Matlab/Python
2. Background knowledge in machine learning or signal processing or embedded systems development
3. Prior experience in working with machine learning frameworks (like PyTorch, Keras) is a plus



FACULTY MENTOR
Dinesh Bharadia

PROJECT TITLE
Bespoke FPGA Based Communication Testbed

PROJECT DESCRIPTION
Description: Recent developments in cutting edge wireless access systems such as 5G-NR and Wi-Fi 6 have brought immensely configurable high throughput communications within reach. Research on techniques such as massive-MIMO, MU-MIMO and mmWave beamforming holds a lot of promise in improving solutions deployed over the next decade. This project aims to set up a scalable FPGA based communication testbed for research on high bandwidth applications. Implementation of one of mmWave beamforming, MU-MIMO or localization will follow after testbed setup.

Deliverables:

- Interfacing high bandwidth DAC/ADC with Xilinx FPGAs
- Two host-FPGA communication channels to be set up:
    - PCIe based data transfer
    - Network (optical) data transfer
- Setting up drivers/software for piping samples to and from the testbed.

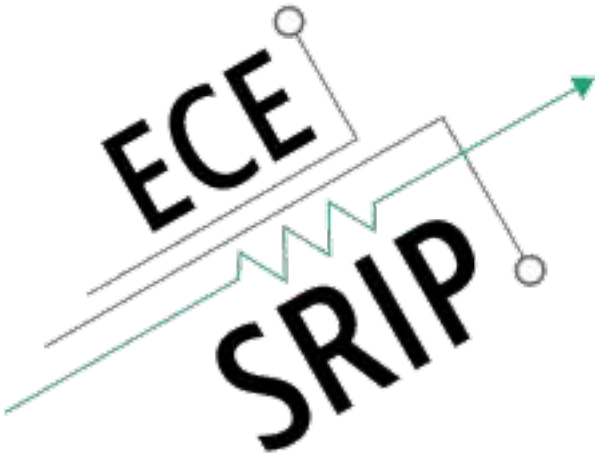
INTERNS NEEDED
1 - 2 Students

PREREQUISITES
Required:

1. Prior experience with hardware description languages (Verilog/VHDL/VivadoHLS)
2. Familiarity with the Xilinx Vivado design suite
3. Understanding of system level design and interfacing with FPGAs

Suggested:

1. Prior experience in building high bandwidth applications on FPGAs
2. Exposure to communication systems and protocols



FACULTY MENTOR
Dinesh Bharadia

PROJECT TITLE
Wireless virtual reality over 5G testbed

PROJECT DESCRIPTION
Description: Virtual reality is getting popular for playing 3D games and watching immersive 360-degree videos. The limitations of current VR headsets is that they are tethered to computers, which limits mobility and poses a tripping hazard. Delivering VR content over a wireless link is challenging due to the high data rates and low latency requirements. Current WiFi devices cannot meet these stringent demands. 5G millimeter-wave (mmWave) communication has the potential to meet the high data rate requirements of VR video. To this end, we have already developed a mmWave testbed with a customized Software-defined radio which can deliver speeds more than 1 Gbps. The goal of this project is to implement VR video streaming over the wireless link using a video codec platform (such as VLC player) and our 5G testbed.

Though 5G can provide high data rates, the wireless link is very intermittent, i.e., suffers from link quality degradation due to blockages and user's mobility. When 5G is down, standard Wifi can be used to maintain the wireless connection. The high-level research goal is to develop rate adaptation and optimization algorithms to satisfy the wireless link conditions. Students will be involved in the bigger project, and the outcomes will be submitted to a top tier conference.

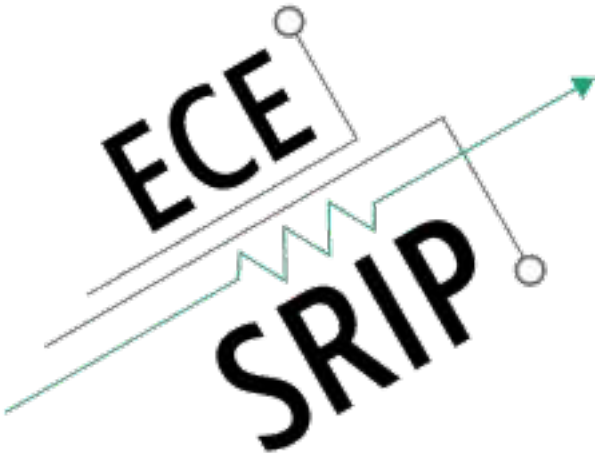
INTERNS NEEDED
1 - 2 Students

PREREQUISITES
Required Skills:

1. Matlab/Python programming
2. Understanding of Video Codec: Encoding, Decoding, and Streaming

Suggested:

1. Understanding of wireless systems



FACULTY MENTOR
Dinesh Bharadia

PROJECT TITLE
Smart Radio: Simultaneous Communication and Sensing

PROJECT DESCRIPTION
Description: Our smartphone is equipped with radio frequency (RF) chips such as WiFi and Bluetooth for communications. Besides communications, RF also has a lot of applications in wireless sensing such as localization and tracking, activity recognition, and vital sign monitoring. Usually, wireless sensing requires particular waveforms such as Frequency-modulated continuous-wave radar (FMCW), which cannot be used for communications. The current standards for wireless communications are based on Orthogonal frequency division multiplexing (OFDM), which is not suitable for certain sensing applications. In this project, we will explore recently proposed Orthogonal time-frequency space (OTFS) waveforms, which has the potential to simultaneously communicate with the receiver as well as can be used for sensing applications. We will focus on a vehicular application where a vehicle equipped with an RF device communicates with its receiver while simultaneously estimating the range/velocity of nearby vehicles. Students will work with simulation tools in Matlab or python as well as implement the system on a software-defined radio (SDR) platform for real-world measurements.

INTERNS NEEDED
1 - 2 Students

PREREQUISITES
1. Matlab/Python programming
2. Understanding of wireless communications system