FACULTY MENTOR

Dinesh Bharadia

PROJECT TITLE

RFCam: Radio Frequency (RF) Spectrum Summarization for Security and Policy Enforcement

PROJECT DESCRIPTION

In a world where the RF spectrum is buzzing with activity from countless devices, understanding its usage is key to enhancing communication, bolstering security and privacy, and refining policy enforcement. Our project is at the cutting edge of this challenge. We are developing a system that succinctly summarizes how the RF spectrum is utilized. Think of it as creating a camera, but instead of capturing images, we're capturing RF frequency data! This project is a comprehensive systems development venture, merging radio hardware, signal processing, software development, and machine learning into one. It’s an exciting opportunity to be part of a team shaping the future of RF technology.

This project will be in person.

INTERNS NEEDED

- 1-2

PREREQUISITES

- Strong skills in Python or Matlab programming.
- A good grasp of signal-processing concepts.
- A foundation in communication theory.
- Knowledge of C++/Rust is a plus.

FACULTY MENTOR

Dinesh Bharadia

PROJECT TITLE

Applications of Machine Learning in Radio Frequency (RF) Communication and Sensing

PROJECT DESCRIPTION

In an era where wireless devices are ubiquitous, understanding and optimizing the use of the RF spectrum has become more crucial than ever. Our project is at the forefront of this challenge, exploring innovative applications of machine learning in the field of RF communication and sensing. We are delving into novel uses of ML, such as anomaly detection, modulation classification, and precise localization, to revolutionize how we interact with the RF spectrum. This internship offers a unique opportunity to contribute to groundbreaking research that blends cutting-edge machine-learning techniques with the dynamic world of RF technologies.

This project will be in person.

INTERNS NEEDED

- 1-2

PREREQUISITES

- Proficiency in standard ML development tools (PyTorch preferred).
- Familiarity with signal processing concepts.
- Background in communication theory (beneficial, but not mandatory).

ELECTRICAL & COMPUTER ENGINEERING
SUMMER RESEARCH INTERNSHIP PROGRAM

FACULTY MENTOR
Dinesh Bharadia

PROJECT TITLE
Shoe Insole-based Force Sensing for Treadmill Application

PROJECT DESCRIPTION
Human body-worn sensors are becoming increasingly popular for continuously monitoring vitals. Measuring biomechanical forces exerted by our joints, feet, etc, as we perform day-to-day activities like running, walking, etc, is gaining traction among athletes, hobby runners, and patients undergoing physiotherapy. While there are insole embedded sensors currently that can measure plantar and ground reaction forces, they are either bulky and need the user to wear additional gadgets with additional wiring or come with batteries that make them inconvenient to use or require constant charging/replacement and are prohibitively expensive. Wireless and battery-free sensors are the obvious right direction for body-worn sensing. We have developed RFID-based ForceStickers that can enable such health-based applications.
In this project, we will build a shoe-insole-based force sensor that is battery-free, flexible, and can be read wirelessly from a distance. The tasks will include working with embedded hardware like ESP32, RFID tags, and Force Sensing Resistors (FSR). The goal is to be able to measure vertical ground reaction forces while users run/walk on a treadmill.

This project can accommodate both remote and in-person students.

INTERNS NEEDED
- 1-2

PREREQUISITES
- 3D Printing, CAD, PCB, Embedded Hardware, Matlab/Python programming.
- Basics of Signal processing/communications.
- Prior knowledge of wearable sensors is a huge plus.

ELECTRICAL & COMPUTER ENGINEERING
SUMMER RESEARCH INTERNSHIP PROGRAM

FACULTY MENTOR
Dinesh Bharadia

PROJECT TITLE
Sensing Oral Suction Force in Infants Using Wireless and Battery-free Force Sensors

PROJECT DESCRIPTION
Neonates and newborn infants suffer from impediments in meeting their nutritional needs due to incorrect breast latch and improper breastfeeding techniques. Often this is due to undiagnosed conditions such as Ankyloglossia and/or poor suction force exerted by a developing infant. We are developing the world's first smart pacifier that can be used to wirelessly measure the suction force exerted by the infant's oral cavity by inserting a battery-free bio-compatible force sensor inside a pacifier. We have developed ForceStickers that can enable such biomedical applications. We will extend these principles to the problem described above.

This project can accommodate both remote and in-person students.

INTERNS NEEDED
- 1-2

PREREQUISITES
- 3D Printing, CAD, Matlab/Python coding.
- Basic knowledge of signals and sensing.

FACULTY MENTOR

Dinesh Bharadia

PROJECT TITLE

Smart-surface: Reconfigurable smart surface for mmwave 5G connectivity

PROJECT DESCRIPTION

As 5G gains wider acceptance, it becomes imperative to deliver the promised benefits to the user. While mmwave 5GNR offers the bandwidth and throughput to meet those needs, the point-point nature of the communication needs precise beamforming from the BS to the user. Recently reconfigurable Surfaces have become a widely investigated topic for their ability to "program" the channel. While it is challenging to realize such surfaces in hardware, the programmability, N^2 improvement in SNR, ability to eliminate link-outages due to occlusion, improved mobility, and true MU-MIMO make this a worthwhile problem to solve.

Interns will have the opportunity to conduct experiments with the surface, develop system-level analysis, and derive meaningful insight into the functionality of such surfaces and their application in real-life wireless communication and sensing applications. The intern will work with a PhD student to characterize the smart-surfaces using mmwave phased array and a 5G testbed currently in development, using an FPGA to configure and control the surface. Work done during the internship will be duly acknowledged through a co-authored paper.

This project can accommodate both remote and in-person students.

INTERNS NEEDED

- 1-2

PREREQUISITES

- Some knowledge of Electromagnetics and wave- propagation, RF-circuits, Ansys HFSS (or equivalent EM simulation tool), Matlab/Python, and FPGA programming

FACULTY MENTOR

Dinesh Bharadia

PROJECT TITLE

Smartphone-based Human Health Monitoring System

PROJECT DESCRIPTION

Ubiquitously monitoring human body health is very important. However, the existing human body health detection system is expensive and requires well-trained people to operate it. In this project, we will leverage multimodal smartphone sensors for teeth health detection and imaging with non-contact sensing mechanisms. Obviously, it is hard to use cameras for dental imaging as we need to ask dentists to check our teeth professionally. Our smartphone-based system will be ubiquitous and accessible for dental health. To do so, we first need to leverage multiple smartphone sensors for teeth imaging in a non-contact manner. Then, we leverage the deep learning models to fine-tune the sensing results.

This project can accommodate both remote and in-person students.

INTERNS NEEDED

- 2

PREREQUISITES

- Machine learning, especially deep learning, python, tensorflow or pytorch, Android or IOS app development, acoustic signal, and image processing.

FACULTY MENTOR

Dinesh Bharadia

PROJECT TITLE

Sok: Emanation Based Side-channel Attack and Defense

PROJECT DESCRIPTION

Every electronic device can automatically emit electromagnetic emanations, which have been widely exploited for side-channel attacks and defenses. In this project, we want to comprehensively study these attacks and defenses and come up with a common framework to generalize all these attacks and defenses. Furthermore, we want to identify interesting ideas and insights from this framework and propose future research directions.

This project can accommodate both remote and in-person students.

INTERNS NEEDED

- 1

PREREQUISITES

- Basic signal processing and wireless communication.

FACULTY MENTOR

Dinesh Bharadia

PROJECT TITLE

mmSpoof_v2: Countermeasures Against Spoofing Attacks on Autonomous Vehicles

PROJECT DESCRIPTION

We recently built mmSpoof, a spoofing attack on the radar sensor on autonomous vehicles using a ‘spoofing device’ that can manipulate the radar signal on the air (see mmspoof paper https://wcsng.ucsd.edu/mmspoof/). Such spoofing attacks are dangerous because it is extremely hard to detect them and develop countermeasures against them. Building a robust countermeasure requires understanding and manipulating the radar waveform (e.g., FMCW), building a deep learning-based signal processing pipeline for radar data processing, and augmenting them with other sensors such as Lidars and cameras. Students will get hands-on experience with multiple sensors such as radar, lidar, and cameras through a ROS platform that we developed over the last couple of years and perform their own experiments and data processing pipelines.

This project can accommodate both remote and in-person students.

INTERNS NEEDED

- 1-2

PREREQUISITES

- Some knowledge of wireless communication systems is required. ECE 157A and ECE 157B or ECE 257A students are preferred.

FACULTY MENTOR

Dinesh Bharadia

PROJECT TITLE

CommRad: Augmenting Multi-beam 5G mmWave Systems with Environment Sensing

PROJECT DESCRIPTION

Beam-management is a difficult problem in practical mmWave systems. Recently, with the development of practical constructive multi-beamforming, there is scope for designing mmWave beam-management that achieves reliable high-throughput links. In this proposal, we explore beam-management techniques for constructive multi-beam systems augmented by radar environment sensing. The ability to sense the environment and predict parameters relevant to beamforming, such as angle of departures and locations of users and reflectors, will allow the solution to scale to a multi-user scenario. Our technical tasks involve the development of learning-based beamforming parameter estimation and beam-management policies based on reinforcement learning for constructive multi-beam systems. Our final focus will be a demonstration of our ideas on our 5G-NR testbed in indoor and outdoor scenarios. PS: this project has been sponsored by Qualcomm Innovation Fellowship.

This project can accommodate both remote and in-person students.

INTERNS NEEDED

- 1-2

PREREQUISITES

- Some knowledge of wireless communication systems is required. ECE 157A and ECE 157B or ECE 257A students are preferred.

FACULTY MENTOR

Dinesh Bharadia

PROJECT TITLE

mmReliable_v2 Improving Reliability of a multi-user 5G millimeter-wave system using Machine Learning

PROJECT DESCRIPTION

High bandwidth Millimeter-wave spectrum is poised to be a game-changer for cutting-edge wireless communication and sensing applications. Beamforming is commonly used in mmWave systems to combat the higher attenuation over the air at these frequency ranges. The traditional approach involves finding the receiver's spatial direction and creating a narrow beam toward that direction using phased arrays. While this significantly improves propagation characteristics, it creates a single point of failure that makes mmWave systems notorious for low reliability. In this project, we propose a fundamental shift in beamforming that creates channel-specific beams by utilizing the environment's inherent reflections. We propose to rigorously develop new classes of beamforming and architect management algorithms that improve link reliability. This project would involve developing Machine Learning algorithms (Bayesian learning/LSTM) for tracking a mobile user using only the wireless channel data augmented with our novel beamforming. Further, extending this framework to support multiple users would lead to a tier-1 systems conference/ journal publication. We have all the toolkits with a state-of-the-art 5G testbed at 28 GHz for rigorous testing of our algorithms in a realistic setting (Sigcomm'21 paper called mmReliable http://wcsng.ucsd.edu/mmreliable/). SRIP students work with a current PhD student and co-author the paper.

This project can accommodate both remote and in-person students.

INTERNS NEEDED

- 1-2

PREREQUISITES

- A good understanding of wireless communication and machine learning is required.
- Experience with Python.
- Understanding of LSTM/RNN etc.

FACULTY MENTOR

Dinesh Bharadia

PROJECT TITLE

Developing 5G New Radio testbed with Phased Arrays and USRP in Verilog

PROJECT DESCRIPTION

Beamforming methods need to be critically evaluated and improved to achieve the promised performance of millimeter wave (mmWave) 5G NR in high mobility applications like Vehicle-to-Everything (V2X) communication. Real system deployments and tests are required to verify new algorithms and techniques in a practical setting. In this work, we develop and extend our mMobile (http://wcsng.ucsd.edu/mmobile/) testbed, a custom 5G NR-compliant mmWave testbed, to evaluate beam management algorithms. Our current testbed is primitive without real-time beamforming support. The intern will work with Vivado to develop fast beamforming on Xilinx FPGA platform. SRIP students work with a current PhD student and co-author the paper.

This project can accommodate both remote and in-person students.

INTERNS NEEDED

- 1-2

PREREQUISITES

- Vivado familiarity.
- Good with Verilog.
- HLS programming would be a plus.
- C/C++ desired.
- Familiarity with interfacing protocols such as SPI/ I2C.

FACULTY MENTOR

Dinesh Bharadia

PROJECT TITLE

mmFlexible_v2 Enhancing 5G spectral and energy efficiency by using special IIR filters to flexibly allocate any BW chunk to any user location using a single RF chain

PROJECT DESCRIPTION

To accommodate various wireless traffic demands, the gNodeB should be able to flexibly allocate arbitrary BW chunks to users in different locations. This can be done using a fully digital antenna array; however, this solution is power and area-consuming. A power-efficient alternative is to use an analog antenna array, i.e., deploying a single RF chain. Conventionally, analog arrays used phase shifters only, and true-time-delays have also been recently used. The project explores using suitable systems, not limited to the aforementioned ones, e.g., special IIR filters, to achieve the required space-frequency allocation. This project is an extension of the mmFlexible system, which used Dela-phased arrays to achieve a first-order approximation of the required space-frequency map (details can be found at WCSNG - Research (ucsd.edu)). Additionally, the project involves testing the proposed architecture using hardware. The experiments will entail modifications to the already existing mmFlexible testbed.

This project can accommodate both remote and in-person students.

INTERNS NEEDED

- 1-2

PREREQUISITES

- Good understanding of wireless communications.
- A reasonable background of filter design.
- Experience with Matlab.

ELECTRICAL & COMPUTER ENGINEERING
SUMMER RESEARCH INTERNSHIP PROGRAM

FACULTY MENTOR
Dinesh Bharadia

PROJECT TITLE
Designing a 3-D printed smart orthopedic implant with ForceSticker for implant health monitoring

PROJECT DESCRIPTION
In our lab, we have designed batteryless and wireless ForceStickers, which are thin sticker-like force sensors. In this project, we will explore the orthopedic implant application of ForceSticker. 3-D printed personalized implants are gaining a lot of traction both within the medical community, as well as engineering fields. With our ForceSticker technology, we can sense the impact forces sustained by these implants to characterize the implant's health and if the implant fits well within the body. We have so far demonstrated this on a small-scale knee model with lower forces. For this project, we would be designing a new 3-D printed knee implant and a test setup to apply close to real-world forces on the implant, as well as generalizing the ForceSticker design to fit these newly designed implants and force ranges.

This project can accommodate both remote and in-person students.

INTERNS NEEDED
- 1-2

PREREQUISITES
- 3-D printing, CAD, PCB design, and basic programming background.

FACULTY MENTOR

Dinesh Bharadia

PROJECT TITLE

Radar Simulations and Super Resolution using Generative AI/Deep Learning

PROJECT DESCRIPTION

Autonomous driving is emerging as one of the key technologies of the 21st century. With numerous companies fighting the race to bring level 5 self-driving cars onto roads, achieving completely reliable autonomy in vehicles is still a very challenging problem. Perception sensors, especially LiDARs, and cameras, that form the backbone of autonomous driving systems fail to achieve the required robustness in adverse weather conditions. mmWave radars have emerged as a novel technology that aims to bridge this gap in the near future.
This project aims to develop specialized algorithms for achieving vehicular sensing tasks like scene understanding, object detection, tracking, and path planning. We develop a state-of-the-art mmWave radar simulator to obtain large-scale data and develop end-to-end solutions from signal processing to optimal data representation and deep learning-based post-processing algorithms. We use generative AI to learn radar sensor models and radar reflection properties. We also use deep learning to investigate unsupervised super-resolution techniques for radar sensing.

This project can accommodate both remote and in-person students.

INTERNS NEEDED

- 2

PREREQUISITES

- Strong command of Python language
- Prior knowledge of working with ML/DL algorithms and PyTorch framework.
- Background in signal processing / Radar processing is a plus
- Experience with Generative modeling is a plus (State of the art models of NeRF, Diffusion, etc.).

FACULTY MENTOR

Dinesh Bharadia

PROJECT TITLE

Digital Twin for ORAN: A Twin for 5G Wireless Environments

PROJECT DESCRIPTION

Multimedia applications are witnessing a surge in popularity and constant evolution, often surpassing the advancements in network infrastructure. For application developers, comprehending the performance of these applications on cellular networks poses a significant challenge. Although the concept of digital twins in communication and network systems research is not new, the pursuit of identifying an effective, easy-to-deploy twin or framework for efficient app testing on radio networks remains critical. Our research endeavors to harness the potential of open-source software and hardware to evaluate a comprehensive and lightweight framework for rapid application testing on radio networks during the development phase. We hope to address two fundamental questions: (i) What defines a good digital twin? Has any study compared real-world performance with its virtual counterpart? (ii) Can we benchmark application performance on the twin using real-world channel traces and derive insights into potential RAN parameter functions for specific applications? In this project, you will explore software 5G stacks and software UEs to develop a framework for hosting an end-to-end 5G network on a single machine. You will then be exploring what kind of channel characterization is enough to emulate real-world observations when you run end-to-end applications such as video streaming or video conferencing.

This project can accommodate both remote and in-person students.

INTERNS NEEDED

- 2

PREREQUISITES

- Required skills: C/C++/ Python/ some familiarity with docker containers, some exposure to the LTE/5G wireless communication protocol.

FACULTY MENTOR

Dinesh Bharadia

PROJECT TITLE

Low-power and Low-cost Tracking and Localization of IoT Devices using LEO Satellites

PROJECT DESCRIPTION

The advent of Satellite IoT has been pivotal in extending connectivity to the most remote regions of the world, facilitating a wide range of applications such as asset tracking, environmental monitoring, maritime safety, and agricultural efficiency. Serving as a crucial link, these satellites connect IoT devices in areas beyond the reach of conventional networks. However, a significant challenge lies in the tracking and localization of these devices. Traditional methods, which typically rely on GPS for location tracking and then transmit this data via satellite gateways to ground stations, are resource-intensive and energy-consuming. This project aims to revolutionize this process by shifting the computational load away from end devices, thereby enabling the deployment of low-power, cost-effective IoT devices. These compact devices have the potential to transform outdoor localization and tracking through seamless integration with LEO satellites, opening doors to a multitude of innovative applications in the next generation of IoT.

This project can accommodate both remote and in-person students.

INTERNS NEEDED

- 1-2

PREREQUISITES

- Proficient understanding of wireless communication systems and protocols.
- Experience with software-defined radios and embedded system development.
- Strong programming skills, particularly in Python, Matlab, C/C++.

ELECTRICAL & COMPUTER ENGINEERING
SUMMER RESEARCH INTERNSHIP PROGRAM

FACULTY MENTOR
Dinesh Bharadia

PROJECT TITLE
Building Low-cost Satellite Ground Stations using SDRs and Phased Arrays

PROJECT DESCRIPTION
The satellite industry has witnessed tremendous growth in recent years, primarily driven by the increasing demand for satellite services, advancements in technology, cost-effective small satellites, and lower launch costs. However, this proliferation of satellites, whether for communication, Earth imaging, or other purposes, relies heavily on effective communication with ground stations. To achieve real-time or near-real-time data transfers, the need for more efficient, compact, and low-cost ground stations has become evident. This is especially crucial for imaging satellites, which generate vast amounts (terabytes) of data and require smaller ground station visibility. Traditional large 5-meter radius ground stations are challenging to deploy ubiquitously due to their high costs and maintenance requirements. As a result, there is a growing need for smaller and more affordable ground stations that can enable high-speed data links, addressing the demand for seamless satellite communication in an increasingly interconnected world. In this work, we use commercial off-the-shelf software-defined radios (SDR) and phased arrays to build compact and affordable ground stations.

This project can accommodate both remote and in-person students.

INTERNS NEEDED
- 1-2

PREREQUISITES
- Proficient understanding of wireless communication systems and protocols.
- Experience with software-defined radios and embedded system development.
- Strong programming skills, particularly in Python, Matlab, C/C++.
- Knowledge of phased arrays (beneficial, but not mandatory).