NUST SEECS -School of Electrical Engineering & Computer Science

SEECS

ABSTRACT BOOKLET

BEE - Bachelor of Electrical Engineering

CLASS OF
2025

Department of
Electrical and Computer Engineering

NUST
SCHOOL OF ELECTRICAL ENGINEERING & COMPUTER SCIENCE (SEECS)

Greeting & Message from
Principal NUST-SEECS

Dr. Muhammad Ajmal Khan, SI(M)

PhD (Michigan State University, USA)

It is a pleasure to introduce to you the graduating classes of 2025 in the disciplines of Electrical Engineering, Software Engineering, and Computer Science.

NUST-School of Electrical Engineering and Computer Science (SEECS) is committed to providing first-rate higher education in Pakistan. We emphasize making SEECS a center of excellence for imparting high-quality education in the areas of Electrical Engineering and Computer Science that would lead to the promotion of research and scholarly achievements at National & International levels. We foster a passion for creativity and productivity in our students through an enabling environment of state-of-the-art labs, arranging industry visits, seminars, and international conferences, etc. Besides imparting thorough professional knowledge, we also believe in instilling sound entrepreneurial, social and humanitarian values.

The programs offered at SEECS include Electronics, Digital Systems, RF and Microwave, Telecommunication and Networks, Artificial Intelligence, Machine Learning, Big Data, Cyber Security, and Cloud Computing. Hands-on training in these domains augments the basic knowledge of our students, giving insights into its practical application, an essential prerequisite for potential technical leaders of the 21st century.

The projects showcased in the Open House demonstrate the skill set of our graduating students, and the highly interactive sessions with the industrial professionals provide them a platform for networking. Another aim of holding this event is to address the dire need for industry-academia partnerships in Pakistan. Through Open House, the industry can witness the outstanding research of various disciplines that are being offered at NUST-SEECS. At the same time, the industry feedback helps us update our curriculum according to the contemporary market trends. Henceforth, I take immense delight in presenting the batch of 2025 as the proud product of SEECS and wish them success as they go forward in their respective fields, with all the best for their journey ahead.

Message from Associate Dean - Department of Electrical and Computer Engineering

Dr. Salman Abdul Ghafoor

Professor
PhD (Fiber Optic Communications)

Dear Graduating Students,

Congratulations on reaching this significant milestone in your academic journey. Your years of dedication, hard work, and perseverance have brought you here, and we are immensely proud of your achievements. As you step into the professional world, remember that learning does not end with graduation. The field of electrical engineering is constantly evolving, and staying updated with new technologies and developments is essential. Let your curiosity drive you to explore, innovate, and grow throughout your career. I urge you to use the knowledge and skills you have acquired here, not just for personal success, but for the betterment of society and the progress of our country. Strive to be responsible engineers who make a positive impact through ethical and meaningful contributions. Above all, work hard and remain sincere in all that you do—these qualities will serve you well in every endeavour. We wish you success, fulfilment, and excellence in your future pursuits.

Faculty Heads

Dr. Usman Zabit
Professor
PhD (Opto-electronics, INPT)
University of Toulouse, Toulouse, France
Head of the Institute of Applied Electronics & Computing (IAEC)

Dr. Sajjad Hussain
Assistant Professor
PhD (Electronic Engineering)
Dublin City University
Head of the Institute of Telecommunication (IOT)

Dr. Muhammad Latif Anjum
Assistant Professor
PhD (Robotics And Computer Vision)
Politecnico di Milano
Head of the Department Power, Control & Electronics (P&CE)

Dr. Nosherwan Shoaib
Associate Professor
PhD (RF Metrology)
Polytechnic Institute of Turin
Head of the Department RF & Microwave (RF&M)

Dr. Mohsin Kamal
Associate Professor
PhD (Light-weight Security and Provenance for the Internet of Things)
FAST - National University of Computer and Emerging Sciences (NUCES)
Head of the Department Computer Engineering

Overview of

OPEN HOUSE

NUST SEECS organizes its annual open house to show case the skills of its graduating students. The idea is to provide a platform where our students and industry representatives can mingle and have informal or formal discussions. The students showcase their final year projects which represent their skill set and enable potential employers to identify any matching requirements. The projects are presented by students from:

Department of Electrical and Computer Engineering (ECE)

The department of Electrical and Computer Engineering has divided its projects into five knowledge areas that are Power Electronics and Control, Digital Systems and Signal Processing, Integrated Circuits and Systems, RF & Microwave, and Smart Telecommunications and Systems. There are a total of 71 projects divided into the above mentioned knowledge groups. Most of the projects are aimed at providing technology based solutions for social problems.

At NUST SEECS, we take pride in molding our bright entrants into well trained and appropriately groomed professionals in Computer Science, Software Engineering & Electrical Engineering. Our graduates are actively sought by the industry and our Alumni are occupying promising positions in some of the most prestigious industrial and business houses, both in public and private sectors. We hope you enjoy the hard work of our students and find the right candidate or the next big idea for your company.

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01 Knowledge Group

Digital Systems and Signal Processing

Frailty Assessment System for the Elderly

Group Members: Muhammad Huzaifa | Wajiha Ali

Advisor: Khawaja Fahad Iqbal Co-Advisor: Muhammad Latif Anjum

A japanese funded project for the detection and assessment of frailty among the elderly using visual feedback. he Clinical Frailty Scale (CFS) is a straightforward and accessible tool that can be used to quickly and simply assess frailty. It has been validated in adults aged over 65 years. This tool can help optimize quality of life outcomes for geriatric patients.

Development of IMU-Based Motion Capture Suit using Biomechanics driven Mocap Technology

Group Members: Momina Tabassum | Muhammad Ahmad Saleem | Mustafa Ali

Advisor: Zartasha Mustansar Co-Advisor: Arham Muslim

Project will encompass broad array of interdisciplinary/multidisciplinary research including hardware design, software development, and integration with AI algorithms for data processing and analysis and then calibration and testing of the product.

NeuroRobotics: BCI based robotic arm using EEG and Deep Learning

Group Members: Mahin Shahzad | Umair Naeem | Zartashia Israr

Advisor: Wajid Mumtaz Co-Advisor: Sajjad Hussain

Technological advancements in neuroscience have enabled the development of assistive devices for individuals with motor impairments. This project explores the intelligent control of a robotic arm using Brain-Computer Interface (BCI) and Artificial Intelligence (AI). By leveraging electroencephalography (EEG) signals, the proposed system translates brain activity into movement commands, eliminating the need for muscle intervention. A 14-channel EEG headset will capture brain signals, focusing on the alpha and beta frequency bands linked to conscious thought and movement. Neural network algorithms, such as HS-EEGNET, will be employed to classify the EEG data and control the robotic arm via an ESP32 microcontroller. The system will also be extended for hand rehabilitation, utilizing force sensors and electromyography (EMG) for detecting active movements. The ultimate goal is to

develop a responsive, adaptive assistive device that enhances autonomy and improves the quality of life for individuals with motor dysfunctions.

Algorithm-Hardware Co-Design for Transformer Neural Networks

Group Members: Muhammad Sami Ullah | Muhammad Zohaib Irfan

Advisor: Wajid Mumtaz Co-Advisor: Waqar Ahmad

The Transformer has become an indispensable staple in deep learning. However, deploying efficient Transformers in real-life applications poses significant challenges due to the immense parameters and operations involved in these models. To alleviate this burden, exploiting sparsity has proven to be an effective approach for accelerating Transformers.
Our project aims to develop an energy-efficient hardware accelerator for Transformers, tailored for high-performance computing. We will investigate sparse computation, pruning, and quantization techniques, along with parallel and approximate computing methods, to create a resource-efficient and high-accuracy architecture. Also, we will optimize the balance between computation and memory access to minimize data starvation and computation latency, ensuring an efficient and robust solution for Transformer acceleration.

Design and Simulation of FMCW Radar for Automotive Systems

Group Members: Dania Farrukh Ghouri | Muhammad Ahmad Nazir | Zunaira Aziz

Advisor: Muhammad Shahzad Younis Co-Advisor: Arbab Latif

This project focuses on the design and simulation of a Frequency Modulated Continuous Wave (FMCW) radar system tailored for automotive applications. The primary objective is to develop a radar system that can accurately detect and track objects, such as vehicles and pedestrians, within the vicinity of an automobile. By utilizing FMCW radar technology, the system will be capable of measuring both range and velocity of targets with high precision, making it ideal for advanced driver-assistance systems (ADAS) and autonomous driving scenarios.

Real-time DNN Deployment for Laser Sensing

Group Members: Ahmed Razi Ullah | Muhammad Omais | Zunaira Aziz

Advisor: Usman Zabit Co-Advisor: Wajahat Hussain

This work is in collaboration with INPT, France research team.
The objective is to optimize, quantize and deploy an already developed DNN on an FPGA or some other embedded platform so that real-time sensing can be achieved.
FPGA cards, such as DE-1 SoC, or Jetson Nano board are available with integrated high-speed ADC and DAC for this project.
We have recently published on the use of DNNs for laser sensing, and now we need to implement these DNNs on an embedded system to achieve real-time performance.

Solar-Powered HIDEC with Automated Real-Time Optimization

Group Members: Ali Hassan Khan | Hamna Rauf | Zartashia Israr

Advisor: Muhammad Shahzad Younis Co-Advisor: Arbab Latif

The project develops HIDEC System, powered by solar energy and enhanced with real-time data monitoring for optimization. The system uses sensors to track different parameters and feeding data into an automated control system that adjusts fan speed and water flow to maintain optimal cooling efficiency. This project demonstrates the integration of renewable energy with sensor-driven automation, resulting in an efficient, eco-friendly cooling solution.

AI-Assisted Mobile Funduscopy for Retinal Disorder Diagnosis

Group Members: Abeeha Fatima | Hafiza Zainab Touheed

Advisor: Rafia Mumtaz Co-Advisor: Muhammad Daud Abdullah Asif

The growing burden of diabetic retinopathy, cardiovascular diseases, and other systemic conditions has underscored the need for accessible, portable, and affordable diagnostic solutions. Current fundus examination methods are often limited by specialized equipment, expertise, and geographical constraints, hindering timely interventions. Furthermore, existing screening tools may not be optimized for primary healthcare settings, particularly in resource-constrained environments. This project aims to design and develop a mobile funduscopy system leveraging smartphone technology and AI-assisted diagnosis to enable early detection and diagnosis of retinal and systemic disorders.

Design of an STM32-based Power Transducer with IoT Capabilities for High Transmission Voltage Lines

Group Members: Salman Ali | Zaid Ahmad

Advisor: Usman Khan Co-Advisor: Khurram Javed

The primary objective of this project is to design and develop a power transducer using the STM32 microcontroller that is capable of monitoring high transmission voltage lines. The device will feature IoT capabilities to enable real-time data acquisition, analysis, and remote monitoring. This project will encompass the design of the electronic circuit, coding of the microcontroller, simulation of the circuit, and the creation of a functional printed circuit board (PCB).

Hardware Trojan Detection using Deep Network

Group Members: Easha Tir Razia | Muhammad Mustafa

Advisor: Usman Zabit Co-Advisor: Muhammad Imran

Hardware Trojan detection is very important to ensure secure and reliable systems. In this work, Students need to implement a deep learning based hardware Trojan detection. They shall need to convert RTL into Data Flow Graphs (DFGs) through parser and learn GNN to train such DFGs for detecting HT in the test-bench available online. The validation of the solution can be performed via GNN inference and some of those inference phase GNN inputs (DFG) can be ported over FPGA through their equivalent RTL codes.

Malware Detection Using Deep Learning-Based Image Analysis: A Novel Approach

Group Members: Muhammad Uzair

Advisor: Mehdi Hussain Co-Advisor: Qaiser Riaz

In today's digital age, nearly everything is done online, making data transfer increasingly vulnerable to cyber attacks. Malicious actors often embed malware in seemingly benign files, such as executable files, which can then be unknowingly opened by users, compromising their systems. To address this issue, We will developed and designed a tool to detect malware embedded in files, specifically executable files, using deep learning techniques. The tool works by converting the file into its raw form and generating a gray scale or RGB image of the content. This image is then analyzed by a deep learning model trained on a dataset containing both malicious and benign files. By extracting features from these images, the model learns the distinct patterns and behaviors associated with malicious and benign files, enabling it to accurately classify new files. The aim of this project is to create an effective solution that helps protect users from hidden malware threats, contributing to a safer online environment.

Smart Intrusion Prevention System

Group Members: Muzammil Ahmad | Sundas Rathore

Advisor: Mohsin Kamal Co-Advisor: Sadiq Amin

In recent years, network attacks have become increasingly sophisticated, posing significant threats to organizational and individual security. Traditional malware detection methods often fail to keep pace with the rapid evolution of malware, leading to significant vulnerabilities in real-time network environments. These attacks can result in data breaches, financial losses, and severe damage to reputation. There is an urgent need for advanced, real-time malware detection systems that can accurately identify and mitigate threats based on the semantic behaviors of malicious software.

Design of Silicon Photonic Focusing Optical Antenna

Group Members: Ayesha Azhar

Advisor: Usman Zabit Co-Advisor: Wajid Mumtaz

Integrated Silicon Photonics has the potential to vastly improve the optical sensing systems. In this FYP, an integrated Focusing Grating Coupler for laser sensing applications will be designed. This work is being done in collaboration with University of Malaga Spain research group, specializing in photonic integrated circuit design, and with LAAS-CNRS, France who specialize in laser sensor design.

Design of spectrally tailored optical filters in silicon photonics chips

Group Members: Rana Shahzaib Ur Rehman

Advisor: Usman Zabit Co-Advisor: Wajid Mumtaz

Silicon photonics leverages the well-established CMOS manufacturing processes to fabricate integrated photonic circuits, enabling a compact and cost-effective platform of photonics chips. Optical filters play a crucial role in these optical circuits by selectively tuning specific wavelengths with applications in telecommunications, data communications, or optical sensing among many other areas. This bachelor thesis aims to design and develop spectrally tailored filters with arbitrary spectral response for targeted applications in silicon photonics. The work will involve theoretical modeling, simulation, and potential experimental validation to ensure the designed filters meet the required specifications.

DNN based Direct Measurement from Laser Feedback Signals

Group Members: Huma Tahir | Zoha Ahmed

Advisor: Usman Zabit Co-Advisor: Wajid Mumtaz

Laser Feedback Interferometry or Self-Mixing Interferometry is an established method to measure the motion of a remote object. Typical signal processing methods struggle to extract the motion information when the optical conditions significantly vary. In this project, we aim to train a DNN, by using the recently published variable optical feedback model as well as experimental sensor data so that state-of-the-art performance can be achieved. The project is in collaboration with INPT France.

Early Prediction of Lung Cancer

Group Members: Hashaam Zafar | Malaikah Javed | Moeez Ahmed Qaiser

Advisor: Ayesha Kanwal Co-Advisor: Nazia Perwaiz

Lung cancer is one of the deadliest forms of cancer worldwide. As the cancer stages progress, the survival rate decreases significantly. Early detection is critical for improving treatment outcomes and patient survival. Existing diagnostic methods often fail to detect lung cancer until it has reached advanced stages. Deep learning models

have shown promise in predicting lung cancer risk from CT scans. Potential impact: Early detection improvements could lead to better treatment outcomes and save many lives.

IceWatch: Glacial Lake Outburst Flood (GLOF) Prediction System Using Deep Learning

Group Members: Muhammad Anser Sohaib | Muhammad Talha | Zuha Fatima

Advisor: Ayesha Kanwal Co-Advisor: Nazia Perwaiz

Ice watch is a GLOF(Glacial Lake Outburst Flood) prediction system based on deep learning utilizing satellite imagery data from sentinel 1, sentinel 2 and Landsat. The machine learning model will be trained using datasets containing velocity mosaics, image pair velocities and elevation change over mountain ranges from 1982 till 2022. Convolutional Neural Network(CNN) and LSTM will be combined to develop an efficient flood prediction system that will give an early warning before an incoming GLOF on a user friendly web interface.

Multi-Vendor Marketplace with Integrated Real-Time Delivery System

Group Members: Mohammad Adil Azeem | Muneeb ur Rehman | Sanjay Kumar

Advisor: Muhammad Khuram Shahzad Co-Advisor: Shah Khalid

This project aims to develop a multi-vendor marketplace application that connects
customers, shopkeepers, and delivery personnel through a single platform. The app enables shopkeepers to manage their inventory, customers to browse and purchase products, and delivery personnel to handle real-time delivery efficiently. The platform integrates real-time communication, interactive maps, and flexible payment options, offering a seamless shopping and delivery experience.

02 Knowledge Group
Electric Power and Control

AI-Enhanced MPPT Inverter Design with Reverse Engineering Insights

Group Members: Muhammad Ahmed | Muhammad Moazam Nafees | Taseen Bin Hanzala

Advisor: Iftikhar Ahmad Co-Advisor: Hassan Abdullah

The project revolves around reverse engineering an existing Inverex 3.2kW off-grid bidirectional inverter to understand its design and operation. By dissecting the hardware and firmware, the goal is to gain insights into the inverter's current MPPT (Maximum Power Point Tracking) functionality and bidirectional energy flow system.
After understanding the internal workings of the existing inverter, the next step is to enhance its performance by implementing an AI-based MPPT algorithm. Traditional MPPT methods such as Perturb and Observe are often reactive and suboptimal under rapidly changing weather conditions. By integrating AI, the system will learn and predict the optimal power points based on environmental and operational data, significantly improving efficiency and response time.

The reverse engineering phase will include:
1. Analysis of the inverter's electrical circuitry and embedded firmware.
2. Identification of the existing MPPT algorithm and its limitations.
3. Extraction of key system parameters that will inform the AI-based MPPT design.

In the final phase, the new AI-driven algorithm will be simulated and tested against the current MPPT solution, demonstrating its ability to optimize energy harvesting and improve the inverter's overall performance under various conditions. This project aims to blend reverse engineering with AI to develop a more advanced, efficient, and adaptive MPPT solution for renewable energy systems

Intelligent Control for a 3-Phase Hybrid Solar Micro-Inverter

Group Members: Ghulam Qadar | Muhammad Hamza Farooq | Muhammad Khuzaima

Advisor: Mian Ilyas Ahmad Co-Advisor: Salman Abdul Ghafoor

Solar energy is known for its high efficiency and reliability and has become a promising solution for energy crises. However, typical solar inverters are often high-powered and expensive, making them impractical for individuals needing to power just a few basic household loads. Additionally, older analog hardware is less efficient and can be noisy, potentially shortening the lifespan of home appliances. The objective is to create a cost-effective, advanced digital pure sine wave 3-phase micro-inverter with intelligent DSP control.

The objective is to optimize the conversion of solar energy into electrical energy, enhancing the feedback

compensation circuit using DSP (Digital Signal Processing) control and an advanced Maximum Power Point Tracking (MPPT) algorithm, which ensures maximum power transfer from the solar system. The intelligent control mechanism can be designed with advanced algorithms that maximize efficiency and ensure system stability. By doing so, we can not only enhance energy efficiency but also contribute to a more sustainable energy system.

In addition to intelligent control, the project incorporates a smart IoT-based monitoring system. This system provides real-time data on the performance and health of the solar inverter, enabling proactive maintenance and timely troubleshooting. The IoT monitoring system can be accessed remotely, offering users convenience and ease of use. This real-time monitoring capability ensures that any issues can be promptly addressed, thereby maintaining optimal performance of the solar inverter.

Smart Cell Balancing and Monitoring for EV Batteries

Group Members: Ahmad Hasnain | Muhammad Abdullah Mustafa | Saad Hamid

Advisor: Jawad Arif Co-Advisor: Hassan Abdullah

Electric vehicles (EVs) rely on battery packs for their high energy density and low self-discharge rates. However, inconsistencies in cell voltages, internal resistance, and self-discharge capacities can cause imbalances in battery packs. This leads to reduced battery life, cell degradation, and potential safety hazards. Traditional passive balancing methods are inefficient as they dissipate excess energy as heat. Therefore, there is a critical need for an efficient active cell balancing technique to redistribute energy among cells, enhancing the performance and lifespan of the battery pack.

State-of-Charge Estimation for Drones Using Machine Learning Techniques

Group Members: Murtaza Ahmed Khan | Rimsha Jawad | Saied Ramalan

Advisor: Jawad Arif Co-Advisor: Hassan Abdullah

Unmanned Aerial Vehicles (UAVs), commonly known as drones, are becoming increasingly integral in various applications such as surveillance, agriculture, and delivery services. A critical component of UAV is the battery, which requires an accurate State-of-Charge (SoC) estimation to ensure efficient energy management and prevent mid-flight failures. This project aims to enhance SoC estimation for drones using advanced machine learning (ML) techniques. Current SoC estimation methods for drones often lack the accuracy and real-time adaptability necessary for diverse and dynamic flight conditions. Moreover, existing datasets and models are predominantly designed for Electric Vehicles (EVs), which have different operational profiles compared to drones and do not require a very precise measurement of the SoC of the battery. This project addresses these gaps by developing an ML-based Battery Management System (BMS) tailored specifically for drones.

Thermal Management in EV Battery Pack

Group Members: Bilal Haseeb Hashmi | Muhammad Faiz

Advisor: Jawad Arif Co-Advisor: Hassan Abdullah

The rapid growth of electric vehicles (EVs) has increased the demand for efficient battery thermal management systems (BTMS) to enhance performance, longevity, and safety. Lithium-ion battery packs, commonly used in EVs, are prone to temperature fluctuations, leading to thermal hotspots, performance degradation, and potential safety hazards like thermal runaway. Without proper thermal management, these issues can reduce the efficiency of the battery, shorten its lifespan, and pose risks of overheating. Hence, there is a critical need for an intelligent, real-time thermal management system that can monitor temperature changes, identify hotspots, and actively control cooling systems to prevent imbalances and maintain optimal battery health.

This project aims to devise a hybrid thermal management system for a modular battery pack configuration, consisting of three individual battery packs of 3 kWh each, combined to form a total capacity of 10 kWh. The system will leverage a combination of liquid cooling, phase change materials (PCMs), and thermal interface materials (TIMs) to achieve optimal thermal management, ensuring safety, efficiency, and longevity of the battery packs. By addressing the limitations of existing BTMS solutions, our project seeks to contribute to the advancement of sustainable energy technologies and the broader adoption of electric vehicles and renewable energy storage systems.

Energy Positive Human Activity Recognition Using Solar and Kinetic Signal Fusion

Group Members: Alishba Arif | Hafsa Misbah | Rameen Shahzad

Advisor: Neelma Naz Co-Advisor: Mohaira Ahmad

In today's world, wearable Internet of Things (IoT) devices for healthcare and activity monitoring are becoming more popular. However, their widespread use is limited by the short battery life caused by the high power consumption of conventional inertial activity sensors. To address this, we suggest wearable, miniature solar and kinetic energy harvesters that can function as both an activity sensor and an energy source, enabling energy-positive human activity recognition (HAR). The energy collected should be sufficient for activity classification using ML models, transmitting the inferred activity class, and obtaining activity signals. We also hope to achieve better activity classification through the signal fusion.

EyeSense: AI-Powered Smart Glasses for Currency Identification

Group Members: Abdul Fatir

Advisor: Mohsin Kamal Co-Advisor: Sadiq Amin

EyeSense: AI-Powered Smart Glasses for Currency Identification

GestureVox: PSL to Voice System

Group Members: Amna Bushra | Hassan Ali Irtaza | Numaira Atif

Advisor: Mohsin Kamal Co-Advisor: Nazia Perwaiz

The aim of this project is to develop wearable gloves capable of translating sign language gestures in Pakistani Sign Language (PSL) into text and speech using machine learning models. The gloves will be equipped with flex sensors and motion sensors to capture movements of hands and fingers, which will be processed by a microcontroller. Machine learning will be used by the system to recognize gestures and output the corresponding words. The goal of this project is to bridge the communication gap between the signer community and non-signers in Pakistan.

The signer community of Pakistan faces serious challenges with the hearing population due to widespread lack of knowledge about PSL. The existing solutions are quite costly and inaccessible. Furthermore, technology solutions such as cameras for gesture detection come with physical limitations and privacy concerns. This project aims to develop a low-cost, portable sensor-based solution that will eliminate the need of visual capturing and bridge the gap between signers and non signers.

Adaptive Questioning Using Multimodal Sentiment and Response Evaluation

Group Members: Muhammad Shafay | Syed Ahmad Shah

Advisor: Mohsin Kamal Co-Advisor: Sadiq Amin

This project aims to create a sophisticated system that integrates real-time sentiment analysis, response evaluation, and behavioral analysis to improve dynamic questioning. By combining these elements, the system can assess not only the emotional tone and content of a person's answers but also their non-verbal behavior. This comprehensive approach enables the system to determine whether responses are adequate and suggests follow-up questions based on a thorough analysis of the individual's interactions. The goal is to enhance the effectiveness of questioning processes in various applications, from security screenings to interviews.

AI-Driven Self Driving Robot

Group Members: Faizan Hussain

Advisor: Mohsin Kamal Co-Advisor: Sadiq Amin

This project aims to use a real environment for developing and testing AI-based self-driving robot. The simulation will provide a versatile platform for experimenting with different machine learning (ML) and deep learning techniques, including Convolutional Neural Networks (CNNs), Reinforcement Learning (RL), and traditional ML approaches. The focus will be on enabling a car to autonomously navigate various scenarios, such as urban streets and highways, while avoiding obstacles.
The simulation will feature realistic environments with dynamic elements like traffic lights, pedestrians, and other vehicles. It will be designed to accommodate multiple algorithms for tasks such as object detection, lane tracking, path planning, and decision-making. Deep learning models like CNNs can be used for perception tasks (e.g., object detection and recognition), while RL or other learning-based techniques can handle decision-making and control.

Integrating Radar, Machine Learning, and Computer Vision for Fast-Moving Object Detection

Group Members: Aazmir Ahmed Bhatti | Hasan Ali | Rayan Malik

Advisor: Iftikhar Ahmad Co-Advisor: Muhammad Latif Anjum

This project aims to develop an innovative assistive technology in the form of smart glasses designed specifically for visually impaired individuals to help them recognize currency notes. The smart glasses will be equipped with a built-in camera, AI-based image processing, and text-to-speech capabilities, offering a seamless and efficient solution for currency identification.

Key Components:
Image Capture: The smart glasses will be integrated with a high-resolution camera to capture real-time images of currency notes. This component ensures that the system can accurately capture the visual information needed for processing.

AI-Based Image Processing: The captured images will be processed using advanced AI models such as Vision Transformers, YOLO 8, or Convolutional Neural Networks (CNN). These models will analyze the visual data to detect and recognize the denomination of the currency notes. The AI models are trained to handle various conditions such as different angles, lighting, and wear and tear of the notes.

Text-to-Speech Conversion: Once the currency note is identified, the information will be converted into speech. The smart glasses will communicate the denomination of the currency note to the user via a built-in headset, ensuring that the information is accessible and easy to understand.

Objective:
The primary goal of this project is to empower visually impaired individuals by providing them with a reliable and user-friendly tool to independently identify currency notes. This will significantly enhance their ability to perform everyday financial transactions with confidence and ease.

Motion Generation for Humanoid Robots

Group Members: Eaman Safdar | Noor Ul Eman | Omair Siddique | Omer Amin

Advisor: Yasar Ayaz Co-Advisor: Khawaja Fahad Iqbal

This research aims to develop efficient and realistic motion generation algorithms for humanoid robots to enable them to perform complex tasks in static environments. The goal is to create flexible and adaptive algorithms that enable humanoid robots to navigate various types of obstacles efficiently and safely, rather than relying on rigid, obstacle-specific methods. This includes incorporating generative AI techniques to enhance the adaptability and fluidity of the robots' movements.

Paper Programming for Low Income Countries

Group Members: Alishba Ibraheem | Muhammad Saher

Advisor: Wajahat Hussain Co-Advisor: Muhammad Latif Anjum

Programming has become an essential part of primary and middle school education, but many conventional solutions for teaching coding require expensive digital devices, creating an accessibility gap for students in low-income areas. Paper-based programming offers a low-cost, engaging alternative by allowing students to use affordable materials, such as paper and markers, alongside shared mobile devices. This enables a collaborative learning experience where students can explore programming concepts without the need for costly equipment. However, many current paper-based programming solutions are limited in their flexibility and expressiveness, restricting the scope of programming languages they can support.

This approach leverages computer vision and object detection technologies to recognize and interpret various Scratch blocks drawn by children. By developing a mobile app that translates these blocks into Scratch code, we offer an engaging and low-cost platform that supports computational thinking, logical problem-solving, and creativity. The mobile app is designed to be user-friendly, making it accessible even to children with limited exposure to technology. It emphasizes the importance of providing equitable learning tools and enhancing programming education in underdeveloped regions.

The main benefit of this project is that it allows children to learn the basics of programming without access to expensive hardware. By using paper and a simple mobile device, the app democratizes learning, making it possible for children from low-income backgrounds to explore programming concepts and develop valuable skills for the future. The goal is to create a scalable and cost-effective solution that can be implemented in various educational settings, promoting inclusivity and access to technology-driven education.

Sentiment Analysis From Masked Face

Group Members: Muhammad Abu Bakar Dodhy | Muhammad Saad Faran Malik

Advisor: Sadiq Amin Co-Advisor: Mohsin Kamal

The widespread necessity of face masks, initially spurred by the COVID-19 pandemic and now reinforced by severe smog conditions in various regions, has significantly impacted daily interactions. With masks covering key parts of the face, recognizing emotions through traditional facial analysis systems has become increasingly challenging. These limitations are especially critical in environments where understanding human emotions is essential, such as healthcare, safety, education, and customer service. Our project proposes a facial sentiment analysis system specifically designed to operate under conditions where masks are worn.

By focusing on the upper face, the system will analyze key visible features, such as eye movement patterns, eyebrow positioning, and forehead dynamics, to detect and classify emotions. Using advanced computer vision and machine learning techniques, we will develop and train models capable of distinguishing between different emotional states despite the limitations imposed by masks. The system will be rigorously tested in various real-world scenarios to ensure accuracy and reliability. This innovative approach will offer a practical solution to sentiment analysis in an era where mask-wearing is increasingly necessary due to both health and environmental concerns. Recent work in sentiment analysis from masked faces has primarily relied on visible features, such as eyes and eyebrows, but has shown reduced accuracy compared to multimodal approaches that incorporate additional cues like voice and body language. Our project aims to improve emotion detection accuracy using only facial features, addressing this gap in current research.

Weed detection in crop fields Using UAVs and AI to enhance sustainable agriculture

Group Members: Abdullah Ayaz | Abdurrahim Muhammad Ghani | Waleed Amir

Advisor: Rafia Mumtaz Co-Advisor: Muhammad Daud Abdullah Asif

By the year 2050, Pakistan's population is expected to reach 403 million people. Such an increase in population would also demand a corresponding increase in food production. However, a major hindrance to this is weeds that siphon resources away from the crop. Weeds cause yield losses in crop fields in the range of 20-40% on average which inhibits the efficiency of crop production. These economic losses have been estimated to be upto 36 million tons which is an annual amount of 260 billion PKR.

Since antiquity, weed removal has been done using herbicides on large scales. But, using herbicides has been proven to enter into the food crops and harm consumer health, causing diseases like cancer. Therefore, we propose a solution, UAVs(Unmanned Aerial Vehicles) equipped with a weed detection model. In today's age where computer vision and advances Deep learning have shown promising results, our model will use deep learning to identify weeds within crop fields. This allows for automated UAVs to remove weeds using selective lasers or herbicides without affecting the crop plants for the most part. Thus, preventing any unintended effects on the crop plant and boosting the production of farms.

Solarhealth: Health monitoring system for solar parks

Group Members: Anas Ali | Rayyan Akmal

Advisor: Tassawar Kazmi Co-Advisor: Sajjad Hussain

A wireless remote monitoring system for solar photovoltaic (PV) plant is proposed in this paper. It is an Internet of Things (IOT) application implemented with an objective to offer a cost effective solution of monitoring system, which continuously presents remote energy yields and its performance either on computer or on handheld gadgets such as smart phones.

Sunair - Hybrid wind and solar energy generation system

Group Members: Danyal Irfan Butt | Muhammad Hibbaan Abdullah | Ryan Rasheed

Advisor: Tassawar Kazmi Co-Advisor: Ahsan Azhar

The increasing demand for renewable energy sources has accelerated the adoption of photovoltaic (PV) systems. However, the performance and reliability of these systems are highly influenced by environmental conditions such as temperature, humidity and dust, which can cause degradation over time. This project proposes a novel approach to condition monitoring of PV systems by analyzing electrical parameters such as voltage, current, and power output combined with environmental data, to develop a robust monitoring system to enhance performance and longevity.

03 Knowledge Group
Integrated Circuits and Systems

AI-Enhanced Bioimpedance Meter for Advanced Health Monitoring

Group Members: Awais Ahmed | Muhammad Maahd Junaid | Muhammad Taqi Raza Kazmi

Advisor: Usman Khan Co-Advisor: Qurat ul Ain

Bioimpedance, the measure of impedance in biological tissues and organs, holds significant potential in assessing human health. Factors such as body water content and associated minerals can notably influence bioimpedance, making it a valuable metric for healthcare applications. This project endeavors to pioneer an AI-enhanced bioimpedance meter aimed at comprehensive health monitoring, particularly focusing on body water content.
The proposed system will employ bioimpedance spectroscopy, spanning frequencies ideally from 1k Hz to 100k Hz, to accurately characterize the bioimpedance of individuals. By integrating artificial intelligence capabilities, the system will analyze the bioimpedance data collected and deliver personalized health recommendations to users.
Key objectives of the project include:

1. Development of a robust bioimpedance measurement system capable of spectroscopic impedance analysis on human subjects.
2. Implementation of AI algorithms for in-depth analysis of bioimpedance data and generation of health recommendations tailored to individual users.

This approach is designed to be non-invasive and cost-effective, making it accessible for widespread use in healthcare settings. Adherence to established safety protocols for safe current injection through the body will ensure user safety throughout the measurement process.
By combining cutting-edge AI technology with bioimpedance analysis, this project aims to revolutionize health monitoring by providing users with actionable insights into their physiological well-being. Through continued research and development, this AI-enhanced bioimpedance meter holds immense potential for enhancing preventive healthcare practices and improving overall quality of life.

An Indigenous RFID Transponder Chip Design for Animal Tagging Applications

Group Members: Shameer Hussain Khan

Advisor: Hammad M Cheema Co-Advisor: Saman Fatima

In recent years, livestock management has faced significant challenges as we still rely on traditional methods like physical tagging for health monitoring, which are often inefficient and labor-intensive. Disease outbreaks in herds can go unnoticed, leading to the rapid spread of illness, costly treatments, and substantial losses in

productivity. The need for real-time, automated solutions has become a crucial need, as traditional methods fail to provide timely data on animal health. Advanced RFID technology offers a promising solution, enabling wireless, continuous monitoring of livestock without the need for manual intervention, improving both disease detection and management efficiency.

This project develops a passive RFID transponder chip for detecting and monitoring the health of cattle within a herd, eliminating the need for physical marking with tags. The system operates in Low-Frequency (LF) with key components including an RF-to-DC charge pump, a 64-bit/128-bit ROM, and ASK modulation circuits. Optimizing the Power Conversion Efficiency (PCE) of the rectifier is a major focus to ensure efficient energy harvesting from the RFID readers. The scope will be a tape-out ready chip design.

Design and control of an hybrid aerial electric vehicle

Group Members: Maryam Samavia

Advisor: Abdullah Mughees Co-Advisor: Tassawar Kazmi

This project seeks to create an innovative aerial electric vehicle, a hybrid machine capable of seamlessly transitioning between terrestrial and aerial modes. By integrating advanced robotic car technology with cutting-edge drone capabilities, this project seeks to redefine the boundaries of transportation. Leveraging state-of-the-art control algorithms, the vehicle will achieve precise aerial maneuvers and optimize flight paths to conserve energy, ensuring efficient and sustainable operation. The design process will be underpinned by a harmonious blend of control engineering principles, electrical circuit design, power converter technology, and mechanical engineering. Potential applications of this technology span a wide range of industries. In emergency response scenarios, the aerial electric vehicle could swiftly reach inaccessible areas, delivering critical supplies or providing medical assistance. Within the realm of surveillance and security, its unique capabilities would enable enhanced monitoring of vast territories, detecting anomalies, and safeguarding sensitive infrastructure. Moreover, in the context of environmental monitoring and conservation, the vehicle could be deployed to gather valuable data on ecosystems, track endangered species, and support sustainable practices. By combining the versatility of a car with the agility of a drone, this project promises to revolutionize transportation, emergency services, security, and environmental stewardship.

Development of AI Enhanced Electrochemical Impedance Spectroscopy System for Monitoring Battery Health in Electric Vehicles

Group Members: Muhammad Ahmad | Muhammad Ali Haider | Uraib Asif Muhammad

Advisor: Usman Khan Co-Advisor: Muhammad Daud Abdullah Asif

The performance and longevity of batteries used in Electric Vehicles (EVs) are crucial factors determining the overall efficiency and reliability of the vehicle. Electrochemical Impedance Spectroscopy (EIS) presents a powerful technique for non-invasive assessment of battery health, offering insights into the electrochemical processes occurring within the battery.

Understanding Electrochemical Impedance:
Electrochemical impedance refers to the opposition encountered by the flow of electrical current through the electrochemical system of a battery. It comprises both resistive and capacitive components, representing the combined effects of electrolyte conductivity, charge transfer kinetics, and diffusion processes within the battery.

Electrical Equivalent:
The electrical equivalent circuit of a battery typically includes resistors and capacitors, each representing different aspects of the battery's behavior. For instance, the solution resistance reflects the ionic conductivity of the electrolyte, while charge transfer resistance accounts for electrode kinetics.

Spectroscopic Analysis:
Spectroscopic analysis involves varying the frequency of the applied electrical signal and observing the corresponding changes in impedance. This approach enables the characterization of different electrochemical processes occurring within the battery across a wide frequency range. By analyzing impedance spectra, researchers can elucidate the mechanisms governing battery performance and degradation.

Importance of Monitoring Electrochemical Impedance:
Monitoring electrochemical impedance is instrumental in assessing battery health and predicting performance degradation over time. Changes in impedance spectra can indicate variations in electrode morphology, electrolyte properties, and the formation of degradation products such as solid-electrolyte interphase (SEI) layers. Early detection of these changes enables proactive maintenance and prolongs battery lifespan.

Proposed Project:
The proposed project aims to develop an Electrochemical Impedance Spectroscopy (EIS) system tailored for monitoring the health of batteries utilized in Electric Vehicles. This involves the design and implementation of an electronic circuit capable of performing impedance measurements over a wide frequency range. The system will acquire impedance data from EV batteries and utilize AI algorithms to analyze the data, predict battery health, and provide recommendations to EV users.

Conclusion:
The integration of electrochemical impedance spectroscopy with AI-based analysis represents a promising approach for real-time monitoring and management of battery health in Electric Vehicles. By enabling proactive maintenance and optimized battery usage, this technology has the potential to enhance the efficiency, reliability, and sustainability of electric transportation systems.

Design and Verification of AXI to MIPI Bridge

Group Members: Syed Hussain Ali

Advisor: Muhammad Imran Co-Advisor: Abid Rafique

This project focuses on designing and verifying an AXI (Advanced extensible Interface) to MIPI (Mobile Industry Processor Interface) interconnect, essential for efficient communication in System-on-Chip (SoC) architectures. The design involves creating an interconnect that converts AXI protocol signals to MIPI signals, ensuring seamless data transfer. Verification employs simulation and formal methods to validate functionality, performance, and reliability. The goal is to achieve protocol compliance and integration efficiency, advancing mobile communication technologies and enhancing next-generation mobile device performance.

AI-V: Integrating Neural Processing Unit with RISC-V

Group Members: Sheharyar Zahoor | Usman Ayub

Advisor: Abid Rafique Co-Advisor: Muhammad Imran

This project focuses on the design and development of a Neural Processing Unit (NPU) based on the RISC-V Instruction Set Architecture (ISA) for efficient edge AI applications. The aim is to leverage the open-source and modular nature of RISC-V to build a customizable NPU tailored to the unique requirements of AI inference tasks at the edge. The project will focus on optimizing the RISC-V core to support vector operations, which are essential for accelerating machine learning workloads, specifically convolutional neural networks (CNNs).

The development process will involve multiple stages. Initially, the project will focus on identifying and addressing the limitations of standard RISC-V cores in AI applications. This will include modifications to the instruction set, as well as hardware accelerations for matrix multiplication and accumulation, commonly referred to as MAC operations.

The optimized RISC-V NPU will then be integrated with various AI models, starting with small-scale TinyML models, to demonstrate its capabilities in terms of efficiency, speed, and accuracy. Real-time simulations and edge computing scenarios will be tested to ensure the system performs under different operating conditions. The final outcome will be an NPU that effectively balances power consumption with the accuracy and speed required for AI inference at the edge.

Enigma-V: Accelerating Cryptography on RISC-V

Group Members: Muhammad Aqdas Chaudhary | Muhammad Sufiyan Sadiq | Rukhaima Maryam

Advisor: Abid Rafique Co-Advisor: Muhammad Imran

As the demand for secure and efficient cryptographic processing continues to grow, particularly in the realms of IoT, edge computing, and embedded systems, the need for optimized cryptographic operations on modern processors is critical. While post-quantum cryptography (PQC) is gaining attention, conventional pre-quantum cryptographic methods, supported by the newly ratified symmetric cryptographic extensions in RISC-V, still offer significant advantages. These include lower complexity, reduced computational overhead, and more efficient implementations on existing hardware, making them practical for many real-world applications.

This project focuses on the integration and acceleration of symmetric cryptographic operations in a RISC-V processor using both scalar and vector extensions, specifically designed to optimize conventional cryptography. These extensions, which have been recently ratified, can significantly improve instruction count and overall efficiency, according to recent performance results.

RISC-V, an open-source, license-free ISA supported by over 200 organizations, including Google, Qualcomm, and Samsung, offers a flexible and extensible platform well-suited for such enhancements. By leveraging the modularity of RISC-V's instruction set, we aim to implement and test these cryptographic extensions on an open-source RISC-V core, targeting IoT and edge applications where resource and energy constraints are paramount.

The project will focus on optimizing cryptographic algorithms such as AES and SHA by using these specialized scalar and vector extensions, which can dramatically reduce the clock cycle count and energy consumption. Our goal is to scrutinize the efficiency gains provided by the cryptographic extensions, explore potential bottlenecks, and propose further optimizations for maximizing performance on embedded devices.

By comparing the efficiency of these cryptographic extensions with both pre-quantum and post-quantum cryptographic schemes, this project will highlight the practicality and advantages of conventional cryptography in scenarios where scalability and efficiency are crucial. Ultimately, the project aims to contribute to the ongoing advancement of cryptographic security in resource-constrained environments, enhancing the usability and performance of secure RISC-V-based systems.

Hardware Acceleration of Vision Transformer Inference

Group Members: Mehboob Khaliq

Advisor: Abid Rafique Co-Advisor: Christian Weis

This project on hardware acceleration of Vision Transformers (ViTs) investigates the development of custom hardware solutions to significantly improve the computational efficiency of ViT models, which have gained prominence in computer vision due to their superior performance in image classification and object detection tasks. However, ViTs are highly resource-intensive, particularly due to their reliance on self-attention mechanisms and large matrix multiplications. The project focuses on designing specialized hardware architectures, such as FPGA-based accelerators or ASICs, to reduce the computational complexity and energy consumption of these models.

Key areas of exploration include optimizing data movement, reducing memory access overhead, and maximizing parallelism to accelerate core operations like self-attention, multi-head attention, and feed-forward layers. The goal is to implement these optimizations while maintaining or even improving the accuracy of the models. This research aims to provide scalable and energy-efficient hardware solutions that can meet the growing demand for high-performance vision models, especially in real-time and edge computing scenarios, such as autonomous vehicles, drones, and mobile devices.

Hardware Assisted Homomorphic Encryption (HE) Acceleration

Group Members: Moonis Amir Zaman | Muhammad Bilal Khan

Advisor: Muhammad Imran Co-Advisor: Waqar Ahmad

Fully homomorphic encryption is an encryption technique that enables computation on encrypted data . This exciting cutting-edge cryptography technique offered privacy-preserving operations on ciphertext with potential use in a variety of applications, ranging from healthcare to finance. However, the performance costs inhibited the widespread use of homomorphic encryption (HE). Several limited version of HE were proposed called the somewhat homomorphic encryption (or SHE schemes), that are usable up to a limited number of operations on ciphertext. Some noticeable schemes include the CKKS, BGV and BFV, mostly named after their research team's initials. These schemes are much more practical and consequently are worth exploring for acceleration on FPGAs.

This project will focus on designing and developing a specially optimized hardware accelerator for these homomorphic encryption schemes (the CKKS scheme) on FPGAs because of the advantages it offers (Key switching in CKKS instead of the expensive bootstratpping in other schemes). We will use the OpenFHE which is an open-source library providing tools to build HE applications that work on encrypted data, based on any SHE schemes as the user prefers (CKKS, BGV, BFV etc) . It works on various operating systems, making it accessible to a wider audience including both researchers and developers. Several noticeable research works in this regard are presented that have primarily tried to accelerate the Number theoretic transform or the NTT operation used in CKKS scheme and happens to be the most computationally intensive and frequently used operation . NTT in software is slow and not a straightforward task due to its complex architecture and consequently researchers have tried to implement NTT on FPGAs due to the advantage of acceleration, either partially in a hardware software co-design or completely, using hardware supporting parallelism . In this context a hardware only NTT engine with flexible architecture for NTTs that is able to accommodate a range of input lengths (215-217) with different radix symmetry and an efficient modular multiplication united is often explored. A conflict free memory usage for NTTs is also researched and is desirable. A recent open source code is also available for Aloha-HE .

ISA Extension for RISC-V Based PQC Kernels for IoT Applications

Group Members: Ali Raza | Muhammad Abdullah

Advisor: Muhammad Imran Co-Advisor: Waqar Ahmad

The security infrastructure we rely on today is considered broken when a scalable quantum computer is successfully realized. Consequently, the National Institute of Standards and Technology (NIST) in USA initiated a call develop and standardize of new post-quantum cryptography (or PQC also called quantum-resistant cryptography) schemes replacing established public-key mechanisms (NIST PQC). After 3 competitive rounds, the initial 69 submissions have been reduced to 4 winner candidates in 2022 and 4 moved forward to round 4. As PQC is supposed to replace modern public-key schemes in the near future, it will only be considered as a feasible alternative if its constructions can be similarly efficiently implemented on many of the embedded processors existing in today's digital and pervasive environment. These embedded processors make the backbone of computing and communication, actuating the revolution of the IoT today, with a sky-rocketing demand of more ubiquitous intelligence in future.

This project will investigate efficient and lightweight implementations of PQC algorithms on an open-source RISC-V processor as would be used for IoT and edge applications. Since 3 out of the 4 winners of the NIST PQC are lattice based in nature, the prime candidates for acceleration will be the CRYSTALs family of lattice-based schemes (Kyber and Dilithium). RISC-V is an open-source Instruction set architecture (ISA) RISC design that is licence-free and practical to use by both academics and industry. Its instruction set is currently supported by several popular software toolchains and currently has over 200+ organizations including Google, Qualcomm, Samsung are part of its foundation. The project will follow the recommendations from NIST PQC process to take up software implementations targeting the RISC-V platform, keeping in mind to experiment with novel approaches that minimise the resource and energy usage for embedded and/resource constrained devices.

This project will test, evaluate, and scrutinize the practicability of lattice-based quantum resistant cryptographic schemes (from the NIST PQC) for an IoT end-node device by aggressively exploring several optimizations techniques. RISC-V's instruction set is designed for modularity and extensibility, based on which domain-specific architecture aimed at a particular application like PQC can be developed. We will consider primarily the tightly coupled Instruction set extension (ISE) that relies on the existing processing pipeline, leading to a significant reduction of the clock cycle count and energy consumption . The project will analyse the performance bottlenecks in these implementations to determine how best to improve the efficiency of the algorithms while running on RISC-V using existing and/or custom ISE. This will be followed by an investigation of the performance trade-offs of any proposed approaches.

Low Dropout Voltage Regulator Chip Design for Power Management Applications

Group Members: Muhammad Saad Munawar

Advisor: Qurat ul Ain Co-Advisor: Hammad M Cheema

Design and implement a Low-Dropout Voltage Regulator (LDO) tailored for Power Management Integrated Circuits (PMICs) using Cadence Virtuoso. The primary function of the LDO in a PMIC is to regulate the output voltage, providing a stable and precise voltage level despite variations in the input voltage or changes in the load. This project aims to create an efficient and stable voltage regulator with low quiescent current, fast transient response, and optimal performance for integration into PMICs.

MaskOff: Real-Time Face Unmasking with GANs Acceleration

Group Members: Hassaan Ahmed | Mohammad Saad Jawad | Syed Zain Ali Jafri

Advisor: Muhammad Imran Co-Advisor: Abid Rafique

Practical use of the sophisticated architecture of Generative Adversial Networks require hardware implementation for real-time processing. Design of such an architecture is via the different trade offs between computational operations, memory bandwidth management, parallel processing, resource usage, performance and latency. An SoC based architecture to process and control the various layers of GANs deployed on an FPGA-SoC is proposed as the final result.

Next-V: Application-Class Linux-Capable RISC-V Processor IP

Group Members: Abdul Rafay | Muhammad Umar Adam | Umer Ali

Advisor: Muhammad Imran Co-Advisor: Abid Rafique

The goal of this project is to develop a RISC-V processor that is capable of running Linux. We will build upon a simple RISC-V RV32IMAC core. The project requires that all the necessary extensions specified in the RISC-V privileged ISA document for making a simple core OS-capable are implemented. The designed core will be prototyped on FPGA along with UVM-based verificaiton and physical design.

PreFetch-V: Hardware-Based Cache Prefetching in RISC-V

Group Members: Abdullah Siddiqui | Muhammad Huzaifa Qureshi | Muzammil Ahmed

Advisor: Muhammad Imran Co-Advisor: Abid Rafique

This project is about design and implementation of a cache prefetcher for a RISC-V processor and evaluate its performance on various benchmarks with and without the
cache prefetcher.

RISC-V Goes Real Time

Group Members: Abdul Hadi | Hamza Attiq | Muhammad Ahmad Raza

Advisor: Abid Rafique Co-Advisor: Muhammad Imran

Our project "RISC-V Goes Real-Time" is centered on running Zephyr RTOS on a custom RISC-V RV32IMAC core, showing the versatility of RISC-V in real-time embedded applications. This project involves building a system-on-chip (SoC) around the core, integrating some peripherals, and configuring Zephyr RTOS to manage real-time tasks efficiently. Key optimizations include implementing advanced interrupt handling mechanisms and designing control and status registers module to enhance system performance. This project aims to demonstrate how RISC-V can serve as an excellent platform for real-time processing in embedded systems, offering flexibility, scalability, and open-source innovation.

RVV+ - Tensor Processing with RISC-V Vector

Group Members: Ahmad Raza | Muhammad Shayan Khan Babar

Advisor: Abid Rafique Co-Advisor: Muhammad Imran

With the growing demand for efficient matrix computations in machine learning and artificial intelligence, hardware accelerators like Tensor Processing Units (TPUs) play an increasingly vital role. This project aims to enhance the computational efficiency of a RISC-V vector core by implementing custom tensor instructions optimized for matrix operations. We implement three custom instructions designed to accelerate multiply-accumulate (MAC) operations, reduce clock cycles, and streamline data handling through the vector core's registers. Our implementation is parameterized to support various matrix sizes, ensuring scalability and flexibility across different workloads. We benchmark our design using a range of matrix sizes, from 4x4 to larger dimensions, allowing us to evaluate the performance improvements compared to standard instruction sets. Key performance metrics, such as power consumption, hardware utilization, and execution time, are analyzed to demonstrate the effectiveness of our approach in enhancing tensor computation efficiency.

SoC-V: RISC-V Based Reprogrammable System on Chip (SoC)

Group Members: Aayan Alam | Fizza Haq | Hassan Usman

Advisor: Abid Rafique Co-Advisor: Muhammad Imran

This project deals with the design of a general purpose solution for a variety of computational tasks requiring both hardware acceleration and systematic software based processing. In order to tackle such requirements, an SoC is to be designed which features a hard RISC-V based processor with out of order superscalar execution and a reprogrammable fabric allowing for reconfigurable hardware. Both elements are part of one complete package, and the elements are interfaced over high speed modern interconnects, allowing for seamless communication throughout a typical application.

SRAM-Based In-Memory Computing Unit for AI Acceleration

Group Members: Muhammad Ammar | Muhammad Ismaeel Butt | Syed Muhammad Muslim | Zehra Ali

Advisor: Muhammad Imran Co-Advisor: Abid Rafique

In recent years, computing has witnessed several groundbreaking advancements, with two particularly noteworthy: computing in memory and neural network computing. These technologies hold the promise of transforming how we approach computing, with the potential to drive progress across various fields, including healthcare, finance, and transportation.

Computing in memory introduces a new architecture that utilizes in-memory computing units to perform data operations. This approach can significantly enhance the speed and efficiency of data processing by minimizing the need to transfer data between processing units and memory. It is especially advantageous for applications involving large datasets and requiring rapid processing, such as financial analysis or deep learning. In this project, our goal is to create a specialized memory chip, known as an SRAM-based machine learning accelerator. This chip is designed to efficiently perform multiplication and accumulation operations directly within the memory. These operations are crucial for calculating dot products, which are commonly used in machine learning algorithms. Our design has a dual function. It can act as a regular SRAM, storing data as usual, and it can also work as a machine learning accelerator, speeding up certain computations by processing data in parallel directly within the memory. Once we complete the design of this in-memory computing unit (IMCU), we plan to integrate it with a RISC-V processor that uses a five-stage pipeline. This integration will allow the processor to leverage the speed and efficiency of our accelerator for machine learning tasks while maintaining its general-purpose computing capabilities.

04 Knowledge Group

Smart Telecommunication Systems & Networks

EnviroSense: Empowering Safety with IoT-enabled Smart Environmental Monitoring System for Gas Detection and Analysis

Group Members: Ahsan Abdul Rehman | Rehoboam Rock

Advisor: Usman Khan Co-Advisor: Qurat ul Ain

For our final year project, we propose the development of EnviroSense, an innovative solution aimed at revolutionizing environmental safety through advanced gas detection and analysis. EnviroSense leverages the power of IoT to create a smart environmental monitoring system that seamlessly integrates gas sensors, front-end electronics, microprocessors, server-based AI processing, and a user-friendly GUI. Our project seeks to address the pressing need for real-time monitoring of harmful gases such as carbon monoxide, carbon dioxide, methane, and nitrogen dioxide in various environments.

The system will be designed to continuously collect and analyze data from gas sensors, transmitting it to remote servers for processing and interpretation using AI algorithms. The insights derived from this analysis will be presented to users through a visually engaging GUI, empowering them to make informed decisions and take proactive measures to ensure environmental safety. EnviroSense represents a unique opportunity to merge cutting-edge technology with environmental science, offering a comprehensive solution to mitigate the risks associated with hazardous gas exposure.

Solaris - a Blockchain-based Peer-to-peer Energy Marketplace

Group Members: Humayun Kamal Siddiqui | Muhammad Talha Kamran | Rimla Akhtar

Advisor: Syed Taha Ali Co-Advisor: Arshad Nazir

Our project aims to establish a decentralized peer-to-peer (P2P) energy trading platform within a local microgrid, leveraging blockchain technology and IoT devices. By implementing an auctioneering system on our local blockchain network using ESP32-equipped smart meters and Raspberry Pi, powered by Solidity smart contracts, we aim to facilitate efficient energy transactions on an Ethereum-based blockchain. Utilizing solar panels as our primary energy source, we will integrate an AI model to dynamically determine energy prices based on real-time market conditions, enhancing user engagement and sustainability within the microgrid community.

Real-Time Bitcoin Transaction Fee Prediction Using Mempool and Live Network Data

Group Members: Malik Ahmed Nadeem | Muhammad Saqib | Syed Ali Ahzum Bukhari | Syed Safi Haider

Advisor: Syed Taha Ali Co-Advisor: Wajid Mumtaz

This project focuses on developing a machine learning model for real-time prediction of Bitcoin transaction fees using data from the mempool and live network activity. By analyzing transaction sizes, timestamps, and other key blockchain metrics, the model aims to improve the accuracy of fee estimations. The approach combines time series analysis with deep learning techniques to enhance decision-making for Bitcoin users, optimizing transaction efficiency on the network.

Smart Freight - securing logistics and transport routes with IoT and Smart Contracts

Group Members: Abdul Moaiz | Ali Hassan Bukhari | Syed Muhammad Tayyab

Advisor: Syed Taha Ali Co-Advisor: Arshad Nazir

Cargo theft is a global yet under-reported issue that causes significant economic losses. Traditional methods for ensuring container security are inadequate in countering the sophisticated and non-violent nature of cargo theft. Through extensive research on prevalent cargo theft strategies, the framework proposes different conditions for smart contracts to distinguish between a legitimate container unlock and a theft attempt. When these conditions are violated, a cargo theft event is triggered on the blockchain, facilitating rapid recovery of stolen goods. Additionally, the immutable record of theft incidents offers valuable insights for creating effective reports and planning efficient shipping routes by marking previously recorded theft locations as red zones.

Build health checks for stateful Kubernetes add-ons

Group Members: Ali Farooq | Saad Akram Khan Niazi

Advisor: Hassaan Khaliq Qureshi Co-Advisor: Abdur Rehman

This final year design project (FYDP) is focused on the development of health checks for stateful Kubernetes add-ons. Kubernetes, an open-source container orchestration platform, requires robust monitoring and health check mechanisms to ensure the high availability and reliability of its components. This FYDP will specifically target the implementation of health checks and functionality checks for stateful add-ons, which are more complex due to their persistent state and storage requirements. The project aims to enhance the resilience and operational efficiency of Kubernetes clusters by ensuring that stateful add-ons are continuously monitored and automatically recovered in case of failures.

Design and Development of AI-Enhanced USV Swarm System

Group Members: Lukman | Mahnoor Ibrar | Muhammad Majid Ferozi | Muhammad Sami Akram

Advisor: Mian Ilyas Ahmad Co-Advisor: Salman Abdul Ghafoor

This project involves development of an indigenously designed and developed swarm of USVs that can be used for multiple applications. The development work is planned to be completed in the following three milestones.

1. Model-Based System Engineering of USV swarm.
2. USV Hull Design and Fabrication.
3. USV Swarm Design and Testing

The integration of AI and machine learning allowed USVs to make real-time decisions, adapt to dynamic environments, and optimize routes. AI-powered algorithms enabled tasks like anomaly detection, adaptive path planning, and even learning from experience. Their utility will be explored in this project.

GitHub Issues Scraper Using LangChain

Group Members: Ghania Sarwar | Naima Yaqub

Advisor: Hassaan Khaliq Qureshi Co-Advisor: Ayesha Khaliq

This final year design project (FYDP) aims to develop a GitHub issues scraper using LangChain. The objective is to automate the process of identifying and summarizing GitHub issues containing specific keywords. The scraper will search through repository issues, extract relevant data, and provide summaries in a predefined format. This tool will help developers and project managers quickly identify and understand key issues, improving project management efficiency and issue resolution times. By leveraging LangChain's natural language processing capabilities, the project will ensure accurate keyword detection and meaningful summarization.

Kubernetes Cluster Visualization and Management Operator

Group Members: Malik Asfar Ahmad | Umer Abdullah Khan

Advisor: Hassaan Khaliq Qureshi Co-Advisor: Faizan Fareed

Project Overview
This final year project focuses on the development of a Kubernetes Operator that enhances the operational capabilities of managing Kubernetes resources within a cluster. The operator is designed to run seamlessly within a Kubernetes environment and expose a user-friendly web interface on a designated endpoint. The primary function of this interface is to enable users to visualize all resources running in the cluster, understand the relationships between these resources, and access detailed configurations of each resource directly through their YAML manifests.

Objectives
Development of a Kubernetes Operator: Implement an operator that can be deployed to any Kubernetes cluster to monitor and interact with the resources within that cluster.

Interactive User Interface: Develop a web-based UI that provides a visual representation of the Kubernetes cluster's architecture, displaying various resources and their inter-dependencies. It should be able to show the relationships between multiple resources. E.g, it should be able to visualize children pods for a replica set.

Resource Interaction: Enable users to interact with the visualization to retrieve detailed information, such as fetching the YAML manifest of any Kubernetes resource by clicking on its representation in the UI.

Real-Time Updates: Ensure that the UI reflects real-time changes within the Kubernetes cluster, allowing for up-to-date tracking and management of resources.

Write a Kubernetes Admission Controller to enforce EKS Best Practices

Group Members: Eisa Sarwar | Hamza Bashir | Muhammad Huzaifa Bin Shamayl

Advisor: Hassaan Khaliq Qureshi Co-Advisor: Faizan Fareed

Overview
Amazon Elastic Kubernetes Service (EKS) is a managed Kubernetes service that makes it easier for organizations to run Kubernetes on AWS without needing to install, operate, and maintain their own Kubernetes control plane. As Kubernetes environments grow, maintaining security and operational standards in line with best practices becomes challenging. This project aims to create a Kubernetes Admission Controller tailored to enforce the best practices as outlined in the AWS EKS documentation. The controller will serve as a critical gatekeeper, intercepting and validating changes to the cluster configuration before they are applied, ensuring compliance with established standards.

Objectives
Study and Analysis: Gain a comprehensive understanding of EKS best practices as documented by AWS. This includes security configurations, cluster management, networking, and workload management practices.

Network for Monitoring Atmospheric Parameters and Air Quality Index (AQI)

Group Members: Ahsan Tahir | Muhammad Abdurahman Aldakhil

Advisor: Nazia Perwaiz Co-Advisor: Sidra Sultana

This project aims to develop a prototype Network for Air Quality Monitoring in Islamabad, leveraging state-of-the-art technology and strategically placed sensors to continuously monitor atmospheric parameters and Air Quality Index (AQI) levels.

This initiative not only provides stakeholders with real-time insights into current air quality conditions but also lays the foundation for informed decision-making and targeted interventions to address pressing environmental concerns.

Blue Shield- An Aqua drone for Water Quality Management and Environmental Sustainability

Group Members: Azzan Rauf | Mohammad Saad Husnain | Muhammad Abdullah

Advisor: Rafia Mumtaz Co-Advisor: Syed Ali Hassan

The Aqua Drone project aims to enhance water quality management by detecting heavy metal contamination and regulating chlorine levels in real time. Equipped with advanced sensors and soft sensors integrated with a controller and trained models, the drone will collect and process data, providing an interactive user interface for monitoring and action. It will map water bodies and remove visible surface waste, ensuring clean water for households, agriculture, marine life, and the fishing industry. This project will contribute to environmental sustainability by improving water quality and management practices.

Cardiac Telemetry Powered by AI and IoT for Advanced Patient Care

Group Members: Maryam Ijaz | Muhammad Saad Farrukh

Advisor: Rafia Mumtaz Co-Advisor: Muhammad Daud Abdullah Asif

Existing cardiac monitoring devices are expensive, bulky, and inaccessible to many patients, hindering early detection of cardiac issues. Cardiac telemetry offers a cost-effective, portable, solution that can accelerate the diagnosis with AI algorithms, IoT connectivity, and real-time monitoring. The device will be pocket-friendly hence making it more portable, scalable, cost effective, and realizing the concept of telehealth.

Deep Reinforcement Learning for STAR-RIS CoMP-NOMA Networks

Group Members: Ahmad Faisal Mirza

Advisor: Syed Ali Hassan Co-Advisor: Huma Ghafoor

The hub and hosts, and the transmission lines between them, form a graph with the topology of a star. Data on a star network passes through the hub before continuing to its destination. The hub manages and controls all functions of the network. It also acts as a repeater for the data flow. In a typical network the hub can be a network switch, Ethernet hub, wireless access point or a router.

The star topology reduces the impact of a transmission line failure by independently connecting each host to the hub. Each host may thus communicate with all others by transmitting to, and receiving from, the hub. The failure of a transmission line linking any host to the hub will result in the isolation of that host from all others, but the rest of the network will be unaffected.[2]

The star configuration is commonly used with twisted pair cable and optical fiber cable. However, it can also be used with coaxial cable as in, for example, a video router.

DRL-based Approach to Optimize Energy Efficiency in NOMA-based IoT Networks

Group Members: Muhammad Uzair | Saleha Ahmed

Advisor: Syed Ali Hassan Co-Advisor: Arsalan Ahmad

Network Slicing (NS) was proposed as a viable solution in Release 15 of Third Generation Partnership Project (3GPP) to allocate the limited resources among different service types for improving their Quality-of-Service (QoS). However, the advanced vehicular applications such as autonomous driving, platooning, remote driving, etc. have stringent QoS demands and the standard NS architecture is not sustainable for these services. Therefore, we propose a solution compatible with the standard 3GPP NS architecture that implements an Actor-Critic based Deep Reinforcement Learning (DRL) algorithm in the Network Slice Subnet Management Function (NSSMF). The algorithm allocates and manages the limited resources among different slices based on their real-time traffic demands. We generate real-time traffic for each service type and train the algorithm to improve the QoS of each service type in the network. The proposed method is evaluated for the training performance of the proposed algorithm as well as the Service level agreement Satisfaction Ratio (SSR) of each slice. The results exhibit that the proposed method not only improves SSR of each slice, but also performs well in case of increased node density in the network.

Implementation of an integrated network for smart cities in coastal areas

Group Members: Javaria Ishtiaq | Maryam Naseem Dar

Advisor: Huma Ghafoor Co-Advisor: Syed Ali Hassan

The Coastal Bend Region (CBR) of Texas is vulnerable to acute and chronic environmental stressors stemming from natural and industrial sources, including flooding and erosion from high tides, storm surge events, and ship traffic, as well as higher levels of air and water pollution due to expansion of nearby industrial operations. Despite the multitude of environmental hazards facing the region, formal monitoring systems are limited and provide an incomplete view of local-level conditions. In addition, networks for communication and decision-making are often localized and/or fragmented. As a result, CBR communities lack the comprehensive data and decision-making structures needed to plan for, respond to, and mitigate the impacts of potential hazards. This project will advance the understanding of how smart and connected technologies can be integrated into and support regional communication networks to build adaptive capacity in the face of cumulative impacts from climate change and industrial expansion, using the CBR as an exemplar.

Machine Learning based Secure Key Distribution over the Optical Link

Group Members: Abubakar Tahir | Hafiz Muhammad Ahsan Sheraz | Muhammad Ali

Advisor: Salman Abdul Ghafoor Co-Advisor: Ahmad Salman

The involves Detecting Eavesdroppers using Machine Learning based Techniques. Actual quantum key distribution that uses the principles of Quantum Mechanics can be performed by a single photon source only. However, we can implement other methods of securing the link, which includes machine learning based techniques. We

will transmit the key using a continuos wave laser source and use the key to decode an encrypted signal. A system will be trained on the received optical signal using a suitable ML algorithm under normal conditions (no eavesdropper). After the system is trained and deployed, an eavesdropper can be detected by the trained system by observing the change in the pattern of the received optical signal.

Performance Analysis of IRS based wireless communication Systems

Group Members: Wajiha Fatima

Advisor: Syed Ali Hassan Co-Advisor: Huma Ghafoor

The intelligent reflecting surface (IRS) is evaluated as a novel radio technology for enhancing wireless communication systems. To improve the spectral efficiency of upcoming wireless networks, significant attention has been given to IRS, a planar metasurface composed of multiple reflecting elements.

05 Knowledge Group

RF & Microwave

Design and Development of RF Front of GNSS Anti Jam System using AI/ ML

Group Members: Muhammad Abdullah Khan | Muhammad Ibadullah Hammad | Syed Anas Hussani

Advisor: Wasif Tanveer Khan Co-Advisor: Ahsan Azhar

The project aims to design and develop RF front end of anti jam GNSS System that will provide resistance to jamming signals with power around -45dBm. The project will start with system design simulations followed by schematic design and layout of different modules. All modules will be integrated together in a package. A parallel activity related to the development of an RF Design tool using LLM will be carried out and the design that was done using conventional tools will be compared to the design done by the AI tool.

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