2025

ENGINEERING CAPSTONES

Design of a Reliable, Intuitive Prosthetic Controller
Real-Time Sentiment-Enhanced Deep Reinforcement Learning Ensemble for Dynamic Market Strategies
Optimized Explainable Deepfake Detection
Enhancing Robotic Object Navigation Using Vision-Language Transformer and Common-Sense Reasoning

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FOREWORD

MESSAGE FROM OUR DEAN

The Engineering Capstone is a major design course structured to immerse students in the process of developing engineering and technology solutions. It is a defining feature of the Engineering undergraduate experience that also provides the opportunity to integrate technical, societal, and aesthetic concerns with applied design solutions. The mission to create a design through imagination and innovation is leveraged from the knowledge and skills acquired throughout the four-year curriculum, together with the culmination of ideas from the Junior year and hard work throughout 2024-25.

This year's projects align with today's Engineering advances as well as our institutional research priorities of biomedical and health systems; cybersecurity; environmental sustainability; robotics and AI; and urban systems. The Capstone Festival gave Seniors the opportunity to showcase their Capstone Projects incorporating design solutions to solve real world problems. The projects presented by the Class of 2025 are highlighted in this booklet; each represents the highest aspirations of undergraduate intellectual development, creativity, and engagement with original creative work.

To the Class of 2025, well done! Your projects are a testament to your incredible talent and hard work and we salute you.

With offers to join top international graduate schools, take up positions in large corporations, enjoy gap years, or explore opportunities in the UAE, we wholeheartedly congratulate all of you on your wonderful academic achievements.

On behalf of the Engineering Division, our best wishes for a successful future ahead and please keep in touch!

Samer Madanat
Dean of Engineering
New York University Abu Dhabi

LETTER FROM THE CAPSTONE COORDINATOR

The real-world engineering problems are cross-disciplinary in nature, with diffuse boundaries between them. The strength of our undergraduate engineering programs (Civil Engineering, Mechanical Engineering, Electrical Engineering, Computer Engineering, Bioengineering and General Engineering) is in developing engineers to solve such real-world problems. At NYUAD, the capstone courses, namely, Senior Design Capstone Project I (ENGR-UH-4011) and Senior Design Capstone Project II (ENGR-UH-4020), are structured to fulfill the requirements of all engineering programs/majors simultaneously. The scope of the challenge is defined and the execution process is structured such that each team member satisfies the requirements of their individual program.

The capstone program experience is designed to educate the students on the core principles of the staged gate process of project management, an established industry standard. Capstone coordinators and faculty advisors collectively work together to manage expectations and set challenging yet realistic project goals to enhance the quality of the program. Program content and processes are developed to ensure that capstone requirements are fulfilled to meet the ABET and Commission for Academic Accreditation (CAA) standards.

The goal of the Capstone Design Project is to provide students with a major design experience that leverages the knowledge and skills acquired through their undergraduate studies and co-curricular experiences. Its staged gate process structure includes a process of design with measurable metrics, and incorporation of appropriate engineering standards and multiple realistic constraints. Emphasis is placed on clearly framing the design problem and following the design process to produce an optimized design solution. Students are encouraged to build prototypes of their designs and seek validation of their solutions through simulations and experiments, as appropriate.

The emphasis is on students applying the design process to solve real-world problems in a 21st-century, global context. The projects address engineering and technology topics that overlap with the sciences, social sciences, liberal arts or business. The Capstone provides an opportunity to integrate technical, human, aesthetic, business, and ethical concerns with engineering design. Students practice critical skills in communication, team-building, and project management. Students complete their design and build/test their prototypes, if applicable, during the spring semester. The senior year culminates in a comprehensive project report.

Senior Design Capstone Project I (ENGR-UH-4011) and Senior Design Capstone Project II (ENGR-UH-4020) collectively offer the engineering capstone experience to seniors. Senior Design Capstone Project I is two credits, which runs for the whole of the fall semester. Senior Design Capstone Project I focus on different aspects of the capstone project, such as problem definition and creating the design solution. Senior Design Capstone Project II in spring consists of two seven-week modules. The design solution proposed in the Senior Design Capstone Project I is implemented in the first module. It is tested and validated in Module II.
This year, there were 82 senior students working on capstone projects. For some projects, multiple groups worked on the same topic. The titles of the projects are listed below:

1. **Design of an aerodynamic force-capture unit for harnessing clean energy**
2. **Development of a passive wearable exoskeleton for assisting movement and reducing muscle activity**
3. **Design of a microscope stage incubator**
4. **Design and 3D printing of biomimetic scaffolds by bone density mapping of sheep bones for regenerative medicine**
5. **Development of Improved Glaucoma Drainage Devices (GDD) to Address Postoperative Complications**
6. **Design of End-to-End Digital Wireless Communication System**
7. **A Non-invasive Glucose Monitoring wearable device**
8. **MindArm 2.0: Towards Affordable and Efficient Mind Controlled Prosthetics**
9. **Imitation Learning from Multi-View Human Demonstrations.**
10. **LLMs for secure code generation**
11. **Enhancing Robotic object navigation using Vision-Language transformer and common-sense reasoning**
12. **Optimization of multimodal foundation models for explainable real-time Deepfake detection in resource-constrained environments**
13. **Real-Time sentiment-enhanced deep reinforcement learning ensemble for dynamic market strategies**
14. **Zero-shot object navigation using VLMs and Tree-of-thoughts reasoning**
15. **Reliable and Intuitive upper-limb Prosthetic Control System**
16. **Design solutions for a community Sea-port in Abu Dhabi**

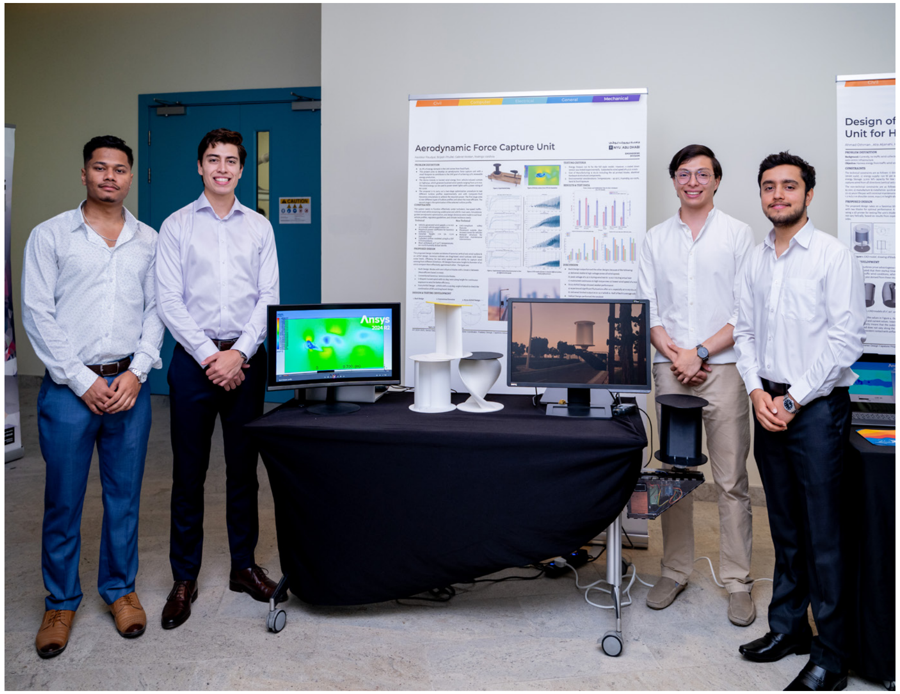
I take this opportunity to congratulate all the teams on their successful completion of the capstone projects and wish them all the best in their future endeavors.

Sincerely,

Pradeep George, PhD
Clinical Associate Professor and Coordinator of Engineering Capstones
New York University Abu Dhabi

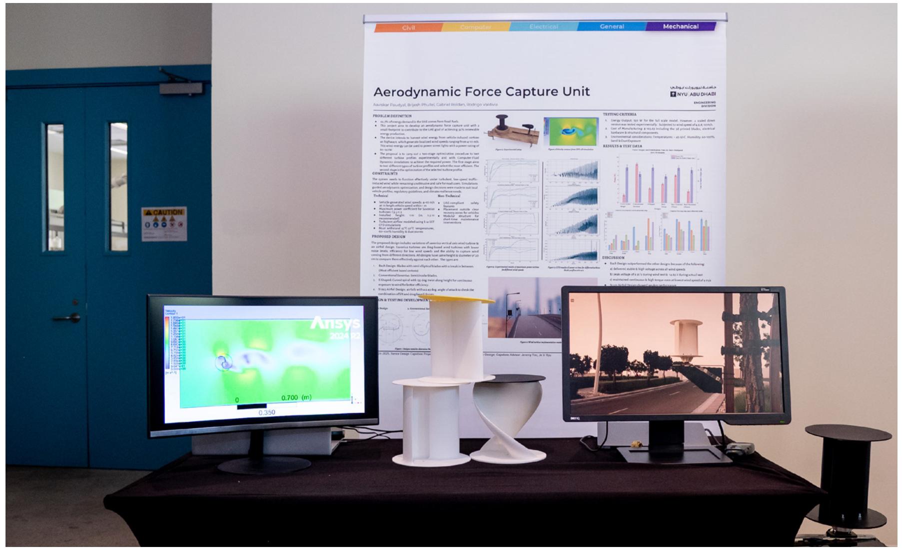
CAPSTONE PROJECTS

Design of an Aerodynamic Force-capture Unit for Harnessing Clean Energy



Aaviskar Paudyal, Brijesh Phullel, Gabriel Roldán, and Rodrigo Valdivia

This project aims to design an aerodynamic force-capture unit capable of harvesting energy from the airflow generated by traffic on highways. The primary objective is to power 120-watt LED streetlights while ensuring minimal disruption to the landscape and maintaining a small footprint. To achieve this, the design process will involve CAD modeling, computational fluid dynamics (CFD) simulations, and iterative prototyping to optimize power generation.



Although extensive research has been done on this topic, proposed capture units exhibit an overall inefficient performance. Therefore, this project will build upon existing literature and models to develop a more efficient design expected to demonstrate a reliable, low-maintenance solution that supports the growing demand for green technologies in urban planning. Moreover, by integrating sustainable energy solutions into existing infrastructure, this project seeks to reduce energy costs and contribute to eco-friendly power generation.

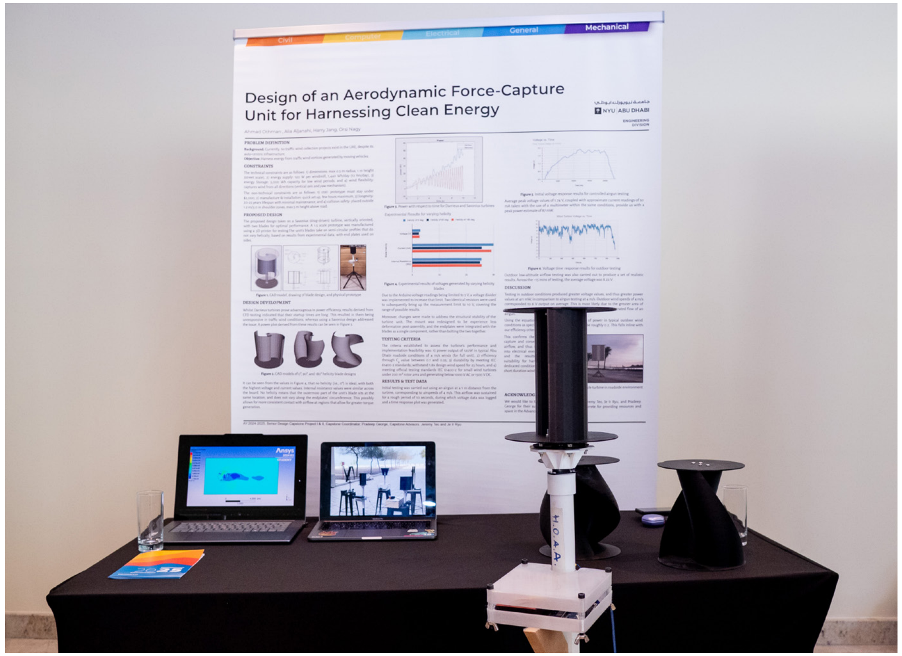
Capstone Advisor

Prof.Jeremy Teo and Prof. Je Ir Ryu

Design of an Aerodynamic Force-capture Unit for Harnessing Clean Energy

Ahmad Othman, Alia Aljanahi, Harry Jang, and Orsi Nagy

The increasing global energy demands, coupled with the finite nature of carbon-based energy sources and their environmental impact, demonstrate the urgent need for innovative renewable energy solutions. This project explores the design and implementation of an aerodynamic force-capture unit to harness clean energy from vehicular traffic on highways. Specifically, it focuses on the development of a Savonius Vertical-Axis Wind Turbine (VAWT) to convert the aerodynamic forces created by passing vehicles into electrical energy.



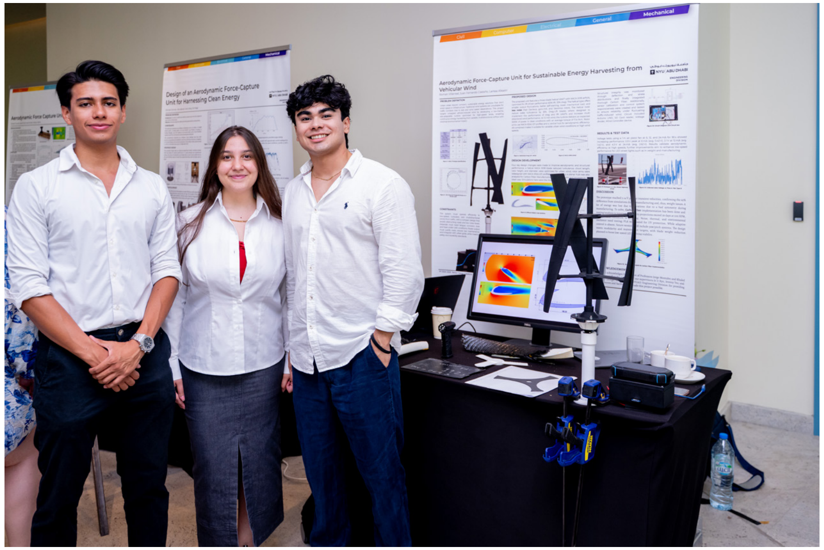
The proposed solution focuses on an untapped energy source in vehicle-generated wind while addressing the technical, environmental, and economic challenges of renewable energy adoption. This design emphasizes compactness, efficiency, and safety, aligning with Abu Dhabi's urban and environmental standards. Through computational modeling, simulations, and prototype testing, the project evaluates key parameters such as power generation and turbine efficiency under likely highway-side wind conditions.

This proposal highlights the potential of integrating renewable energy technologies into existing infrastructure, contributing to energy sustainability and environmental responsibility. By adhering to ethical principles and leveraging advancements in wind turbine technology, the project aims to create a scalable and economically viable solution to supplement urban energy demands. The findings will pave the way for future applications of traffic wind energy harvesting in the UAE and beyond.

Capstone Advisor

Prof.Jeremy Teo and Prof. Je Ir Ryu

Aerodynamic Force-capture Unit for Harnessing Clean Energy



Fernando Castaño, Larissa Al Kseiri, and Roman I. Villareal

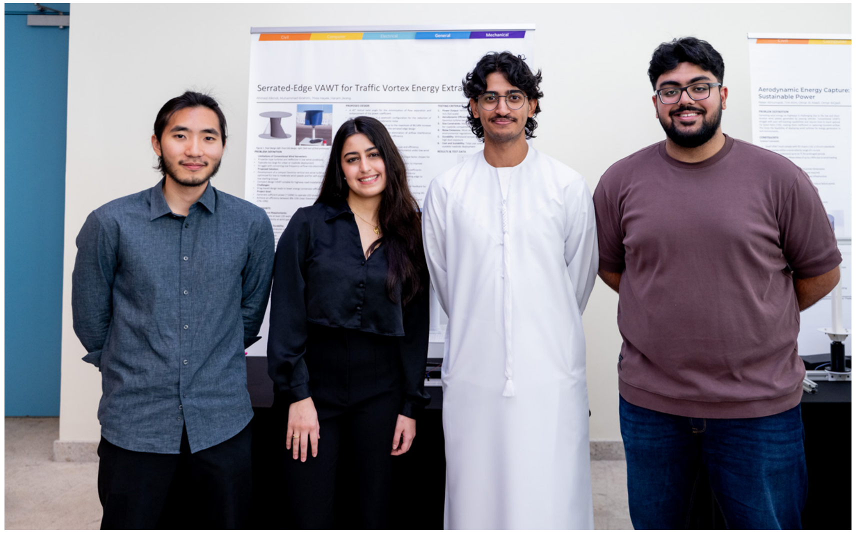
Energy conservation and environmental sustainability have become paramount in global and regional development agendas, especially as carbon-based energy sources continue to deplete natural resources and contribute to climate change. Transitioning towards sustainable energy solutions requires the integration of innovative technologies that can harness renewable resources, including “free” energy from environmental and man-made sources. This project proposes an aerodynamic force-capture unit designed to harvest energy from traffic-induced wind, converting vehicle-generated airflow into electrical power. Focusing on the UAE, and specifically Abu Dhabi, this study recognizes that the region’s high-speed highways produce significant airflow from dense vehicle traffic, a largely untapped source for renewable energy.

Previous initiatives in Abu Dhabi have explored solar and large-scale wind installations; however, wind energy collection directly from urban environments and traffic wind flows remains underdeveloped. Existing studies primarily emphasize large, open-area wind farms, neglecting the potential of vehicle-induced wind in high-traffic zones as a sustainable energy source. This capstone project fills this gap by leveraging engineering principles from fluid mechanics, aerodynamics, and sustainable design to develop a small-scale, durable turbine system optimized for urban deployment. The proposed unit aims to deliver reliable power to support infrastructure, such as LED streetlights, with minimal environmental footprint and high resilience in high-temperature, humid, and dusty conditions typical of the UAE. The project will analyze airflows and turbulence created by vehicular motion, optimize blade design for variable, multi-directional wind capture, and ensure compliance with American Wind Energy Association (AWEA) and ASTM standards for safety, structural integrity, and efficiency.

Capstone Advisor

Prof.Jeremy Teo and Prof. Je Ir Ryu

Design of an Aerodynamic Force-capture Unit for Harnessing Clean Energy



Ahmed Alkindi, Muhammad Ibrahim, Thea Hayek, and Haram Jeong

Harnessing wind energy from traffic-induced vortices presents an innovative approach to sustainable energy generation, particularly in regions like the United Arab Emirates where high- speed traffic creates significant air turbulence.

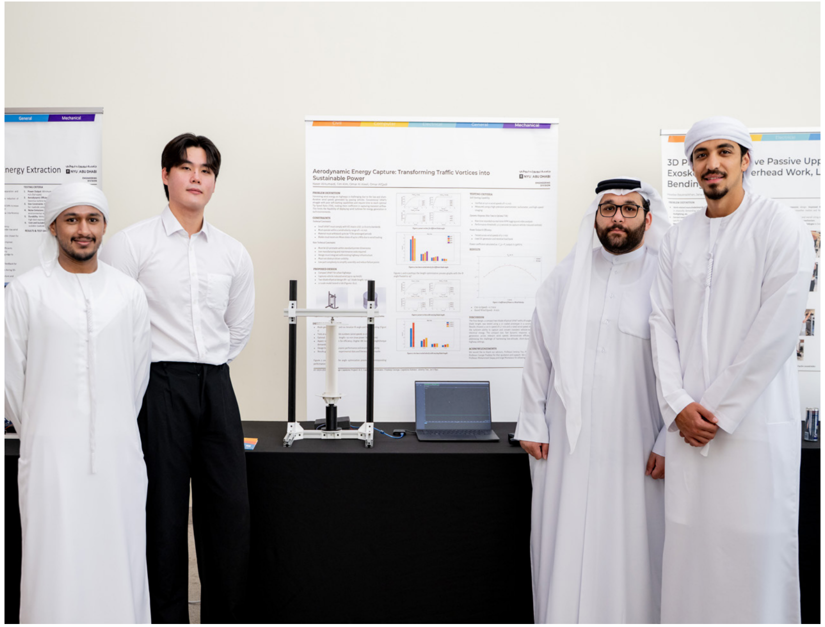
This project focuses on the design of an aerodynamic force-capture unit capable of converting these low-speed traffic-generated vortices into electrical energy, aimed primarily at powering streetlights. The unit is designed to function efficiently without significantly altering the landscape, offering an eco-friendly and non-intrusive energy solution. This study involves detailed aerodynamic design, material selection for durability and lightness, and the development of a working prototype.

The proposed system integrates computational simulations, computer aided modeling, and real-world prototyping to evaluate key performance metrics such as energy output, structural integrity, and suitability for urban and highway environments. Our findings will contribute to the practical application of traffic-driven wind energy systems in Abu Dhabi and other urbanized regions, enhancing the role of clean energy in modern infrastructure.

Capstone Advisor

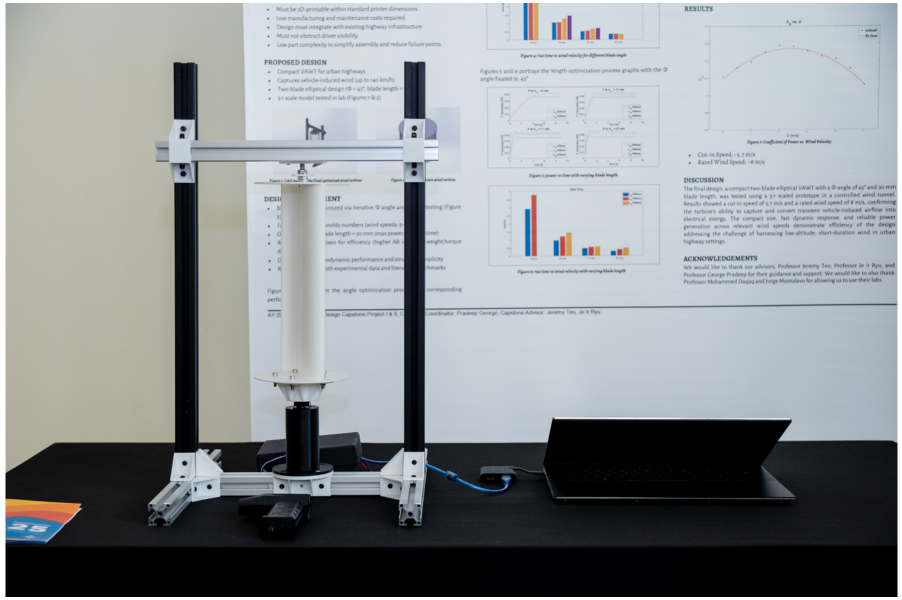
Prof.Jeremy Teo and Prof. Je Ir Ryu

Aerodynamic Energy Capture: Transforming Traffic Vortices into Sustainable Power



Naser AlHumaidi, Tim Kim, Omar Al Aleeli, and Omar AlQadi

Harnessing clean energy has become a global trend, with many nations striving to utilize available resources for power generation. Contemporary renewable energy sources often require large spaces and can be noisy, limiting their installation to remote areas and creating challenges for urban energy generation. Fortunately, the urban landscape, characterized by highways and extensive infrastructure, allows for energy harnessing on a smaller scale that is more eco-friendly, less noisy, and visually appealing.



One effective method for capturing energy in these settings is the use of small wind turbines, which convert wind energy into mechanical movement to produce electricity. In the UAE, highways are primarily maintained at speeds of 100 km/h, enabling vehicles to generate sufficient wind to start the turbines and produce energy.
While several wind turbine prototypes have been researched, many are site-specific, tailored to factors such as weather conditions and vehicle speeds that vary by region.

Our project evaluates multiple prototypes, analyzing their efficiencies, strengths, and weaknesses through simulations tailored to UAE highways. Based on the existing turbine designs, this project aims to optimize turbine blades such that the turbine can self-start at wind velocity as low as 1 to 2 m/s and has rated wind velocity of 3 to 7 m/s; short start-up time near 0.5 seconds is also one of the important criterias. From preliminary CFD analysis, 2 bladed wind turbine with an elliptical horizontal cross-sectional profile was selected as the strongest candidate for such specifications of the turbine.

Capstone Advisor

Prof.Jeremy Teo and Prof. Je Ir Ryu

Development of a Passive Wearable Exoskeleton for Assisting Movement and Reducing Muscle Strain

Jana Awadalla, Maadaa Bayarsaikhan, and Seif ElShafie

Firefighters are routinely exposed to physically demanding tasks that contribute to work related musculoskeletal disorders (WSMD), which impacts their work performance and long-term health. This project aims to develop a passive wearable exoskeleton for firefighters that provides movement assistance to reduce strain on their body. More specifically, the exoskeleton will target three movements: lifting, overhead activities, and bending.

The design optimizes load-bearing and assistive force distribution through passive mechanical systems like gas springs, cam-based mechanisms, and variable stiffness mechanisms.

The exoskeleton's structural components are fabricated using heat-resistant Polyphenylene Sulfide (PPS) via 3D printing, while flame-resistant Kevlar webbing forms the adjustable straps. Ceramic fibers provide insulation and cushioning around sensitive components, particularly the gas springs, which utilize high-temperature nitrogen systems rated for operation up to 220°C. By incorporating modularity, compatibility with Self-Contained Breathing Apparatus (SCBA), and quick donning features, this exoskeleton ensures functionality in high-stress scenarios, enhancing firefighter safety and efficiency.

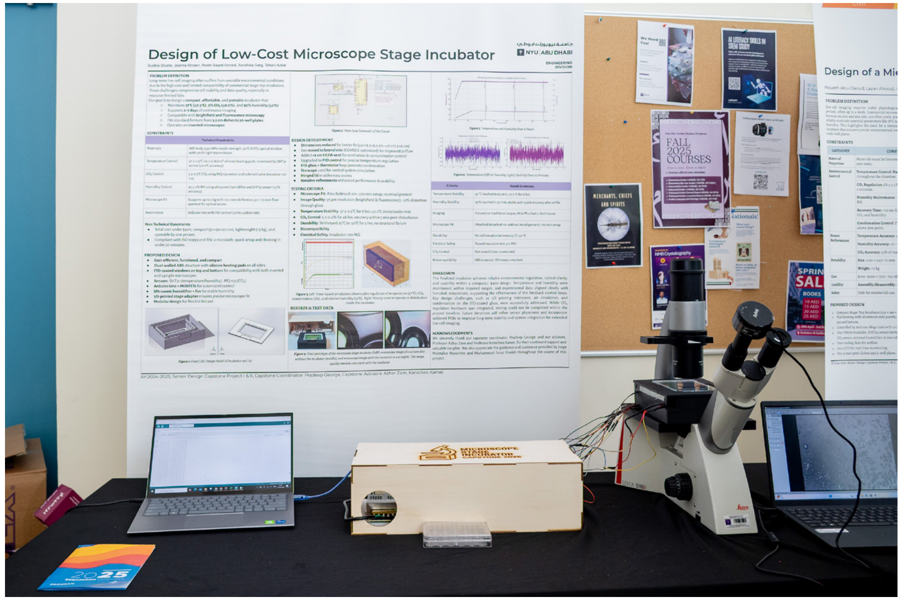
Capstone Advisor

Prof. Mohamad Eid and Prof. Fares Abu-Dakka

Design of a Microscope Stage Incubator

Sanshika Garg, Reem Wesam, Joanna Almasri, Bushra Shums, and Tehani Azkar

This project focuses on the development of a versatile, cost-effective microscope stage incubator designed for long-term live-cell imaging. The incubator integrates precise control systems for temperature, humidity, and CO_2 levels to create an optimal environment for cell culture during microscopic observation. Key features include a biocompatible incubation chamber with optical-grade windows to ensure clear imaging, a modular stage adapter compatible with various microscope models, and an automated feedback system for real-time environmental adjustments.



The design incorporates compact heating elements and an innovative humidity control mechanism to minimize condensation, thereby maintaining an unobstructed imaging field. Preliminary testing demonstrates that the incubator maintains environmental parameters within ±0.1°C, 95% relative humidity, and 5% CO_2, significantly improving the precision and reproducibility of live-cell imaging experiments.

Unlike bulky, specialized commercial systems, this design focuses on easy assembly, disassembly, and intuitive controls, making it accessible for routine use in diverse research environments. By maintaining stable conditions for cell cultures over extended periods, this incubator will contribute significantly to fields like cell biology and developmental research, enhancing the accuracy and reproducibility of live-cell imaging studies while supporting both high-end and routine research applications.

Capstone Advisor

Prof.Azhar Zam and Prof. Kenichiro Kamei

Design of a Microscope Stage Incubator for Live Cell Imaging

Amna Alrustamani, Layan Alkasaji, Marine Ramaroson, Mouath Abu-Daoud, and Reem Al Tamimi

This capstone project focuses on the development of a portable, cost-effective ($200-500), and easy-to-assemble microscope stage incubator designed for long-term cell and tissue imaging, supporting continuous imaging for up to one week.

The incubator provides precise control of environmental conditions, including temperature, humidity, and CO_2 levels, ensuring the maintenance of live cell viability over extended imaging periods. Compact with maximum dimensions of 115x173x40 mm, it should be compatible with inverted microscopes and suitable for both brightfield and fluorescent imaging.

The system should maintain a physiological temperature of 37°C, a humidity level above 95% to prevent media evaporation, and a CO_2 concentration of 5% to regulate pH. By addressing the high costs of commercial systems, this modular incubator delivers high-performance imaging at an affordable price, making real-time, high-quality cell imaging accessible to a broader range of researchers.

Capstone Advisor

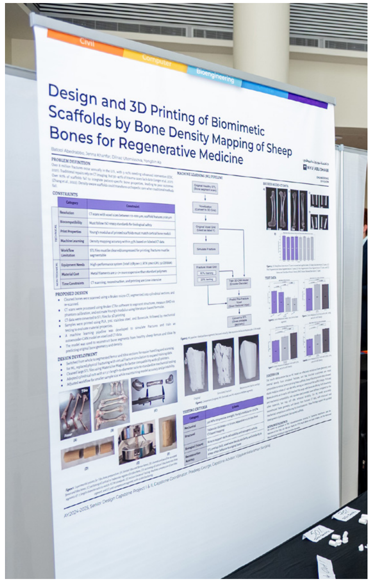
Prof.Azhar Zam and Prof. Kenichiro Kamei

Design and 3D Printing of Biomimetic Scaffolds by Bone Density Mapping of Sheep Bones for Regenerative Medicine

Batool Abedrabbo, Jenna Khanfar, Dilnaz Utemissova, and Yongbin Ko

This project aims to develop a machine learning-based algorithm capable of reconstructing fractured bones and generating 3D-printable STL files that incorporate bone density information. The focus is on sheep bones, which are scanned in their intact state using high-resolution micro-CT before fractures are induced. Post-fracture scans are then obtained to provide the algorithm with paired datasets for training.

The algorithm learns to predict and reconstruct the pre-fracture state using only the fractured bone data, ensuring independence from external references during practical application. By integrating density data into the STL files, the algorithm enables the creation of scaffolds that replicate the mechanical properties and structural integrity of natural bones.



The reconstructed bones will be validated by 3D printing and comparing their mechanical properties with the intact contralateral bones. This approach offers a novel solution for bone tissue engineering, with potential applications in veterinary and human orthopedics.

Capstone Advisor

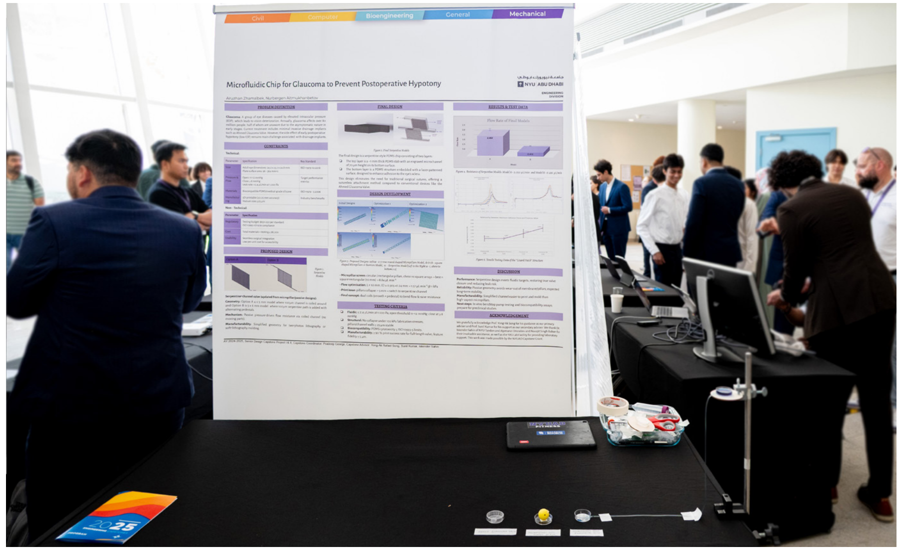
Prof. Vijayavenkataraman Sanjairaj

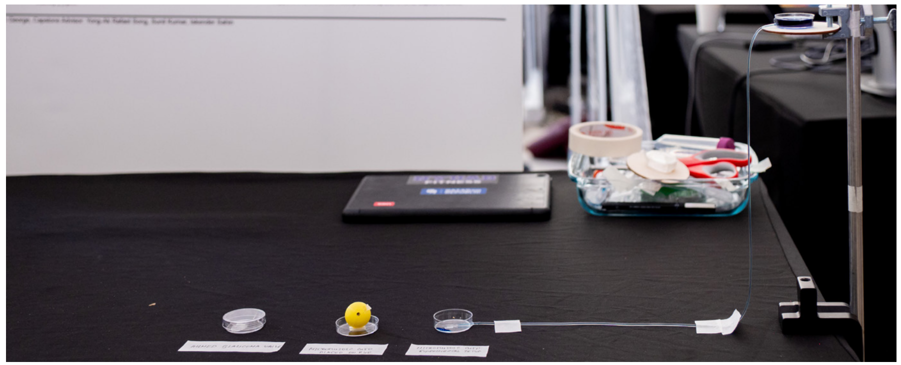
Development of Improved Glaucoma Drainage Devices (GDD) to Address Postoperative Complications

Nurbergen Aitmukhanbetov and Aruzhan Zhamalbek

Glaucoma is a disease in the eyes occurring due to elevated intraocular pressure (IOP) that is the leading cause of irreversible blindness, affecting an estimated 70 million people globally which is expected to rise 111 million by 2040. Current treatments and medication includes reducing the IOP which is considered normal in the range of 11 to 21 mmHg either by medication, laser treatment or incisional surgeries. However, with an advancement of technology once considered the last resort of treatment, incisional surgeries became a golden standard with the help of Glaucoma Drainage Devices (GDD).

The Ahmed Glaucoma Valve, a commonly used GDD, operates on the principle of silicone valve that acts based on concentration, however complications like early hypotony (excess fluid leakage) within the first weeks of post surgery and late hypertonia clogging of valve by fibrosis and biological tissues requires modification of AGV to work effectively.
This proposal aims to modify the Ahmed Glaucoma Valve both mechanically and biologically to improve efficiency in the mentioned complications.





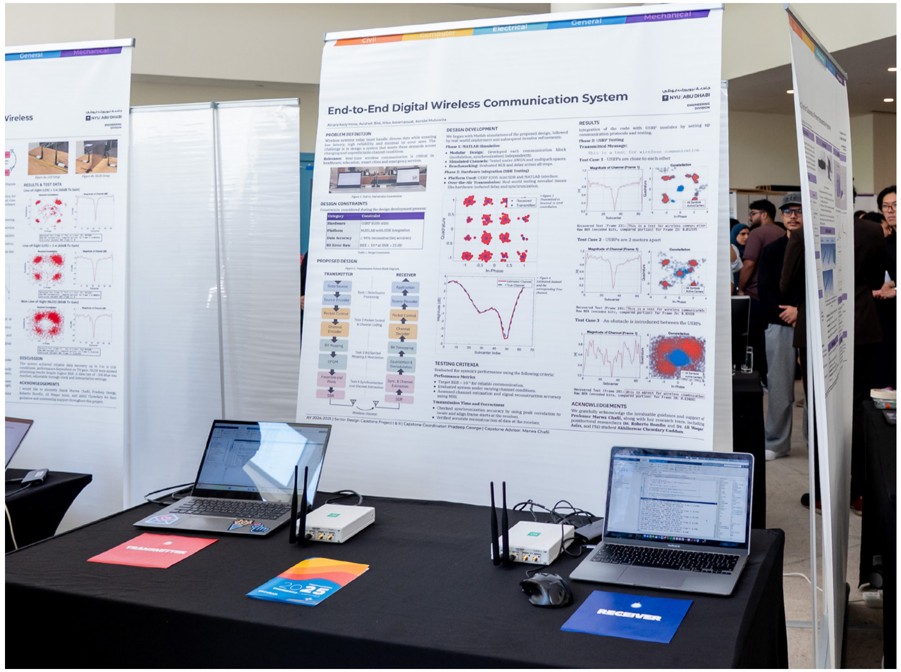
Capstone Advisor

Prof. Rafael Song, Prof. Sunil Kumar, and Prof. Iskender Sahin

Design of End-to-End Digital Wireless Communication System

Avi Bist, Ainara Kazymova, Hiba Assamaouat, and Kundai Mutuwira

Our capstone project focuses on designing a comprehensive end-to-end wireless communication system, applying advanced analog and digital communication techniques. With a process that captures external data and takes it through a sequence of processing schemes including encoding, mapping, orthogonal frequency demultiplexing followed by a deprocessing schemes. The aim is to develop a system capable of transmitting any type of data—whether text, images, audio, or video—in real or near real-time. We prioritize minimizing data loss and interference, ensuring reliable and efficient transmission.



Capstone Advisor

Dr. Marwa Chafii


NYU ABU DHABI

End to End Wireless Communication System

Nasheed Ur Rehman, Mansoor Abdulrazzaq, and Hussieny Shaaban

Wireless communication systems are fundamental to modern technology, enabling applications from cellular networks to the Internet of Things (IoT) and real-time multimedia streaming. This project aims to design and implement an end-to-end digital wireless communication system that enhances efficiency and reliability using advanced techniques. The system architecture integrates key digital communication components, including source coding, packet control, modulation, synchronization, and channel estimation.

Data streams, including text, images, and video, are processed into waveforms using Orthogonal Frequency Division Multiplexing (OFDM) to enable efficient and reliable over-the-air transmission. Techniques are employed to enhance synchronization, mitigate interference, and improve channel estimation for robust communication.

The system is implemented in MATLAB and interfaced with a USRP B210 software-defined radio (SDR) platform for practical over-the-air transmission and reception. By modularizing the system into fundamental blocks—such as bit-symbol mapping, channel encoding/decoding, and synchronization—we facilitate incremental development and validation at each stage. Performance is evaluated using metrics like bit error rate (BER), data rate, and estimation accuracy to ensure reliable communication under realistic conditions. This project demonstrates the complete lifecycle of a wireless communication system, from data source to user application, showcasing its functionality through real-time transmission of multimedia content.

Capstone Advisor

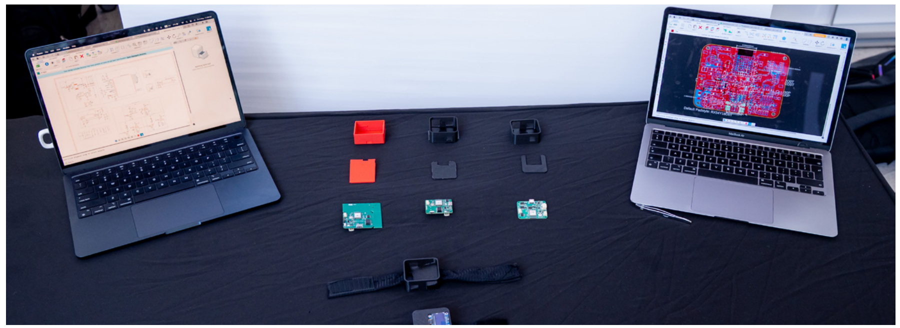
Dr. Marwa Chafii

A Non-invasive Glucose Monitoring Wearable Device

Aste Mayaya, Christopher Sami, and Mandy Liao

According to the International Diabetes Federation, 1 in 10 people worldwide is living with Diabetes mellitus, a chronic metabolic condition in which blood glucose level fluctuates out of the normal range (90-120 mg/dL). External insulin and regular glucose monitoring are important for controlling glucose levels and alleviating the symptoms of diabetes as well as other related non-communicable diseases caused by high blood sugar.
However, conventional glucose monitoring methods are invasive, painful, costly, have a risk of infections, and are disruptive to patients' lives. Therefore, the need for a continuous and non-invasive technique is crucial for a timely, safe, and risk-free result. Non-invasive techniques also prove to be vital when users have a sudden surge in blood sugar levels and need immediate interventions crucial for their health.
In this project, we aim to develop such a continuous non-invasive glucose monitoring system using Near-Infrared (NIR) Spectroscopy, combined with machine learning for accuracy tuning.

The proposed system, controlled by the Arduino nano BLE, will emit 3 wavelengths of NIR (850nm, 940nm, 1500nm) on the wrist of the patient and capture the reflected light with a photodiode.
The received signal will then undergo signal processing with a trained Artificial Neural Network. The proposed system will be tested using in vitro and in vivo techniques, and error analyses will be conducted with the Clarke Error Grid (CEG), Root Mean Square Error (RMSE), Mean Absolute Derivative (MAD), and Mean Absolute Relative Difference (MARD) analyses to ensure maximum accuracy. In the measurements, we will prioritize accuracy over response time, targeting a lower data rate as long as it is a suitable sampling frequency for glucose fluctuations.



Capstone Advisor

Prof. Mohamad Eid and Prof. Sohmyung Ha

MindArm 2.0: Towards Affordable and Efficient Mind Controlled Prosthetics

Azaz-ur-Rehman Nasir, Samroz Ahmad Shoaib, Khalid Elsherbiny and Saleh Zewail

The development of MindArm 2.0 aims to address the challenges of upper limb prosthetics by creating an affordable, non-invasive solution that integrates cutting-edge technologies. This system utilizes EEG-based intent recognition, depth-sensing devices such as Apple Vision Pro or Pupil Labs Neon 5 glasses, and multimodal sensors, including pressure, TOF, and IMU sensors. The prosthetic incorporates a stereo camera for fine-tuned depth estimation and is powered by the NVIDIA Jetson Orin Nano for real-time processing. Key features include advanced grasp pose estimation and natural joint movement achieved through optimized motor control.

This project seeks to overcome limitations in current prosthetics by providing precise, responsive functionality with minimal energy consumption. With EEG accuracy exceeding 85% and depth estimation deviation under 5%, the prosthetic is designed to adapt dynamically to user intent and environmental contexts. Innovations include the integration of depth-sensing and sensory feedback mechanisms to refine object interaction.
By leveraging modular design and iterative optimization, the project aims to deliver a user-friendly and highly functional prosthetic arm that restores autonomy and enhances quality of life for individuals with limb loss.

Capstone Advisor

Prof. Muhammad Shafique and Prof. Mahmoud Rasras

A Portable and Modular Framework for Scalable Robot Policy Learning and Data-Collection

Omar Rayyan, John Abanes, and Mahmoud Hafez

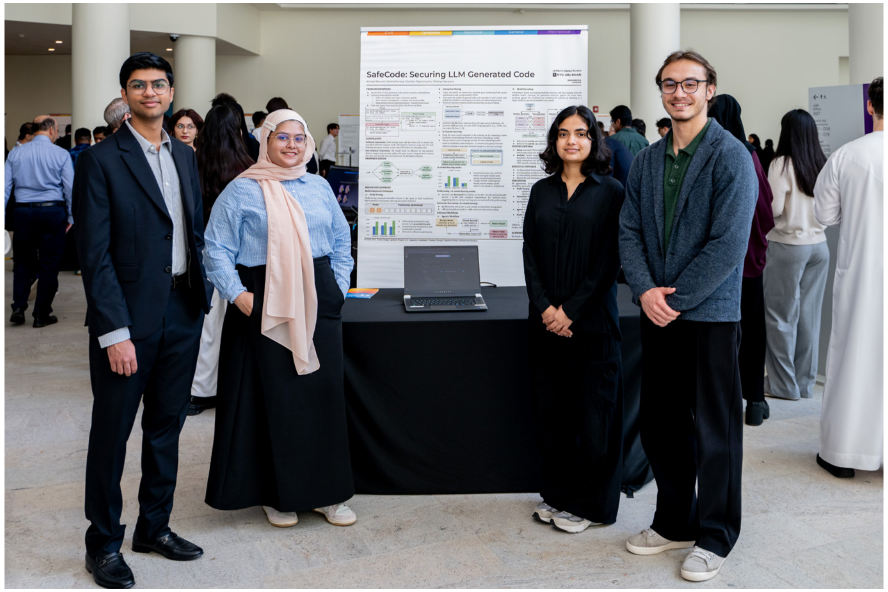
The framework addresses a critical bottleneck in robotics: the challenge of scaling data collection to enable advanced learning models for real-world applications. Robotics data collection requires extensive real-world interaction, and teleoperation remains one of the most practical methods for minimizing the embodiment gap between data collection and deployment. However, teleoperation is constrained by high hardware costs and its dependence on manipulators that replicate the physical constraints and affordances of real-world robotic systems. Given that foundational models in robotics require vast amounts of data to achieve breakthroughs, there is an urgent need for innovative approaches to significantly scale up data collection capabilities.

To address these challenges, this capstone project proposes a novel portable and modular framework that integrates a tendon-driven gripper mechanism, state-of-the-art (SOTA) machine learning models, and efficient data collection methodologies. Machine learning inference and policy learning are powered by a NVIDIA GeForce RTX 4090 GPU, which provides the necessary computational resources for high-performance real-time data processing. The GPU accelerates tasks such as object detection, grasp planning, and reinforcement learning model updates. Leveraging its 24 GB GDDR6X memory and 16,384 CUDA cores, the RTX 4090 ensures efficient handling of large-scale robotics datasets and high-throughput inference. The framework's key innovation lies in its gripper design: a tendon-driven mechanism with a single motor controlling one fixed and two movable fingers. This design offers enhanced dexterity, an external and wider field of view, and improved adaptability, enabling the gripper to securely handle objects weighing up to 2 kilograms. By building on and refining prior approaches, this project aims to establish a more versatile and scalable system for robotics data collection.

Capstone Advisor

Prof. Anthony Tzes, Prof. Fares Abu-Dakka, and Dr. Tarek Taha

LLMs for Secure Code Generation



Fatima Farooq, Ahmed Farrukh, Dikshya Neupane and Vladislav Zapromyotov

Large Language Models (LLMs) have emerged as powerful tools for generating functionally correct code, yet they remain vulnerable to producing insecure code, posing significant challenges for security- critical applications.

This project builds on the SVEN framework to advance controlled code gen- eration by leveraging prefix-tuning techniques, enabling the generation of code with specific security properties while maintaining high functional correctness.

Our approach incorporates advanced prefix initialization strategies, layer-specific prefix tuning, and hyperparameter optimization to enhance both computational efficiency and security accuracy. By extending the dataset to cover additional CWEs (Common Weakness Enumerations) and optimizing memory usage, we aim to create a scalable, efficient framework for secure code generation.

The outcomes of this project will include an optimized LLM, a comprehensive benchmarking dataset, and a comprehensive evaluation of prefix-tuning's effectiveness compared to state-of-the-art methods.

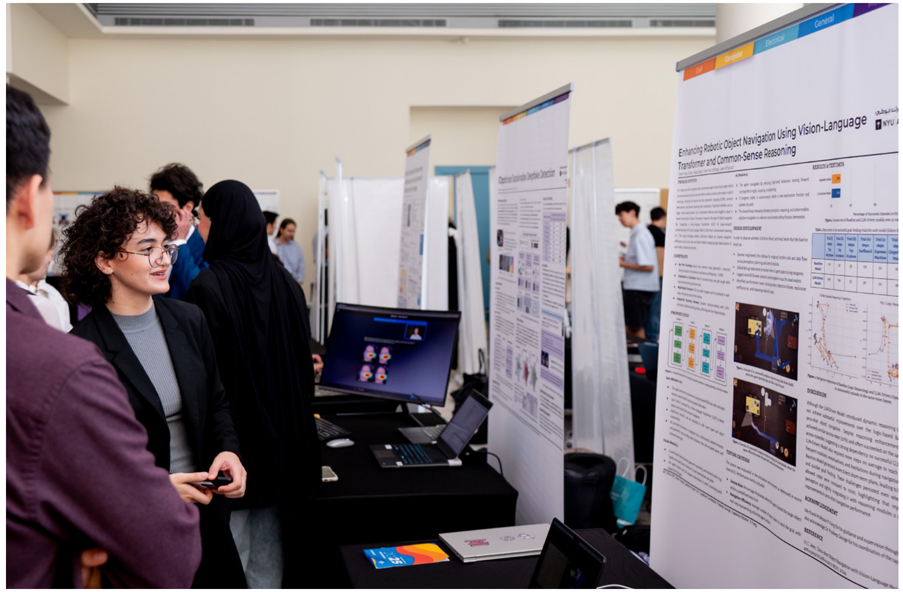
Capstone Advisor

Prof. Muhammad Shafique

Enhancing Robotic Object Navigation Using Vision-Language Transformer and Common-Sense Reasoning

Ulan Kundizbay, Leen Kharouf, Irem Naz Celen, and Haya Basit

This capstone project proposes an innovative approach to robotic navigation and object manipulation in dynamic environments by integrating the Vision- Language Transformer (VLT) model with Large Language Models (LLMs) to harness enhanced common-sense reasoning. Traditional autonomous navigation systems, such as those employing Probabilistic Soft Logic (PSL) models, are constrained by limited adaptability and inability to interpret complex scenarios.



Our approach leverages advanced modules, including the Vision-Language Model (VLM) Understanding Module and Semantic Mapping Module, to pro- cess RGB and depth data, generate semantic maps, and guide navigation. Us- ing the Tree-of-Thoughts reasoning framework, the system achieves globally informed decisions, enabling backtracking and refinement during exploration. Benchmarked on PASTURE and RoboTHOR, the model achieves a 36.9% success rate (SR) and 16.6 success weighted by path length (SWPL), significantly outperforming existing methods. The system excels in spatial and appearance- based tasks, with SRs of 33.3% and 35.0%, respectively.

By bridging perception and action through intelligent reasoning and seman- tic mapping, the VLTNet sets a new standard for zero-shot object navigation. Its efficiency and adaptability make it suitable for diverse real-world applica-
tions, including search-and-rescue, logistics, and smart home environments.

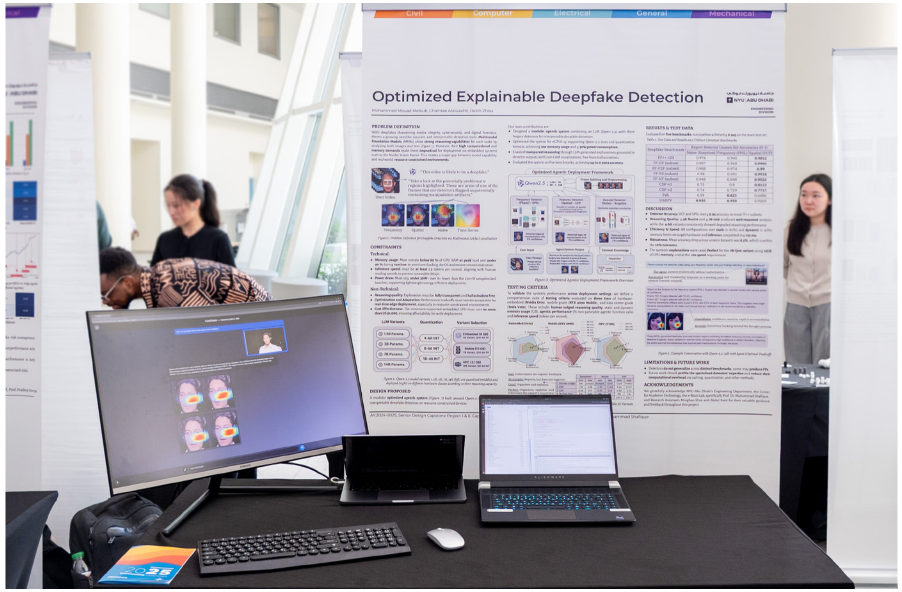
Capstone Advisor

Prof. Yi Fang

Optimization Framework for Multimodal Foundation Models in Real-Time Deepfake Detection Across Resource-Constrained Environments

Ruilin Zhou, Chaimae Abouzahir, and Mohammed Mouad Melouk

The proliferation of deepfakes poses significant threats to media integrity, cybersecurity, and digital forensics. Multimodal Foundation Models (MFMs) have the potential to revolutionize deepfake detection due to their advanced reasoning capabilities.
However, their substantial computational and memory demands inhibit deployment on resource-constrained embedded systems. This project addresses the challenge of adapting MFMs for efficient, real-time deepfake detection on embedded hardware.

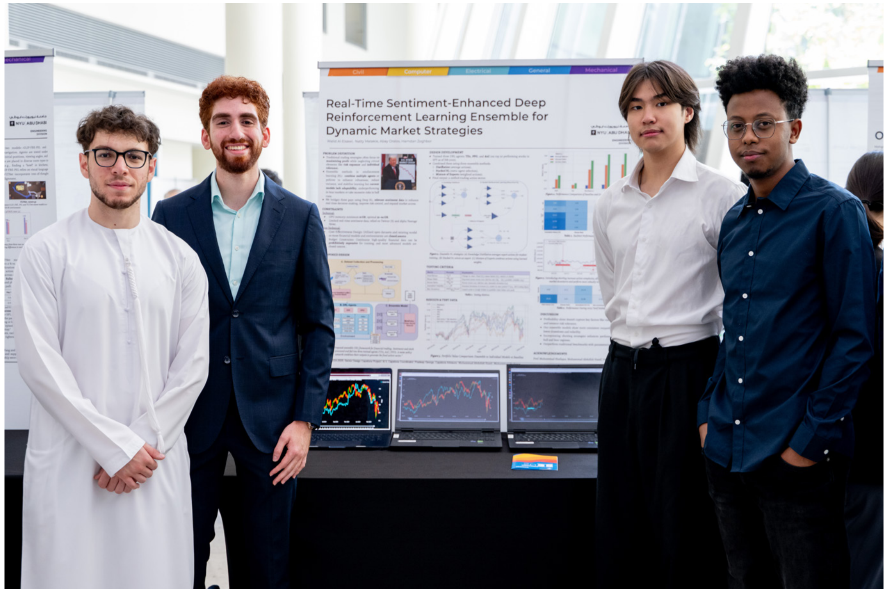


We propose a two-fold solution. First, we design and employ dataset augmentation techniques where efficient Convolutional Neural Network (CNN)-based detectors are used to leverage spatial information. In addition, a transformer-based model is used to leverage temporal information. Using Explainable AI principles (XAI), we extract labels for our data relying on such expert detectors, enhancing the dataset's robustness. Second, we fine-tune Qwen2-VL on the augmented dataset to gauge model performance, and apply pruning methods to optimize computational costs without significantly compromising accuracy. The optimized models are deployed on embedded systems with varying computational overheads, such as the NVIDIA Jetson Xavier, to achieve real-time deepfake detection with interpretable outputs. Our approach effectively bridges the gap between the high resource requirements of advanced MFMs and the limited capabilities of embedded devices.

Capstone Advisor

Prof. Muhammad Shafique

Multimodal LLM-aided Sentiment Driven Ensemble DRL for Finance Suitable for Local Computing



Abay Oralov, Hamdan Zoghbor, Walid Al-Eisawi and Natty Metekie

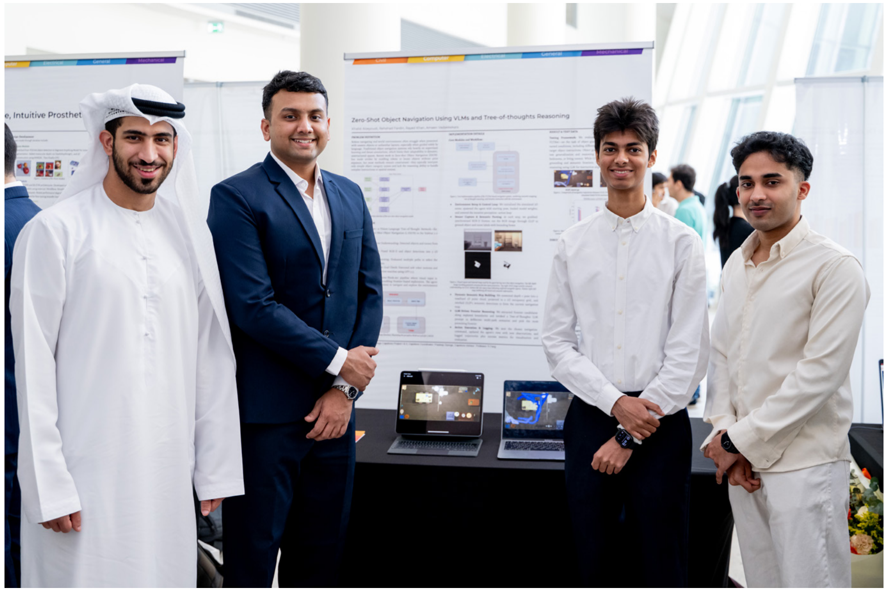
The stock market is a multifaceted and dynamic system influenced by a variety of data sources and signals, including technical indicators, market sentiment, and fundamental financial data. Traditional stock trading systems often rely on a singular approach, limiting their ability to make well-rounded decisions. This capstone project aims to develop a cutting-edge, multimodal stock trading pipeline that integrates multiple data sources and analysis techniques to generate more accurate and informed trading decisions.

Market sentiment is gauged by performing sentiment analysis on data from news headlines and X posts using FinBERT, an NLP model specifically pre-trained for financial sentiment analysis. Through deep reinforcement learning (DRL), several different agents are trained separately on historical stock market data of various modalities and sources. The outputs of these agents are subsequently combined through an ensemble learning method known as stacking. The objective of the system is to maximize returns by enhancing the accuracy and reliability of stock trading recommendations.

Capstone Advisor

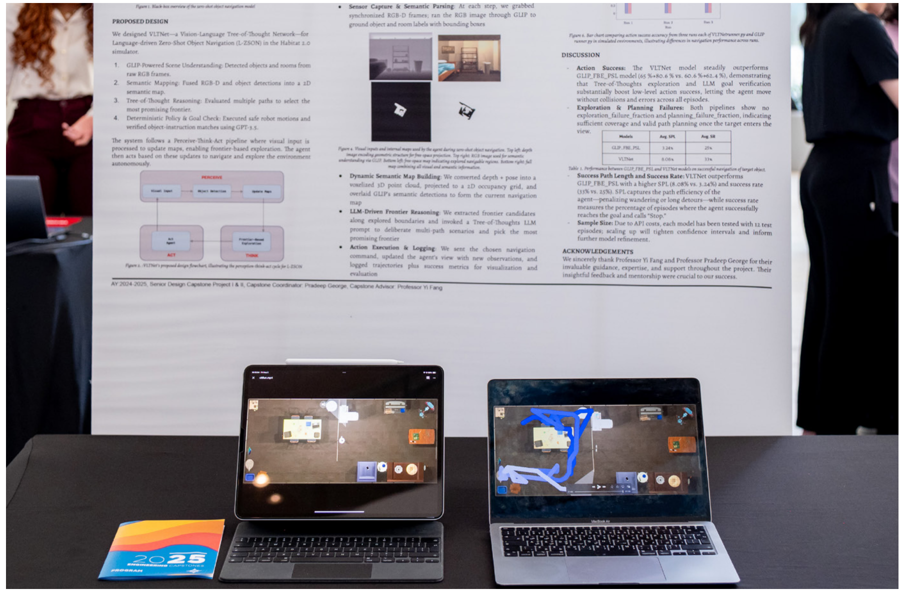
Prof. Muhammad Shafique

Smart Robot Design: Language-Guided Object Navigation and Interaction



Khalid Alzeyoudi, Rehshad Fardin, Rayed Khan and Ameen Vadakkekara

In the realm of autonomous robotics, one of the significant challenges lies in enabling robots to navigate and interact with objects in complex, dynamic environments guided by natural language instructions. Current robotic navigation solutions often rely on predefined environments or extensive training on specific object categories, limiting their adaptability to new, unseen settings. Additionally, existing methods can be computationally expensive and may not integrate well with natural language processing, making them less efficient in real-time scenarios.



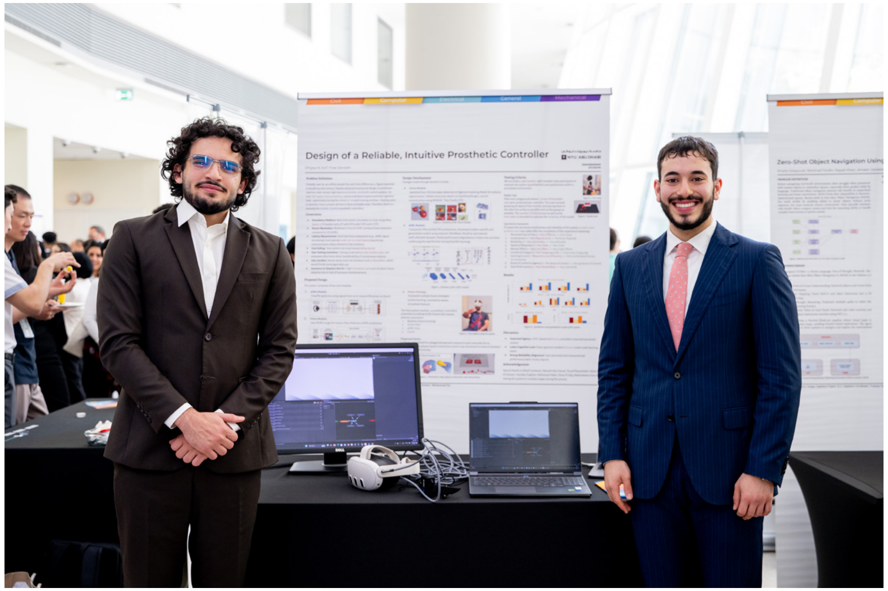
To overcome these limitations, an effective robot design must incorporate advanced vision-language models (VLMs) and large language models (LLMs) for interpreting natural language instructions, robust semantic mapping for spatial understanding, and efficient exploration strategies for zero-shot navigation.

This project aims to address these challenges by developing a smart robot system capable of language-guided object navigation and interaction in unstructured environments. The system will integrate natural language processing, visual perception, semantic mapping, and real-time decision-making to create a comprehensive solution that operates efficiently with minimal computational resources. The goal is to facilitate more intuitive and versatile human-robot interactions, enhancing the robot's ability to understand and act upon complex commands without extensive pre-training on specific environments or objects.

Capstone Advisor

Prof. Yi Fang

Reliable & Intuitive Upper-Limb Prosthetic Control System



Dhiyaa Al Jorf and Firas Darwish

The physical design of upper-limb prosthetic devices has advanced rapidly to allow for very refined high Degree of Freedom (DoF) control. However, control systems for these prostheses remain less than satisfactory, preventing prosthetic users from achieving the full potential of their devices. The main issue for the control systems lies in their reliability and intuitiveness of control, where reliability refers to the correctness of the produced output, and intuitiveness refers to the ease of usability of a system's interface. This proposal describes the design of an intuitive, reliable, upper-limb, myoelectric, prosthetic control system.

The real-time (< 350ms control delay) controller relies on two main input modalities: a prosthetic mounted camera and 8 channels of sEMG data. The vision-based controller will include an domain incremental online learning component to fine tune to the user's grasping preferences. The controller will be used to control a virtual prosthetic in real-time using sensor data worn by the user, and will be tested within the virtual environment to evaluate the success of the proposed system. The combined module should achieve an 85% success rate, where the sEMG and vision modules each independently achieve 80% accuracy and 60% match with with the user intention respectively before online learning. After fine tuning to the user's preferences, the vision modality should match the sEMG prediction 80% of the time.

Capstone Advisor

Prof. Mohamad Eid

Design Solutions for a Community Seaport in Abu Dhabi

Nour Abdelaziz, Amna Al Mheiri, Rayan Alnaqbi, Ines El Beddad, Hessa Sharaf, Ghida Shawaf, and Nurgul Zhumasheva

“Al Murjan Port” is a newly envisioned community seaport located along the coast of Abu Dhabi, adjacent to the fictional town of Al Khail. Designed as a comprehensive capstone project, the port brings together all core disciplines of the Civil Engineering field to deliver an integrated, innovative maritime hub. The design process begins with an optimized port layout through careful site selection and analysis of coastal conditions, supported by dredging and land reclamation to ensure adequate water depth and minimize damage to the marine environment. Geotechnical studies inform us of the local soil profile and support the design of a robust quay wall, with the use of DeepEx modeling. Transportation engineering principles are used to develop a safe and efficient internal road system, validated through geometric design on Civil 3D and AIMSUN traffic simulations.

The port is also equipped with a range of key facilities that ensure it operates effectively while respecting environmental regulations. A steel warehouse supports logistical operations, and showcases the importance of truss design and wind load analysis for steel structures through SAP Modelling. Meanwhile, the administrative building functions as the control center for port management, and its design applies knowledge of concrete design. The selection of beams, columns and slabs is reflected in CAD drawings, which are later exported into a realistic REVIT model. Foundation design provides insight into key innovations, through the use of stone columns for ground improvement and cost-efficiency. The construction of the building was guided by project management, including a detailed Work Breakdown Structure (WBS) and Scheduling techniques to ensure timely and cost-efficient execution. A comprehensive water management system combines a wastewater treatment and desalination plant to meet both the needs of the port and the adjacent town. Sustainability and innovation are embedded in the design of different facilities, in line with the UAE’s vision for more resilient infrastructure. Renewable energy sources such as solar power, low-impact construction techniques like stone column foundations, and smart facility layout all contribute to minimizing the port’s environmental footprint.

Ultimately, “Al Murjan Port” is conceived not just as an industrial asset but as a vibrant hub for community living and commercial trade, thus positioning Al Khail as a dynamic and sustainable center in the evolving maritime landscape.

Capstone Advisor

Prof.Tarek Abdoun and Prof. Waleed Elsekelly

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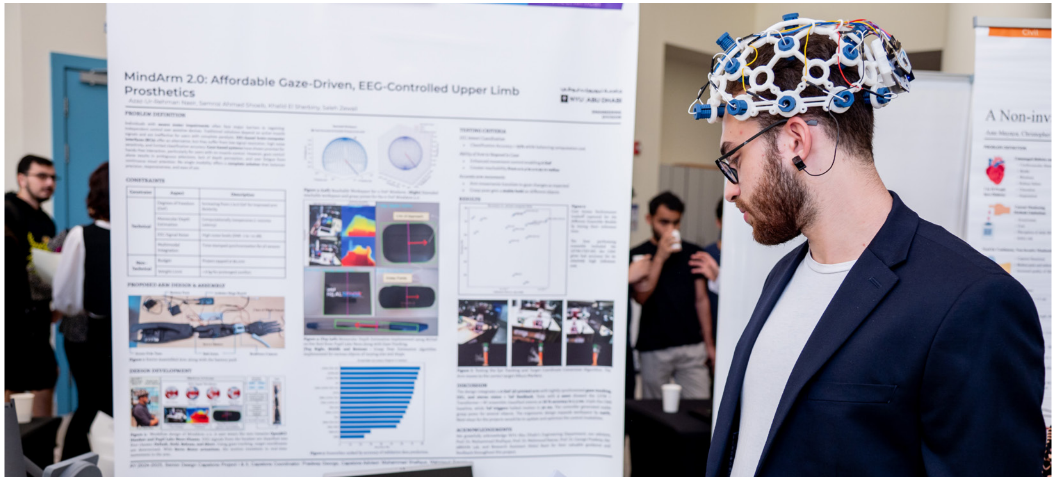
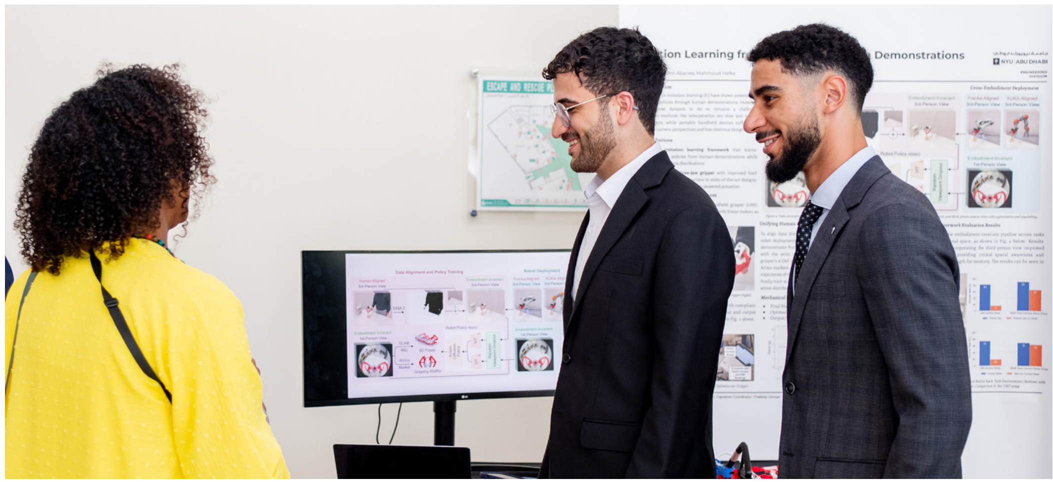

MindArm 2.0: Affordable Gaze-Driven, EEG-Controlled Upper Limb Prosthetics









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Design and 3D Printing of Biomimetic
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