جامعة نيويورك أبوظبي

NYU | ABU DHABI

ENGINEERING
DIVISION

CAPSTONE PROJECTS

CLASS OF 2019

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INTRODUCTION FROM THE DEAN

The Sixth NYU Abu Dhabi Engineering Capstone Festival showcased the Class of 2019's year-long Capstone Projects and is a celebration of the completion of these projects. These were based on the culmination of ideas from their Junior year and hard work throughout 2018-19 using design solutions to solve real world problems.

The Capstone Design Course provides a major design experience leveraging the knowledge and skills acquired throughout the four-year curriculum. Structured to immerse students in the process of design, projects address engineering and technology topics and design innovative solutions following the examination of multiple project parameters. It also provides students with an opportunity to integrate technical, human, aesthetic and business concerns with applied design solutions.

A defining feature of the Engineering undergraduate experience is the Capstone, representing the highest aspirations of undergraduate intellectual development, creativity, and engagement with original creative work. This booklet captures only a small part of the Seniors' innovative and creative projects, which are aligned with today's Engineering advances as well as our own research priorities and includes:

In Bioengineering, our seniors: designed a *Bio-Inspired Lizard Robot Tail* to detect danger; built a less laborious and *Low Cost Turbidostat* to characterize biological systems; and designed a *Continuous Monitoring System for the Mineral Nutrient Uptake by Plants in a Fogponic System* to better absorb nutrients and waste less water.

In Electrical and Computer Engineering our students: designed a *Cosmic Ray Detector-based Random Number Generator* to determine real time data from muon strikes; through *Dental Simulation and Virtual Reality* provide dental students training to enhance the interaction between the dentist and their patients; designed an *Implicit Emotion Communication System using Thermal Feedback*; used deep learning architecture for *Data Visualization and Feature Extraction*; and implemented real time functional hardware through *Memory and Neural Networks* tying with the latest research on the reconstruction of visual working memory.

In Mechanical and Electrical and Computer Engineering, our seniors: designed a *Radio-controlled Car with Dual Power Sources of Solar and Battery* to run the car non-stop; and through their *GLiDAR: Design Optimization and Active Stabilization of LiDAR Sensor Payload for Surveying* aims to support the scientific community's research through high resolution spatial data.

In Robotics, our students: created a *Visual Tracking System for Unmanned Aerial Vehicles*, and developed a *Drone Capturing Aerial Netting System* to detect, pursue and capture invasive drones due to rising breaches of commercial and restricted airspace.

Our Mechanical Engineers: designed a *Fluidic Injection Thrust Reverser System* for high bypass ratio jet engines to reverse the flow of air to eliminate mechanical blockers; and *Reconstructed the Horologium of Harun al-Rashid* from an engineering perspective by rebuilding a water clock based on its original design as a landmark for human achievement.

Our Civil Engineers: designed a *3-Story Educational Building with Ultra-Lightweight Cement Composite* to reduce costs and protect the environment in favoring sustainable materials; and developed *Obstruction Design for Effective Evacuation Under Escape Panic* to optimize the flow of pedestrians during emergency evacuations.

In Transportation: the *Decentralized Control for Mixed Automated/Manual Vehicle Traffic* project aims to adapt transportation infrastructure through mixed traffic of CAVs and human driven vehicles to assign the highest priority; and the *Deep Learning Approaches for Self-Driving Cars in an Adversarial Environment* to improve the performance of self-driving cars through computer vision and security.

And in Environmental Sustainability, Mubasher Iqbal and Saad Sultan won the Best Poster Award during the Sixth International Conference on Water, Energy and Environment (ICWEE 2019) in Sharjah for their Capstone project Paper Based Filter for Water Purification in the category of "*Water Filtration System for Developing Regions*".

We congratulate all of our Engineering Seniors for their academic achievements and take this opportunity to wish them every success as they graduate from NYU Abu Dhabi as Global Citizens.

Sincerely

Samer Madanat
Dean of Engineering, NYU Abu Dhabi

Henok Guluma, Maha Almazrouei and Noora Almarri

DENTAL SIMULATION USING VIRTUAL REALITY

Our project aims to provide dental students with a practical training to simulate dentist-patient interaction. Through the use of virtual reality (VR) interaction with the three-dimensional model, the dental student is expected to be offered with different scenarios, various facial expressions, and both gender situations that could occur in their dentist career. This extends to care for the patient's well-being, before, during, and after the treatment.

Thus, to not increase the common dental anxiety within patients, it is important to ensure neither pain nor fainting is being inflicted to the patient. However, choking expression was picked due to the many things that are usually in a patient's mouth, making it common for materials to slip.

Furthermore, these specific expressions were picked because the variation between them is visibly detectable. Whereas for the scenarios; it includes pre, during, and post treatment experience.

During the implementation of these scenarios, we realized that audio communication is crucial to enhance the interaction between dentists and their patients, and make patients feel comfortable as audio communication pushes to present the dental trainee with the basic knowledge on how to deal with a patient.

Capstone Advisor: Mohamad Eid, Assistant Professor of Electrical and Computer Engineering

Petar Ivanov, Chandan Mishra, Hurbert Shauri and Jagan Subramanian

DESIGN OF A 3-STORY EDUCATIONAL BUILDING WITH ULTRA-LIGHTWEIGHT CEMENT COMPOSITE

In an era where the cost of construction has soared to the highest heights and concern for the environment calls for desperate measures, the need for an approach that addresses these two crucial aspects is inevitable.

This project aims to design an educational building that is not only cost-efficient but also environmentally friendly. The design proposed integrates abundant natural resources of light and surrounding environment landscape to ensure that conducive and comfortable study conditions for the occupants are met while boosting the building performance and minimizing its carbon footprint.

Furthermore, the material selection process in the house is based on criteria dictated by the Leadership in Energy and Environmental Design (LEED) certification, which usually favors sustainable materials that are biodegradable and overall with net-positive effect for the environment.

Capstone Advisor: Kemal Celik, Assistant Professor of Civil and Urban Engineering and Khaled Shahin, Senior Lecturer

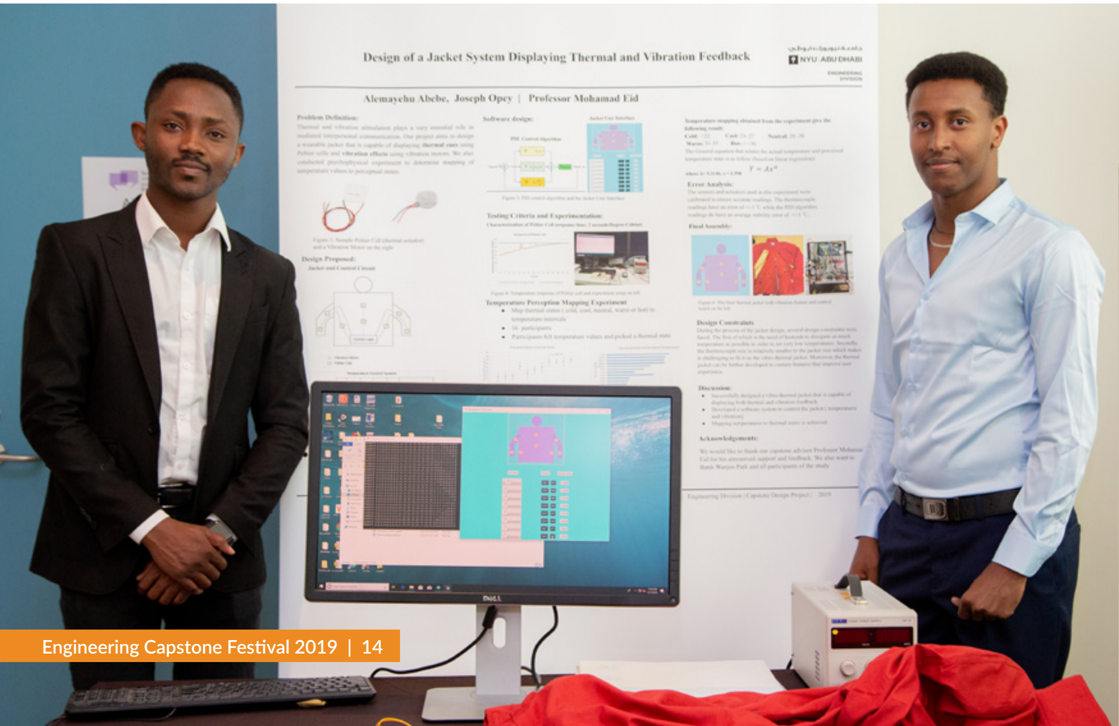
Joseph Opey and Alemayehu Abebe

DESIGN OF AN IMPLICIT EMOTION COMMUNICATION SYSTEM USING THERMAL FEEDBACK

In this capstone project, the design of a thermal actuation jacket is proposed. There have been several thermal jackets on the market most of which focuses on controlling ambient temperature. In this project, an implicit emotion communication thermal actuation jacket design is proposed where different simulation of temperature is possible.

An example of such simulation is apparent thermal motion which is important for emotion communication for example. Several research work experiments have been conducted leading to the proposed design described.

Capstone Advisor: Mohamad Eid, Assistant Professor of Electrical and Computer Engineering



Steffan Holter and Omar Gamil

DATA VISUALIZATION AND FEATURE EXTRACTION

Advancements in the field of big data have brought on the need for new tools to understand the underlying properties of all this information.

Data visualization presents one of the most productive ways of tackling this problem. Our solution focuses on extracting the key features that effectively describe the dataset and visualizing this information on an interactive display.

The fundamental aspect of this design is creating a means for high performance dimensionality reduction. Whilst many solutions exist that use PCA or non-parametric algorithms, they struggle with generalizing to more complex manifolds and sparse data.

Therefore, our approach instead makes use of a deep learning architecture. By creating a complex neural network hierarchy, we aim to optimize the solution and create a data describing mapping that corresponds to the intrinsic dimensionality of the data itself.

Capstone Advisor: Anthony Tzes, Professor of Electrical and Computer Engineering

Veronika Li, Amal Badri, Ushna Usman and Bence Almasi

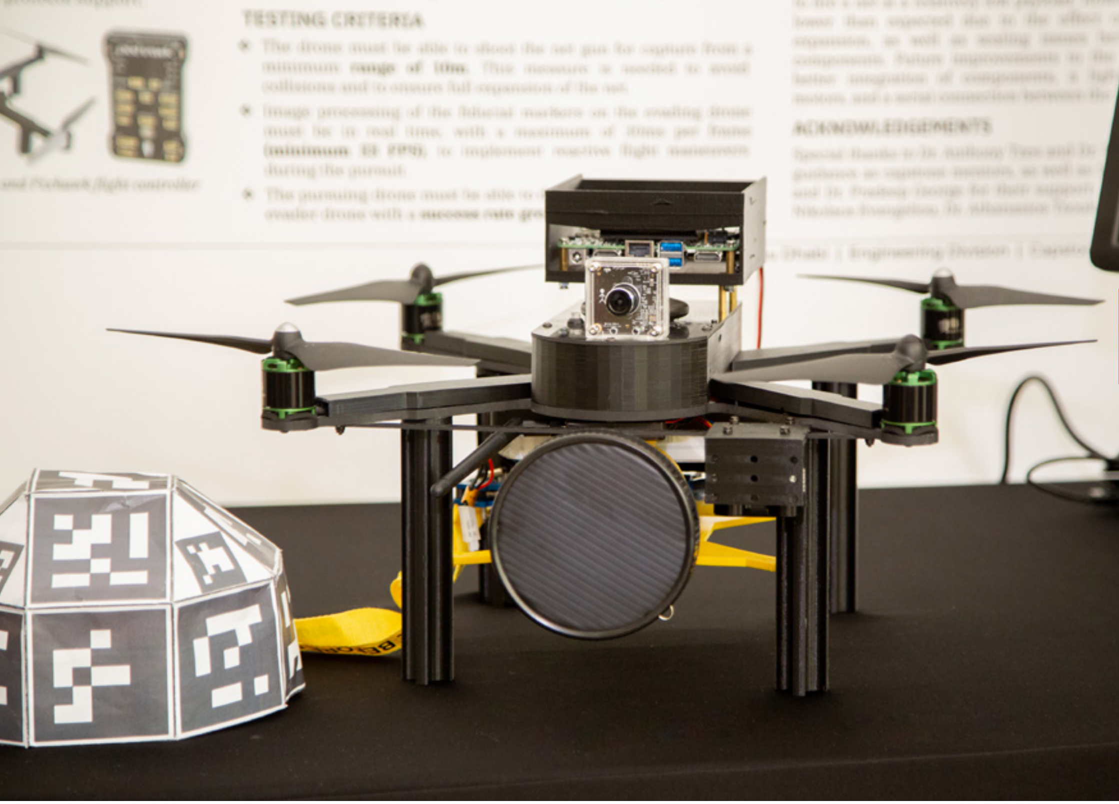
BUILDING A LOW COST TURBIDOSTAT

Continuous culture devices can be used for various purposes such as establishing reproducible growth conditions or maintaining cell populations under a constant environment for long periods. To more accurately characterize biological systems, researchers must turn to static environments, which yield lower noise in quantitative phenotyping. A primary tool for culturing cells in a static environment is continuous culture, where inoculated growth medium is continually diluted with fresh medium.

Turbidostats are powerful characterization tools that provide static culture environments; however, they are often expensive, especially when purchased in custom configurations, and are difficult to design and construct in a lab. Eight culture chambers are controlled simultaneously with the proposed configuration, and all components are readily available from various sources.

We demonstrate that our continuous culture device can be used under different modes, and can easily be programmed to behave either as a turbidostat or fluorostat. Addition of fresh medium to the culture vessel is to be controlled by a real-time feedback loop or simply calibrated to deliver a defined volume. The project aims to build a device which is less laborious and less costly to make in comparison to the already existing commercial versions.

Capstone Advisor: Andras Gyorgy, Assistant Professor of Electrical and Computer Engineering



Ona Thornquist, Hani Alhasni, Ikenna Anigbogu and Pearl Rwauya

DRONE CAPTURING AERIAL NETTING SYSTEM

Aerial drone capturing systems have various methods by which aerial drones are brought down. The need for this system has come to light with the rising breaches of commercial or restricted airspace caused by remotely controlled drones. The design of this project is dedicated to producing an autonomous aerial drone netting system that will detect, pursue, and capture invasive drones.

To achieve this, a detection and tracking algorithm will be implemented in an Nvidia Jetson TX1 on a pursuer drone. The algorithm will output 2-D coordinates of the evader drone through the use of fiducial markers. Subsequently, the coordinates will be used as inputs for the control of the pursuing drone to direct its flight maneuvers.

Once the pursuer is within range of the evader, the pursuing drone will fire a net via its propulsion mechanism and capture the evader. This method can introduce a hands-free solution to the drone problem where the traditional level of skill of the capturer is eliminated from the loop in favor of a quantifiably reliable autonomous system.

Capstone Advisors: Anthony Tzes, Professor of Electrical and Computer Engineering and Philip Panicker, Senior Lecturer

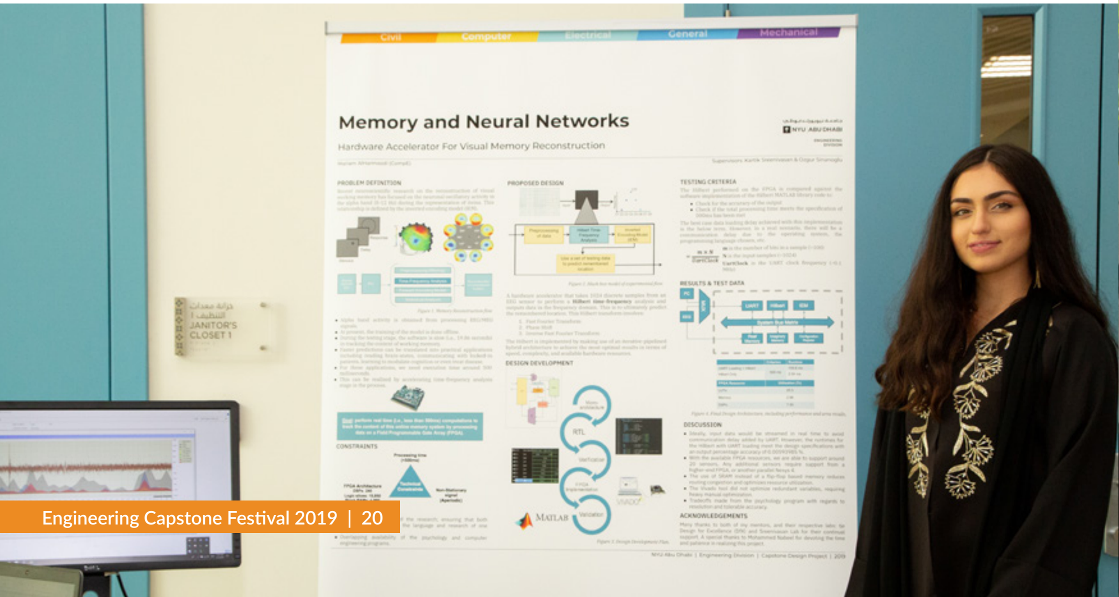
Mariam AlHarmoodi

MEMORY AND NEURAL NETWORKS

In the field of neuroscience, there has been recent research on the reconstruction of visual working memory during the representation of items from the activity of neuronal populations, particularly focusing on oscillatory activity in the alpha band (8-12 Hz).

The objective of this project is a real time (i.e., less than 500ms) functional hardware implementation of memory reconstruction by feeding signals from Magnetoencephalography (MEG) of neural oscillations to a Nexys 4 Artix-7 Field Programmable Gate Array (FPGA) Trainer Board. This is first realized by converting the time-series to frequencies in the alpha region. In this proposal, a Hilbert transform with an iterative-pipelined hybrid architecture is chosen to achieve the most optimal results in terms of speed, complexity, and available hardware resources amongst various other solutions.

Capstone Advisors: Ozgur Sinanoglu, Professor of Electrical and Computer Engineering and Kartik Sreenivasan, Assistant Professor of Psychology



Gjorgji Shemov, Raghav Kedia and Jotham Varghese

A RADIO-CONTROLLED CAR WITH DUAL POWER SOURCES OF SOLAR AND BATTERY

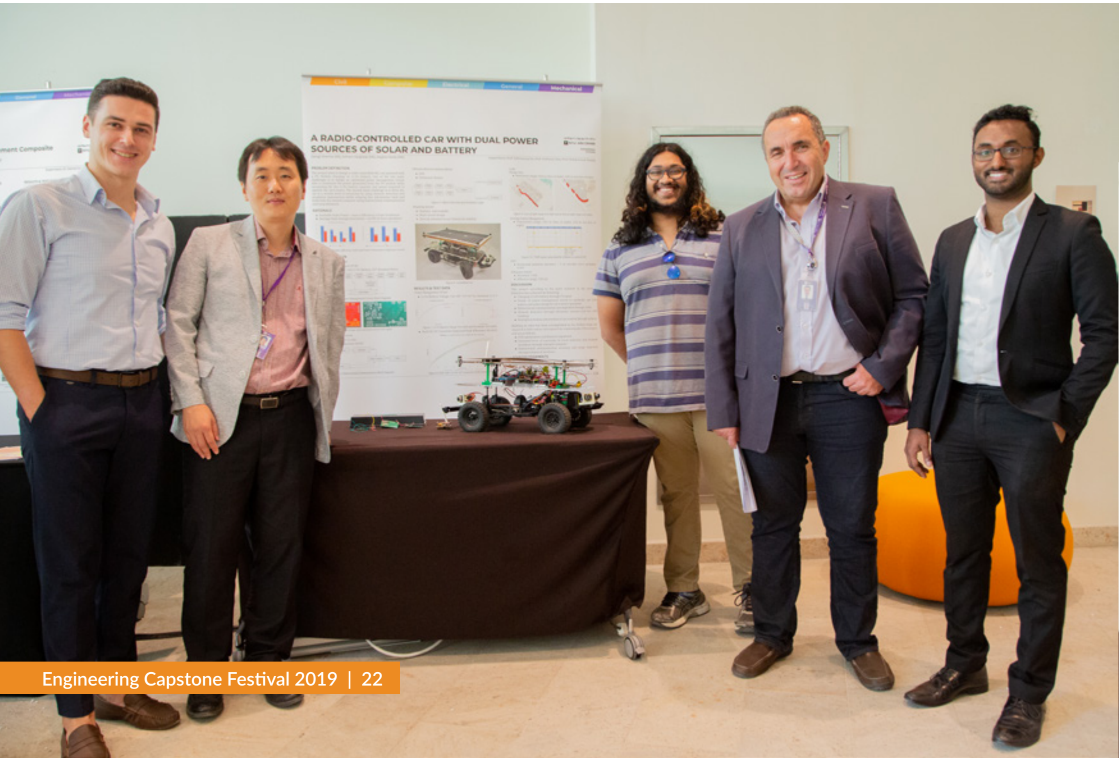
The project aims to design a 1:10 radio-controlled (RC) car powered by 1 Suoaki PV panel and 1 5000mAh Gens Ace Hardcase Li-Po battery, using SCX10 IITM 2000 Jeep® Cherokee as a model car. The main goal of the project is to run the car non-stop, that is 24/7, by charging the battery via the PV panel during the day. One of the main challenges is to provide smooth transition between solar and battery powering of the motor to prevent the car from instant stopping.

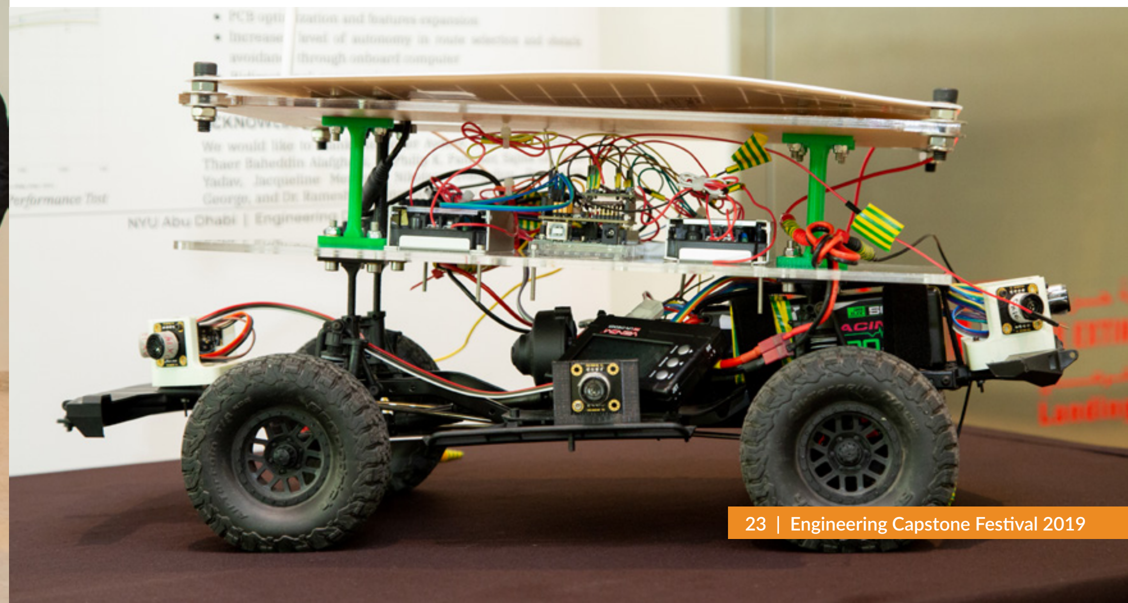
Mini projects have been completed by the student in the field of designing LiPo battery chargers and simulating car performance in the Gazebo Simulation software.

A preliminary printed circuit board (PCB) has been designed and is currently being refined to be manufactured and tested. Several PV panel mounting structures are being prototyped and tested for structural competency and practicality.

The car must navigate between sets of GPS waypoints with minimal human intervention.
This requires the car to be driven to a certain level of autonomy by using obstacle detection and avoidance maneuvers whilst also relaying this information back and forth with the central computer using bidirectional communication over long distances.

Capstone Advisors: Sohmyung Ha, Assistant Professor of Electrical and Computer Engineering, Anthony Tzes, Professor of Electrical and Computer Engineering and Mohammed Daqaq, Professor of Mechanical Engineering





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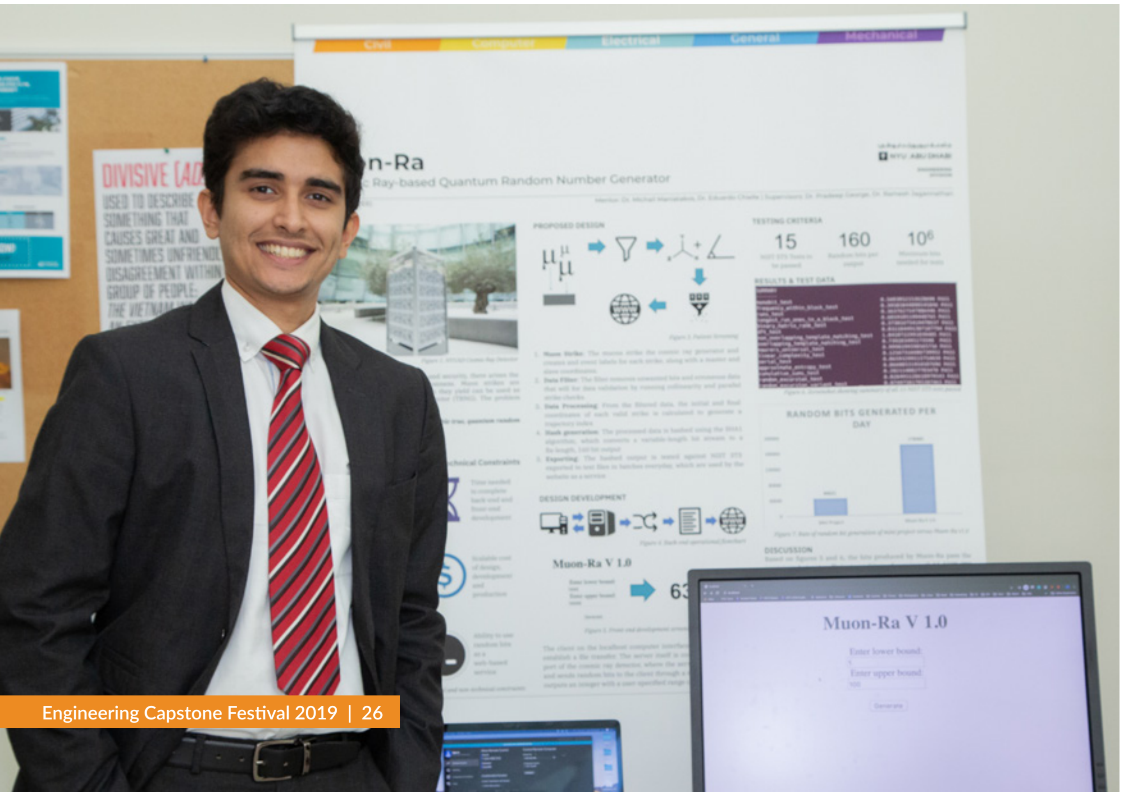
Pranav Mehta

COSMIC RAY DETECTOR-BASED RANDOM NUMBER GENERATOR

Muon decay is a natural phenomenon based on the collision of cosmic radiation with Earth's atmospheric particles. A Cosmic Ray Detector can be used to ionize muons striking the surface of the detector, thus conveying information about a given muon's position of hit, angle of hit and time interval between subsequent hits. Muon strikes are non-deterministic and the information they yield can be used as seeds to a True Random Number Detector (TRNG).

In this work, a Quantum TRNG is proposed that translates position, angle and time interval of muon strikes into random numbers. Several designs are created and evaluated on the basis of the ability of the output to pass randomness tests and rate of throughput. The most robust design is incorporated as an online service that can be used to generate random numbers in real time.



Capstone Advisor: Michail Maniatakos, Assistant Professor of Electrical and Computer Engineering

Daniel Chirita, Paul Niehaus and Halil Utku Unlu

VISUAL TRACKING SYSTEM FOR UNMANNED AERIAL VEHICLES

The goal of this capstone is to create a visual processing routine that detects and tracks airborne drones for security applications in airports, air bases, and other drone frequented locations. The produced platform will realize this function with a pan-tilt-zoom mounted Full HD camera for data acquisition and a computer with a discrete graphical processing unit (GPU) for image processing.

Such camera systems have use in automatic surveillance in both indoor and outdoor locations. By embedding the zoom into the tracking routine, this project aims to extend functionality to over 100 m.

The system is broken down into dynamic object detection, object identification, and camera controller components, and the project aims to provide an integration of existing algorithms in each category to realize the outlined goal.

Capstone Advisor: Anthony Tzes, Professor of Electrical and Computer Engineering

Mahmoud Solimon, Alberto Castillo and Pratik Maisuria

RECONSTRUCTING THE HOROLOGIUM OF HARUN AL-RASHID

The project focuses on the reconstruction of the horologium of Harun al-Rashid from an engineering perspective.

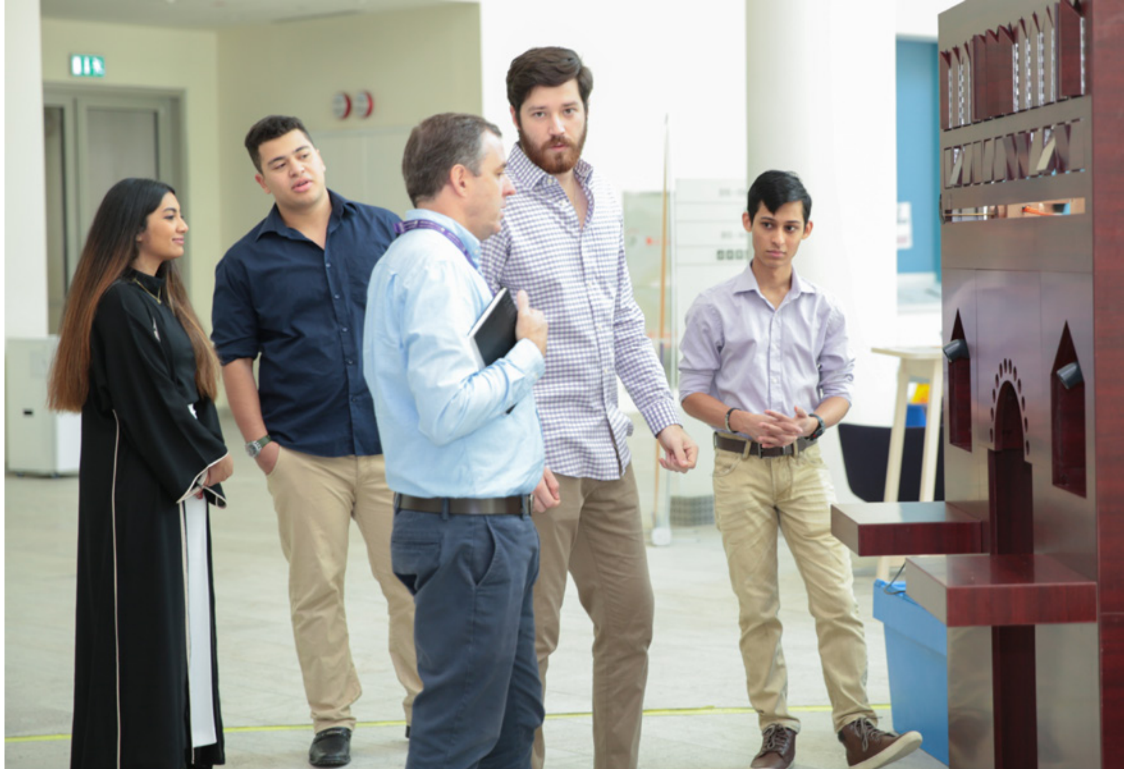
The purpose of the project is to rebuild the water clock in the closest resemblance possible to the original based on existing literature. Furthermore, the project aims to capture the essence of the clock as a landmark in human achievement.

For this purpose the clock is to be reproduced with the same aesthetic artistry as the original, as well as the entirety of the operational mechanism. In the interest of practicality, the clock will first be built at scale, maintaining only the water regulation mechanisms at full size.

A marvel of the ancient world, the engineered replica will stand a testament to the achievement and technicality of muslim engineers of the ancient world, namely Al-Jazari.

In the long term, this capstone serves to mark the start of a project into tourism with a focus on the forgotten engineering marvels of the ancient muslim world.

Capstone Advisor: Mohammed Daqaq, Associate Professor of Mechanical Engineering



Saad Sultan and Mubasher Iqbal

PAPER BASED FILTER FOR WATER PURIFICATION

Problems such as the inaccessibility of clean drinking water and the non-recycling of paper are very common in today's world. Even though steps have been taken to rectify these problems, most of the solutions that exist are either expensive, technical or inaccessible in a lot of regions around the world. This project hopes to solve the problem of the inaccessibility of clean drinking water by designing a device that uses a stack of compressed paper while also making an effort to resolve problems related to paper recycling. The aim is to make the device cheap, easy to handle and readily available. So far, we have conducted several tests and carried out troubleshooting mechanism to solve leakage issues. Data is being collected to test the filtration-efficiency and steps are being taken to improve the flow-rate of the device.

Capstone Advisor: Mohammad Qasaimeh, Assistant Professor of Mechanical and Biomedical Engineering

Shunsuke Kasahara

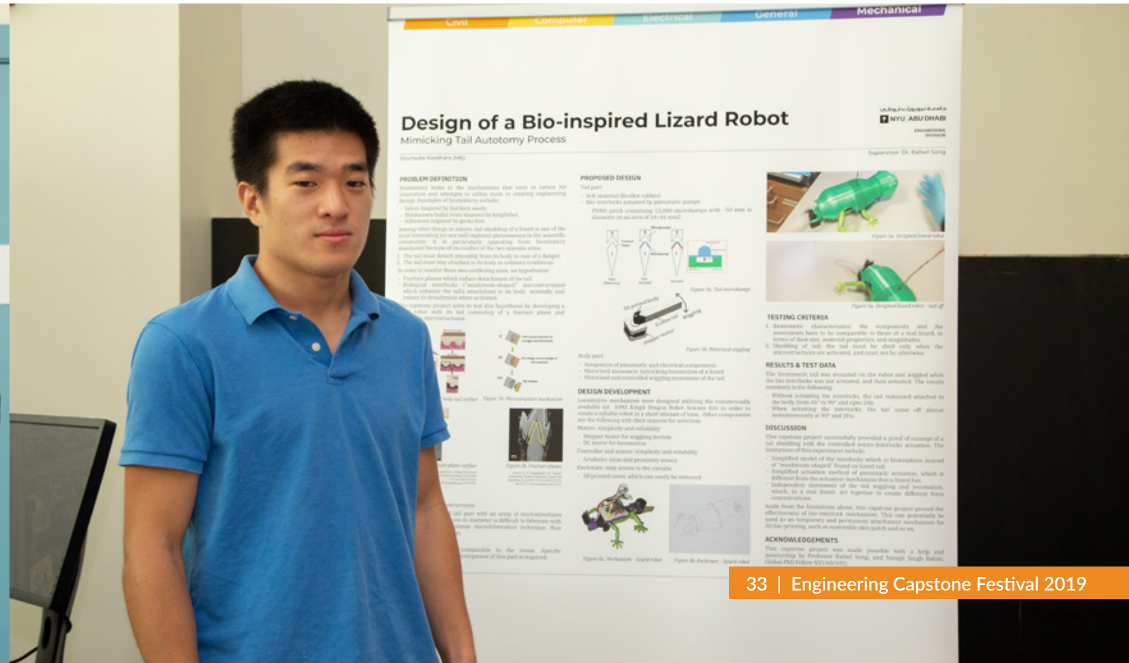
DESIGN OF A BIO-INSPIRED LIZARD ROBOT MIMICKING TAIL AUTOTOMY PROCESS

Bio-inspired by the autotomy process of a lizard, bio-interlock microstructures were hypothesized and fabricated. This was tested and confirmed its effectiveness in a lab setup through experiments for characterization.

To demonstrate the operation of interlock mechanism, a lizard robot was designed and fabricated. This robot detects incoming danger (incoming objects) and releases its tail while running away, as a real lizard would do.

The robot and its tail shedding mechanism using the actuated bio-interlock was successfully demonstrated.

Capstone Advisor: Rafael Song, Assistant Professor of Mechanical and Biomedical Engineering



Janar Jeksen

DESIGN OF A CONTINUOUS MONITORING SYSTEM FOR THE MINERAL NUTRIENT UPTAKE BY PLANTS IN FOGPONIC SYSTEM

Soil less indoor farming practice is a novel technique based on the finding that plants are best able to absorb particulate nutrients in a distance of 1 to 25 micrometers (µm). Therefore, plants that are suspended within enclosed systems rich in nutrient environment can better absorb nutrients for more efficient gardening and less waste of water.

This capstone design project aims at developing a sensor that would measure the particular mineral in the case of potassium that plant can uptake via its roots while being directly exposed to nutrient solution and finding its optimal concentration.

Capstone Advisor: Rafael Song, Assistant Professor of Mechanical and Biomedical Engineering

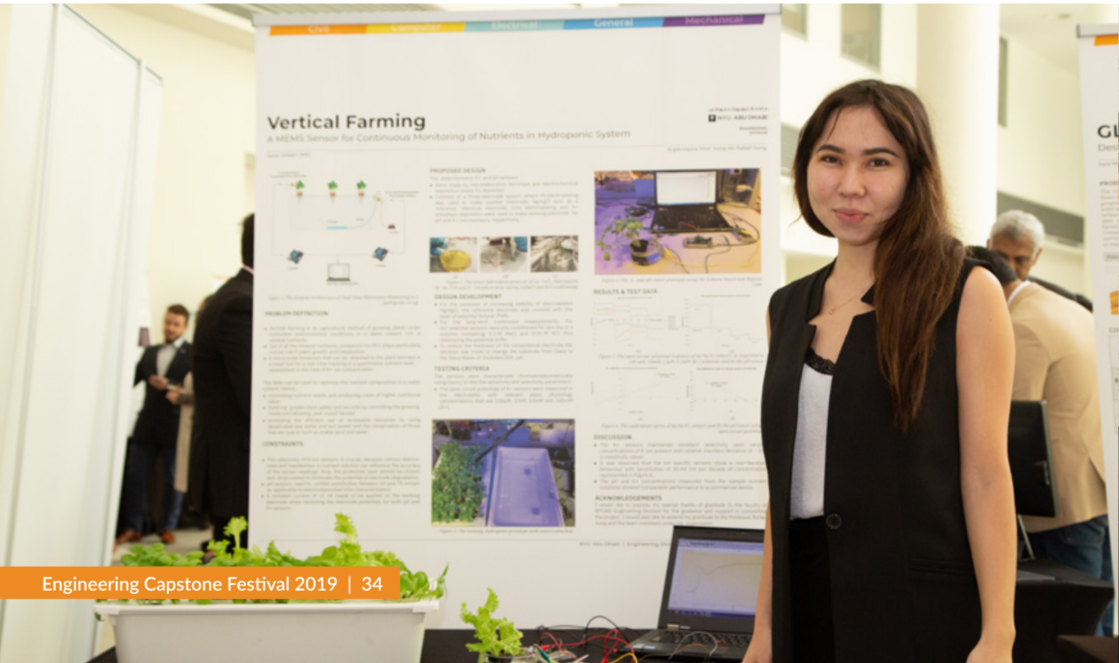
Sara Aldhaheri and Alexander Mackay

GLiDAR: DESIGN OPTIMIZATION AND ACTIVE STABILIZATION OF LiDAR SENSOR PAYLOAD FOR SURVEYING

The GLiDAR is a hardware attachment for the Lockheed Martin INDAGO UAS that will enable the creation of computational three-dimensional modeling of significant geographical features. Our payload uses the LeddarTechM-16 LiDAR sensor to obtain distance measurements along the flight path of the drone that can be coupled with GPS coordinates and IMU orientation data to create a digital elevation map of the studied surface.

The generation of this high resolution spatial data can be used to support many research outcomes within the scientific community.

Capstone Advisors: Mohammed Daqaq, Associate Professor of Mechanical Engineering and Matthew Karau, Lecturer of Engineering Design



Raghav Kumar

FLUIDIC INJECTION THRUST REVERSER SYSTEM FOR HIGH BYPASS RATIO TURBOFAN ENGINES

Conventional Thrust reversers involve the usage of mechanical blockers to block and reverse the flow of air. As they are designed to sustain heavy loads, they are bulky and hence, account for 30% of the nacelle weight (excluding the engine core). This added engine weight results in a 0.5%-1% increase in the specific fuel consumption of the aircraft. The total estimated costs of operating thrust reversers including, their maintenance, sums up to approximately $125,000.

The goal of this project is to design a thrust reverser system for high bypass ratio jet engines that uses fluidic injection to reverse the flow of air, eliminating mechanical blockers completely. The project begins by validating the concepts of Blockerless Engine

Thrust Reversers (BETR) proposed by NASA Langley and culminates with the construction of a working model demonstrating the applicability of an optimized solution. The following report summarizes all the concepts that were thought of before reaching the final design for the Fluidic Injection Thrust Reverser (FITR) and supports the claims with relevant models, simulations, calculations and methodical charts.

Capstone Advisor: Sunil Kumar, Professor of Mechanical Engineering

Ylber Roka, Victor Okoth and Raitis Pekuss

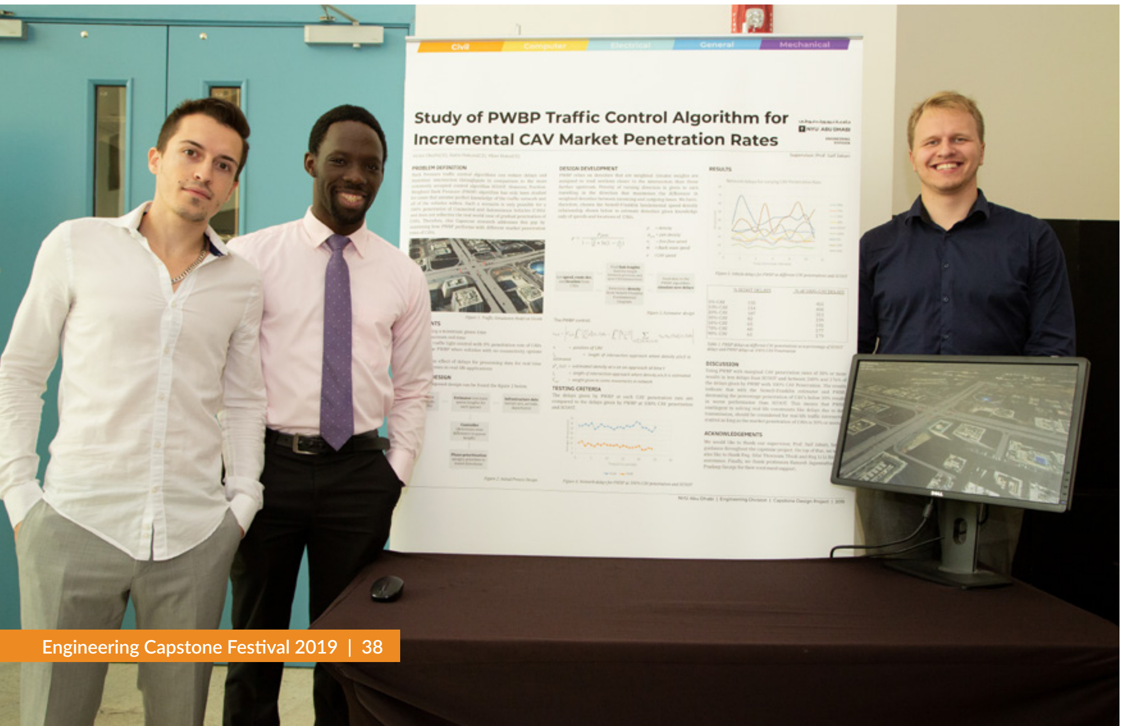
DECENTRALIZED CONTROL FOR MIXED AUTOMATED/MANUAL VEHICLE TRAFFIC

Connected and Autonomous Vehicles (CAVs) are widely expected to revolutionize urban transportation. With fully connected and autonomous vehicle traffic, it is hoped that traffic congestion and accidents as well as jam can be greatly reduced, and throughput maximized. However, CAVs can only penetrate the market gradually. This means that there will be a long time period during which there will be constantly changing proportions of connected and human driven vehicles.

The objective of our Capstone is to adapt the transportation infrastructure, specifically the intersection control, to mixed traffic that consists of connected and autonomous vehicles as well as human driven vehicles. We use decentralized control techniques to assign priority to travel in specific directions at an intersection. Research has shown that these decentralized controls are better than centralized solutions that account for traffic conditions at multiple intersections. We use the back pressure decentralized control which assigns highest priority to travel in the turning direction that maximizes the difference in the length of the inbound and outbound queues. The connected cars will be able to communicate their state to the intersection control, but the human driven ones will be unable to.

We shall therefore use estimation methods to get data about human driven vehicles for more accurate prediction of queue length, on which the intersection control depends. Traffic simulation software VISSIM will be used to test our control process and Kalman filters programmed on Matlab will be used for the estimation of unknown traffic state of human driven vehicles.

Capstone Advisor: Saif Eddin Jabari, Assistant Professor of Civil and Urban Engineering

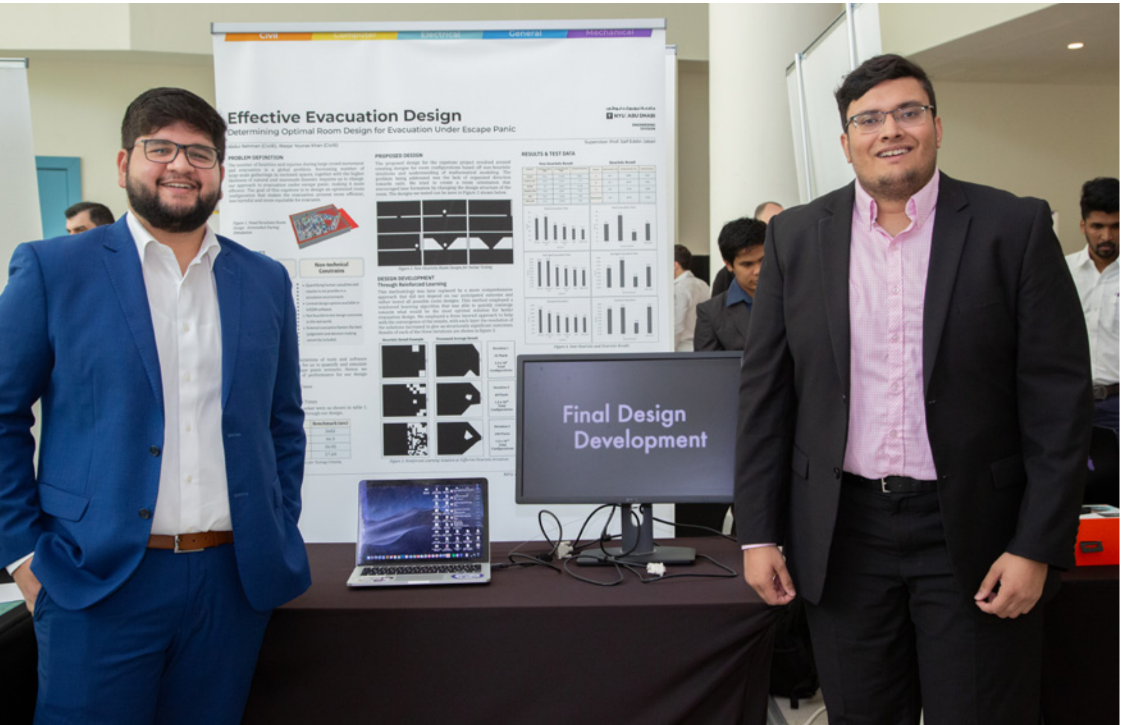


Waqar Younas Khan and Abdur Rehman

OBSTRUCTION DESIGN FOR EFFECTIVE EVACUATION UNDER ESCAPE PANIC

In today's day and age, to find that we have still not optimized our building structures for the safety of pedestrians and occupants of the building itself is a shame. The standards of evacuation design have not changed much in the past half a century. Any progress that is being made being so insignificant in value that adoption of the ideas globally is not a priority. The standard checklist system of meeting the bare minimum requirements of building codes is a fossil of an approach that frankly does not belong to the 21st century.

The 21st century is about minute detail optimization to achieve maximum efficiency and results possible. It is this search that is explained in the following paper where we try and understand the details and try to morph them so as to help us achieve designs that lead to



the goals we have set as aforementioned.

In order to do this, inspiration from Dirk Helbing's work from 2001 was taken that discusses the possibility of improving evacuation rates by introducing obstacles in the pathway of an exit. The project delves further into this concept and by trying to employ one or all of the following; optimized Lagrangian equations, deep neural networks, machine learning and VISSIM.

Based on the results obtained by Helbing, we expect that there is a certain design of obstacles that can improve the flow of pedestrians in an emergency evacuation. This project tries to understand and discover that very geometric answer to this question.

Capstone Advisor: Saif Eddin Jabari, Assistant Professor of Civil and Urban Engineering

Fahad Ahmad, Fathurur Said, Muhammad Osama Khan and
Muhammad Muneeb Afzal

DEEP LEARNING APPROACHES FOR SELF-DRIVING CARS IN AN ADVERSARIAL ENVIRONMENT

This capstone project aims to improve the performance of self-driving cars in adversarial conditions. As such there are two main parts of the project – (1) Computer Vision (object detection and localization) and (2) Security (attacking the object detectors). In light of the criteria above, our team worked on two object detection algorithms, namely YOLO (2D) and VoxelNet (3D). Firstly, YOLO, a state-of-the-art 2D object detection algorithm was implemented from scratch.

The YOLO algorithm was successfully implemented by using a 24-layer Convolutional Neural Network (CNN). Training of the algorithm took about a week (135 epochs) with the PASCAL VOC dataset and resulted in an eventual loss of 3.427, indicating the relatively high accuracy of the object detector. After having successfully completed implementation of the 2D YOLO object detection algorithm, the next goal for the computer vision side of the project was to implement a 3D object detection algorithm. The algorithm chosen for this task was VoxelNet, which is a state-of-the-art 3D object detection algorithm recently published by Apple. The implementation was successfully completed.

The security aspect of the project was started by executing one-pixel (black-box) attacks. Two categories of one-pixel attacks were implemented – (1) targeted attacks and (2) untargeted attacks. After successfully implementing the two types of one-pixel attacks on standard CNNs like ResNet and DenseNet, our team integrated the security attacks with object detection and implemented targeted attacks on the YOLO object detector. However, since YOLO is a state-of-the-art object detection algorithm, fooling the YOLO detector required perturbing around 10 – 15 pixels in contrast to the one-pixel attacks on ResNet and DenseNet.

In the next part, it was decided to test the security attacks using a well-known car simulator known as Udacity. Firstly, the Udacity car simulator was tested with modified input images (flipped, blurred, varied brightness). The results were successful and were able to affect the autonomous mode of the car and thus the car went off the track. To take a further step, the implementation of Generative Adversarial Network (GAN) was started and are focusing on Deep Convolutional Generative Adversarial Networks (DCGANs). The goal is to generate fake images and test them on Udacity simulator and check if it is possible to fool the simulator.

Capstone Advisors: Hoda Al Khzaimi, Research Assistant Professor, Engineering and Yi Fang, Assistant Professor of Electrical and Computer Engineering

HIGHLIGHTS FROM THE FESTIVAL











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