2021

ENGINEERING **CAPSTONES**

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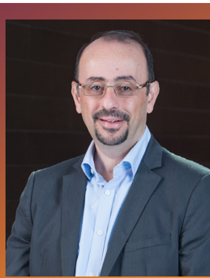
MESSAGE FROM OUR DEAN



The academic year of 2020-21 will go down in history as an extraordinary year with the COVID-19 pandemic affecting everyone the world over with home, studies and work lives upended. We have seen our frontline workers saving lives and keeping life going, as well as leaders providing much needed reassurance and guidance so we can all come back together again. Engineering plays a vital part in this process. Our graduates as engineers and future leaders will be the ones working to build a better world for tomorrow.

The Engineering Capstone is a major design experience structured to immerse students in the process of developing engineering and technology solutions. It provides the opportunity to integrate technical, human, aesthetic and business 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.

Our students have championed innovation and progress and produced projects appropriate of such goals, which represent the highest aspirations of undergraduate intellectual development, creativity, and engagement with original creative work. Having the opportunity to showcase the Class of 2021's Capstone projects is most importantly a testament to the incredible resilience and resolve of our Seniors and the dedication of our faculty.

In aligning with today's Engineering advances as well as our institutional research priorities of biomedical and health systems, robotics, cybersecurity, environmental sustainability and urban systems, this year's Capstones include:

Designed by our Computer and Electrical Engineers

A Machine Learning System to Quantify Haptic Experience

A Non-Contact ECG Monitoring System

ramen: Design and Development of a Raft Consensus Algorithm Coupled with an IEEE 802.11 based Mesh Network for Embedded Systems

Designed by our Electrical Engineers

An Acoustic Monitoring and Localization of Crickets at the Louvre via IoT Technologies & Machine Learning

A non-invasive cell density monitoring device for bacterial batch cultures

Our Mechanical Engineers designed

An Autonomous Wave Powered Desalination Unit

A Quantitative Approach to a Fluidic Injection Thrust Reverser Design for Turbofan Engines

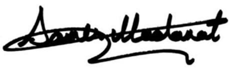
And collaboratively and interdisciplinary, our students designed

A Fabrication and Control of Robotic Laparoscopic System

A three dimensional (3D) printing with low-carbon cement-based material

A Graphical Visualization of Congestion Propagation Speed in the Network

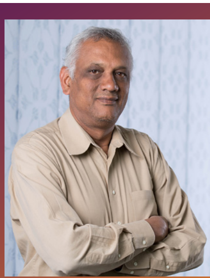
To the Class of 2021, you have made it and there is a lot to be proud of with these exceptional accomplishments from this extraordinary period. With offers to join top graduate schools, take up positions in large corporations, enjoy gap years, complete military service or continue your studies at NYUAD, we wholeheartedly congratulate all of you for your wonderful academic achievements.

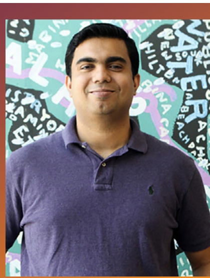


With best wishes for a successful future ahead,

Samer

LETTER FROM THE COORDINATORS





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 and General Engineering) is in developing engineers to solve such real world problems. The capstone coordinators, Pradeep George and Ramesh Jagannathan, have designed a unique, cross-disciplinary capstone experience for the senior engineering students at NYUAD. This is different from the traditional capstone courses found in most of the global engineering offerings which focus on fulfilling the degree requirements for a specific engineering program/major.

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 capstone experience aims at solving a cross-disciplinary challenge for a team of seniors drawn from each of these programs/majors. 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 result in 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 Capstone Project aims to be collaborative and cross-disciplinary across several engineering streams. 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. There is a mid-semester review of the projects. 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 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 Senior Design Capstone Project I is implemented in the first module. It is tested and validated in Module II.

This year there are 26 senior students in 10 capstone projects. The titles and the majors of the team members are listed below:

Design of an Autonomous Wave Powered Desalination Unit
Majors: Mechanical Engineering

Three Dimensional (3D) Printing with Low-Carbon Cement-based Materials
Majors: Civil Engineering

Design of a Machine Learning System to Quantify Haptic Experience
Major: Computer and Electrical Engineering

Non-Contact ECG Monitoring System
Majors: Computer and Electrical Engineering

Indoor Acoustic Localization of Pests via IoT Technologies & Machine Learning
Majors: Electrical Engineering

Design of a Non-Invasive Cell Density Monitoring Device for Bacterial Batch Cultures
Major: Electrical Engineering

ramen: Design and Development of a Raft Consensus Algorithm Coupled with an IEEE 802.11 based Mesh Network for Embedded Systems
Major: Computer Engineering

A Quantitative Approach to a Fluidic Injection Thrust Reverser Design for Turbofan Engines
Major: Mechanical Engineering

Fabrication and Control of Robotic Laparoscopic System
Major: Mechanical and Electrical Engineering

Designing Graphical Visualization of the Maximum Congestion Propagation Speed at the Network
Major: Civil Engineering

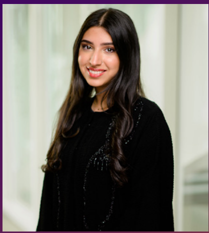
We take this opportunity to congratulate all the teams on their successful completion of the capstone projects and wish them all the best in their future endeavors.

Sincerely

Pradeep George, PhD
Senior Lecturer and Coordinator of Engineering Capstones
NYU Abu Dhabi

Ramesh Jagannathan, PhD
Managing Director, startAD
Vice Provost of Innovation and Entrepreneurship
NYU Abu Dhabi

CAPSTONE PROJECTS



DESIGN OF AN AUTONOMOUS WAVE POWERED DESALINATION UNIT

Shahad Badri (ME), Majid Alabbasi (ME) and Yuanbei Fan (ME)

The objective of the capstone project is to design and model an autonomous wave-powered reverse osmosis desalination unit. Local wave conditions include an average wave height of 0.5 m at depths of 21-30 m in the Gulf region. In the unit, a round buoy extracts kinetic energy from the heaving motions of the ocean waves and drives a submerged positive displacement pump to pressurize seawater through the reverse osmosis membrane in the desalination process. The desalinated permeate is transferred into a reservoir onshore, while the high concentrated brine is discharged to the ocean. Using the "Delbuoy" desalination unit as a benchmark, a more efficient system is developed by implementing bistable springs to create a nonlinear stiffness system. This system is able to reach resonance with incoming sea waves at different natural frequencies, therefore archives a higher permeate production of 0.252 m3/s. The design skips the intermediate step of the electromechanical conversion process, therefore utilizes no generators or motors, which offers advantages such as reduced cost, simplicity in the design and installation process, and increased power efficiency.

Capstone Advisor

Mohammed Daqaq, Associate Dean of Engineering; Professor of Mechanical Engineering
Raed Hashaikeh, Professor of Mechanical Engineering

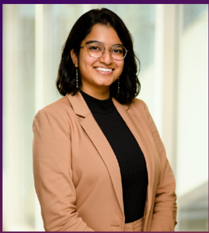
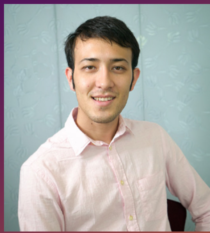
THREE-DIMENSIONAL (3D) PRINTING WITH LOW-CARBON CEMENT-BASED MATERIALS

Dana Ashmawy (CE) and Veronica Wambura (CE)

There is an increasing interest in the 3D printing of cementitious construction materials among civil engineering fields. Recent research has defined 3D printing as one of the fastest, most efficient and most cost-effective methods of building. 3D printing ensures quick repeatability of the construction process as well as lower labor costs since a machine now does the work. While this new technology has many advantages, it also poses a great risk to the environment due to the high use of Ordinary Portland Cement (OPC) in the 3D printing construction industry. Approximately 900 kg of CO2 is emitted for every production of 1 ton of cement. This makes up more than 8% of the man-made emissions of CO2, a potent greenhouse gas. This capstone project aims to find alternative sustainable solutions to OPC that would meet the 3D printing standards as defined by the American Standard of Testing and Materials (ASTM) as well as the Portland Cement Association while also reducing the amount of CO2 emission required during production. Moreover, the project will involve 3D printing different prototypes using the proposed alternative cementitious materials and testing and optimizing the materials' strength, flow and microstructure.

Capstone Advisor

Kemal Celik, Assistant Professor of Civil and Urban Engineering

DESIGN OF A MACHINE LEARNING SYSTEM TO QUANTIFY HAPTIC EXPERIENCE

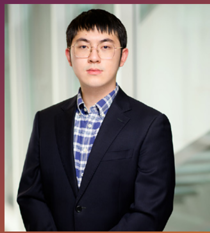
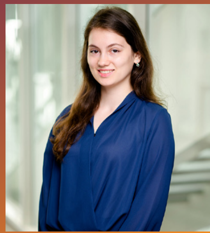
Praggya Jeyakumar (CompE) and Hadi Assadi (EE)

The objective of the capstone project is to design a system to quantify aspects of user haptic experience using brain signals from EEG. We aim to use EEG data collected from a previous study at the Applied Interactive Multimedia lab (AIMlab) to quantify haptic experience using EEG data and machine learning, in particular the haptic delay. Our final machine learning model achieves an accuracy of 83.2 ± 0.573% (reported within a 95% confidence level) in detection of a haptic delay in the user experience from a single trial EEG data stream using a light gradient boosting machine. Using EEG data to quantify haptic experience renders our model more accurate, and objective, which will have many applications in designing haptic electronics, attention rehabilitation, and neuroscience research.

Capstone Advisor

Mohamed Eid, Assistant Professor of Electrical and Computer Engineering



NON-CONTACT ECG MONITORING SYSTEM

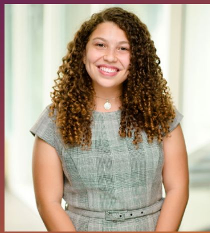
Ghadeer Ghosheh (CompE), Qutaiba Al-Nuaimy (EE), Aren Chen (EE) and Sanja Kastratovic (EE)

Cardiovascular diseases (CVDs) have been proven to be amongst the most deadly diseases worldwide. The majority of deaths associated with CVDs occur amongst patients who have never been previously diagnosed with any CVDs. Many CVDs, such as arrhythmia, manifest their symptoms a long time prior to the onset of any adverse or catastrophic event(s), and as such the early detection of cardiac abnormalities is incredibly important. However, traditional ECG monitoring systems face challenges with respect to their scalability and affordability as they require direct contact with the body and cumbersome equipment. In this Capstone Design Project, we aim to provide a solution to this problem by developing a small-size, non-contact, real-time feedback, and long-term monitoring lead-I ECG system. It is paired with an iOS application that receives the data through Bluetooth Low Energy and utilizes real-time machine learning analysis. The device itself is comprised of three non-contact electrodes designed to sense bio-potential signals, an AD8233 AFE IC used to extract ECG signals, and a CC2650 MCU to read, filter, and transmit them. The device is powered by a 2000mAh lithium ion battery with isolation in digital and analog power using two LDOs. The board's footprint is 8.56cm × 5.4cm, the size of a credit card. In spite of its small form factor, the device still manages to achieve a battery life of 44hrs and an SNR of 25.2dB, all coming in at just below $50. In addition to the above, the machine learning component was also built on a convolutional neural network architecture that was trained and tested with an extensive database of ECG data from the PTB-XL dataset. The model achieved a performance of 0.868 and 0.901 for Area Under the Receiving Operator Curve (AUROC) and Area Under the Precision Recall Curve (AUPRC), respectively. The inference time of our system was also determined to be approximately 49ms for a single ECG signal, thus allowing us to achieve real-time abnormality detection.

Capstone Advisor

Sohmyung Ha, Assistant Professor of Electrical and Computer Engineering
Mohamed Eid, Assistant Professor of Electrical and Computer Engineering





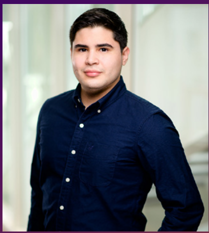

INDOOR ACOUSTIC LOCALIZATION OF PESTS VIA IOT TECHNOLOGIES & MACHINE LEARNING

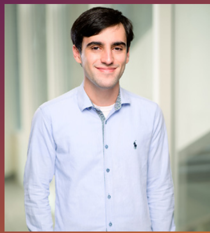
Mariam Elgamal (EE), Yeojin Jung (EE), Farida Shaban (EE) and Mohammed Adib Oumer (EE)

Museums are fighting a constant battle to preserve their invaluable specimens and artwork from pests that can potentially damage them, including the Louvre Abu Dhabi. Museum-wide pest control is not only inefficient, but also has a damaging effect on the museum collection such as metal corrosion, paper deterioration, color changes, and shrinkage of plastics. This project aims to develop a sound detection and analysis system to detect, locate, and determine the population dynamics of crawling and flying pests (e.g., crickets), thereby allowing pest control strategies to be more targeted and efficient. By collecting such information about pests, museum facilities teams can target their use of pesticide to only the affected areas of the museum and hence reduce the total exposure of the museum collections to pesticides throughout the year. Additionally, the collected information could be used to identify trends in the population dynamics and aid in designing long-term non-chemical pest preventative strategies (i.e., traps, ultrasonic pest repellents). Our system utilizes a network of Internet-of-Things (IoT) devices that would collect and process necessary real-time information on the cloud using signal processing, machine learning models and big data analysis methods to aid efficient pest-control plans. Ideally, the system will aid museum administrators in decision-making by providing real-time analysis and visualizations through a user interface on handheld devices such as mobile phones, tablets, and laptops.

Capstone Advisor

Andras Gyorgy, Assistant Professor of Electrical and Computer Engineering





DESIGN OF A NON-INVASIVE CELL DENSITY MONITORING DEVICE FOR BACTERIAL BATCH CULTURES

Cristian Garcia (EE), Rumail Memon (EE) and Ahmad Nasralla (EE)

The proposed system is a device that enables automated non-invasive monitoring of cell density within a biological lab incubator during experiment preparation. The proposed device will have an accuracy within 5% of lab-grade spectrophotometers, battery life of over 48 hours, and a component price below 150 USD. The target users are biological lab technicians currently required to manually measure, monitor, and estimate cell density via sporadic sampling over dozens of hours. The current technique is problematic because it consumes time, requires continuous inspection, involves human error, and occasionally contaminates or invalidates the experiment preparation. Due to time constraints and limitations by the COVID-19 pandemic, full development was not complete. However, the current progress serves as proof of the concept that a device with such requirements is possible.

Capstone Advisor

Andras Gyorgy, Assistant Professor of Electrical and Computer Engineering

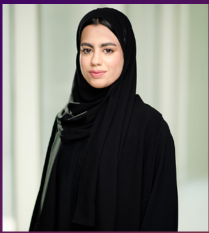
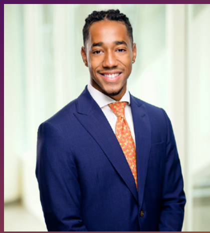
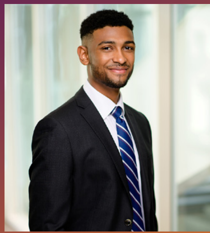
ramen: DESIGN AND DEVELOPMENT OF A RAFT CONSENSUS ALGORITHM COUPLED WITH AN IEEE 802.11 BASED MESH NETWORK FOR EMBEDDED SYSTEMS

Barkin Simsek (CompE) and Nishant Aswani (CompE)

Consensus is a fundamental problem in fault-tolerant distributed systems and involves multiple nodes arriving at a coordinated decision. Reaching a consensus is more challenging if the system is dynamic and if it makes decisions in real-time, as is the case with autonomous vehicles and mobile sensor networks. Thus, consensus algorithms ensure that a cluster of devices can cooperatively complete its tasks even if the cluster loses its leader. However, if a consensus algorithm is built upon a typical hub-spoke network topology, the algorithm may be rendered useless if the singular network access point fails. A mesh network is an alternative, non-hierarchical topology for local networks in which devices can directly communicate amongst themselves without a central node coordinating the process. As a result, a mesh network is resilient to a single point of failure. Our capstone project implements Raft, a distributed consensus algorithm, atop a mesh network for use in low-power embedded systems. As a part of the capstone project, an open-source software library was developed and prototyped on custom-designed printed circuit boards (PCB) with an ESP8266 chip. Our compiled software library consumes 0.33MB of flash memory and is capable of supporting over 100 nodes. During elections, it takes an average of 300ms to elect a new leader with insignificant variation as the network size grows.

Capstone Advisor

Matthew Karau, Senior Lecturer of Engineering Design
Saif Jabari, Assistant Professor of Civil and Urban Engineering

A QUANTITATIVE APPROACH TO A FLUIDIC INJECTION THRUST REVERSER DESIGN FOR TURBOFAN ENGINES

Afraa AlSaeedi (ME), Matthew Jagdeo (ME) and Mohamed Mbarouk (ME)

Engine Thrust Reversal systems on current commercially available turbofan engines rely primarily on mechanical systems to block and reverse the flow of air. These blockers are both extremely heavy (accounting for 30% of the nacelle weight) and contribute to fuel inefficiency. In a study conducted by the General Electric Aircraft Engines Company, it was estimated that the engine-specific fuel consumption can increase by ~0.5-1.0% due to the use of mechanical blockers. This is even more significant as thrust reversal systems are only utilized for a tiny fraction of a plane's operating time. According to the Boeing Company, running thrust reverser systems on a Boeing 767 can cost about USD $125,000 per airplane annually, vastly outweighing the financial savings from reduced brake wear. Depending on the airline and routes flown, this can account for almost 0.5% of the annual operating costs of a B-767. Previous capstone projects have proposed, designed and verified the concept of using Fluidic Injection Thrust Reverser (FITR) systems on high bypass-ratio turbofan engines to reverse the flow of air and eliminate mechanical blockers completely. However, despite work being done to prove the concept, further quantitative analysis of a redesign of the thrust reversal system has yet to be fully carried out. The goal of this project is to design an optimized FITR system and provide a quantitative analysis of its efficiency and feasibility. The project will have three main phases of development, namely; (1) Simulations (2) Modelling and (3) Testing. In the Simulation phase, extensive Computational Fluid Dynamics studies will be carried out on a full-sized and scaled-down model of a turbofan engine with the novel thrust reversal system. Then for the Modelling phase, a scaled experimental model will be prototyped via multiple iterations and small-scale testing will be done to ensure perfect modeling. Lastly, in the Testing phase, the optimal prototype will undergo rigorous testing and the results will be used in the conclusions of this report. The following report summarizes the concepts and iterations that were followed before reaching the final design as well as relevant literature review, project constraints and work management guidelines.

Capstone Advisor

Sunil Kumar, Program Head of Mechanical Engineering; Professor of Mechanical Engineering
Philip Panicker, Senior Lecturer and Coordinator of Engineering Academic Laboratories

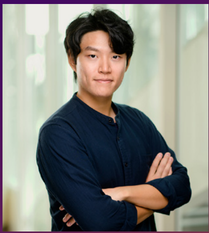
FABRICATION AND CONTROL OF ROBOTIC LAPAROSCOPIC SYSTEM

Ingie Baho (ME) and Elena Negoiu (EE)

Robot-assisted surgery can address the limitations of minimally invasive surgical operations and to further enhance the confidence and precision of physicians conducting open surgery. Increasingly, the research in the industry has been evolving towards the development of completely automated surgical robotic systems. This project focuses specifically on minimally invasive laparoscopic surgery and aims to employ an automated robotic system to conduct the necessary incisions and visualization of the interior organs. This process entails designing and fabricating the laparoscopic tool while mechanically integrating it onto a commercially available robotic system. The performance of the system will be corroborated by a tool-tracking methodology to ensure the integrity of the simulated surgical operation.

Capstone Advisor

Antonios Tzes, Program Head of Electrical and Computer Engineering; Professor of Electrical and Computer Engineering
Mohammad Qasaimeh, Assistant Professor of Mechanical and Biomedical Engineering



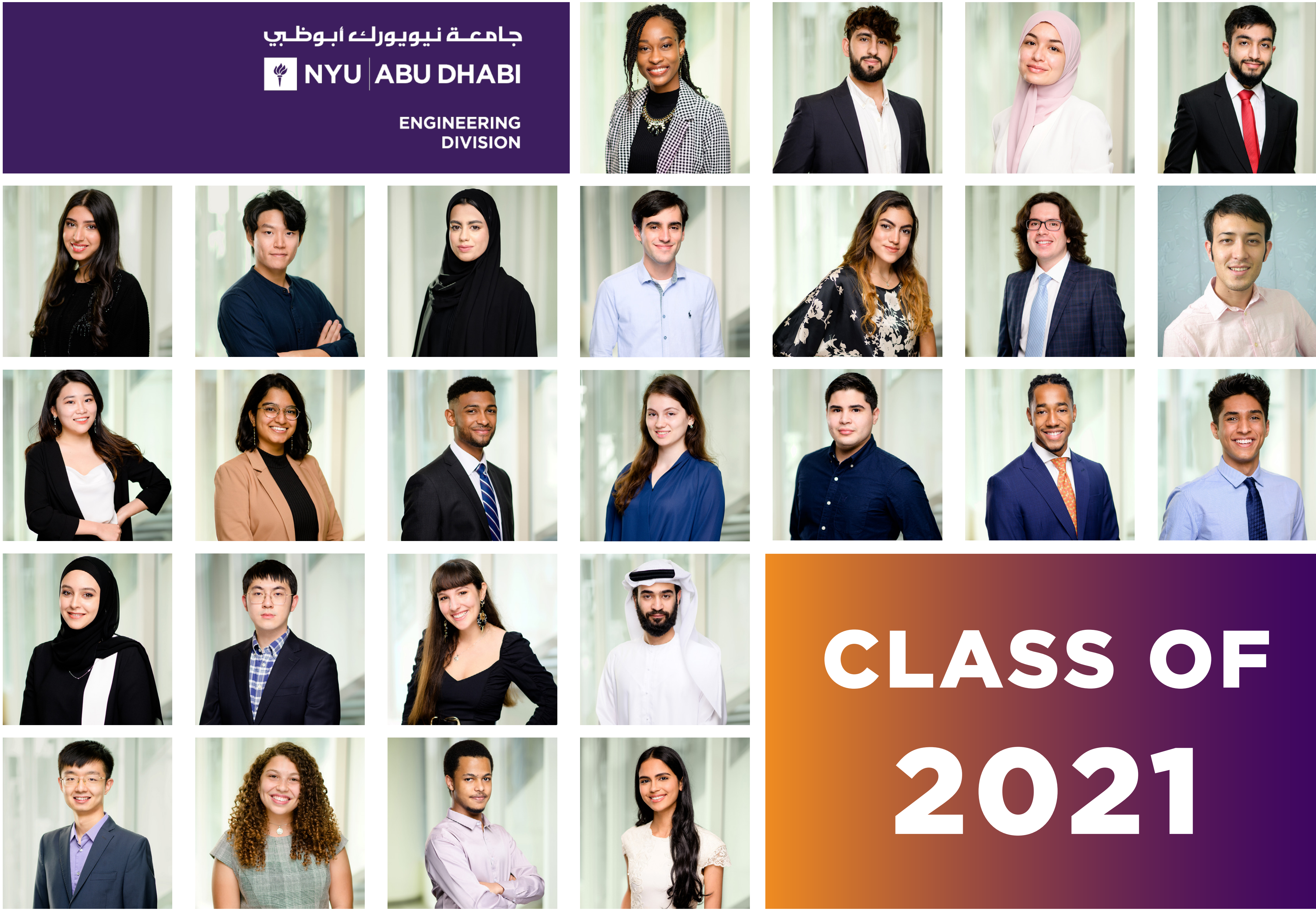
DESIGNING GRAPHICAL VISUALIZATION OF CONGESTION PROPAGATION SPEED AT THE NETWORK

Sungmin Sohn (CE)

The Macroscopic Fundamental Diagram (MFD) is a graphical representation that relates the weighted flow and density of the urban network. Among several uses of the MFD for network traffic analysis, this capstone project focuses on the slopes of the MFD's two branches. The left branch of the MFD represents the free-flow speed of the network while the right branch shows the speed at which the congestion propagates and/or dissipates in the network. Since the introduction of MFD, the main focus of the estimation methods of the MFD was on the left branch (free-flow speed). As a result, the right branch of the MFD representing the congestion propagation and/or dissipation speed in the network has not yet been fully comprehended. The understanding of the right branch of the MFD is important because the maximization of the dissipation speed at the network is desired to mitigate traffic congestion. Without a comprehensive understanding of the right branch of the MFD, no traffic control scheme can be implemented to maximize congestion dissipation at the network. Hence, the goal for this capstone was to design a graphical visualization tool that could show the relationship between the links and the network in terms of the congestion propagation speed. The tool bases its visualization on the analytically formulated mathematical model that interprets the relationship between the links and the network.

Capstone Advisor

Monica Menendez, Associate Professor of Civil and Urban Engineering and Director of the Research Center for Interacting Urban Networks (CITIES)
Andras Gyorgy, Assistant Professor of Electrical and Computer Engineering


جامعة نيويورك أبوظبي
NYU ABU DHABI
ENGINEERING DIVISION
CLASS OF 2021

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