أكاديمية كاوست
KAUST ACADEMY

جامعة الملك عبدالله
للعلوم والتقنية
King Abdullah University of
Science and Technology

KAUST ACADEMY 2025 SPECIALIZATION

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KAUST ACADEMY 2025 SPECIALIZATIONS IN NUMBERS

297

Talented university students from **16** nationalities in **16** different training locations.

45%

total **female** student percentage

134

different projects students worked on.

71
Artificial Intelligence

25
Bioinformatics

15
Cybersecurity

23
Energy Transition

94 DIFFERENT **PROJECT MENTORS**

55 DIFFERENT **LOCAL AND INTERNATIONAL UNIVERSITIES** STUDENTS

ABOUT US

The KAUST Academy specializations program represents a strategic response to Saudi Arabia's Vision **2030** objectives, specifically addressing the critical need to develop local talent in emerging technologies that will drive the Kingdom's economic diversification. By offering comprehensive training in artificial intelligence, bioinformatics, cybersecurity, and energy transition, the program directly targets the four key pillars of Vision 2030's research and development priorities: sustainable environment and essential needs, energy and industrial leadership, health and wellness, and economies of the future. This initiative recognizes that Saudi Arabia's transformation from an oil-dependent economy to a knowledge-based one requires a skilled workforce capable of competing in high-tech industries and research sectors.

The program's multi-stage structure creates a natural bridge between undergraduate education in Saudi universities and advanced professional competency in cutting-edge fields. Rather than leaving recent graduates to navigate this transition independently, KAUST Academy provides a systematic pathway that begins with foundational online coursework through Coursera, progresses through intensive in-person training at universities across the Kingdom, and culminates in international summer programs at prestigious institutions like Oxford, Cambridge, Duke, and University of Toronto. This scaffolded approach ensures that students from diverse academic backgrounds can build upon their undergraduate foundation while gaining practical, industry-relevant skills, with the program having successfully trained over 16,000 students across multiple specializations.







This booklet serves as a comprehensive showcase of the remarkable achievements and outcomes that KAUST Academy's 297 graduating students in 2025 have accomplished through their international summer programs at world-renowned universities. These graduates represent more than mere statistics—they demonstrate the tangible impact of Saudi students engaging with cutting-edge research and advanced methodologies at institutions across the globe. Their success validates the program's effectiveness in not only bridging the gap between traditional university education and specialized knowledge required for Saudi Arabia's emerging technology sectors, but also in positioning Saudi graduates as competitive contributors to international research and innovation networks.

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K.A.CARE

ntdp

الهيئة الوطنية للأمن السيبراني
National Cybersecurity Authority

Site

women & energy

رزم للاستثمار
RZM INVESTMENT

TEAM MEMBERS

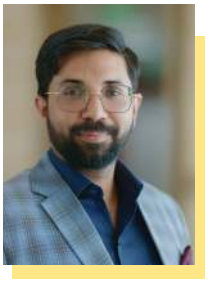


Sultan Albarakati

King Abdullah University of Science and Technology

Doctor of Philosophy in Electrical Engineering

Associate Vice President, Saudi Talent Development

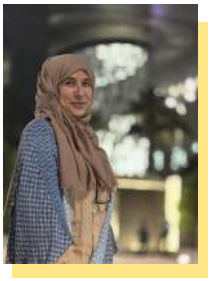


Naeemullah Khan

King Abdullah University of Science and Technology

Doctor of Philosophy in Electrical Engineering

Instruct. Assoc. Professor, Deputy Director KAUST Academy



Oroba Al Nasr

Al Dammam University

Human Research

Promotions & Outreach Specialist

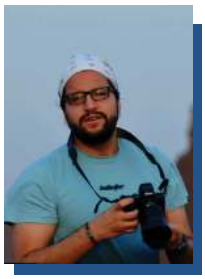


Abdulrahim Alghamdi

Curtin University

Human Research

Master of Commerce, Logistics, Materials, and Supply Chain Management



Abdulaziz Altelmissani

King Abdulaziz University

Medical Laboratory Sciences

Program Coordinator



Ahmed Alhawsawi

Western Kentucky University

Communication Studies and Business Administration

Program Coordinator



Ali Habibullah

King Abdulaziz University

Computer Science

Research Engineer

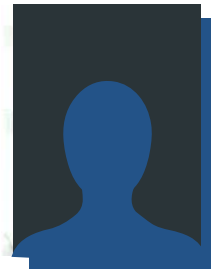


Asim Abdulfattah

Florida Institute

Aeronautical Science, Flight

Program Administrator Pre-University programs



Doa'a Aburayya

King Abdulaziz University

Computer Science

Research Enginner - AI



Emad Surour

Taibah University

Computer Science information systems

Academy Programs Administrator



Farhanaz Beg

National University of Singapore

Computer Science and Engineering

Admissions Lead



Fatma Karabulut Ilter

Istanbul Kültür University

MBA

Program Administrator



Mahmoud Ellouh

King Fahd University of Petroleum and Minerals - KFUPM

Computer Engineering & Cybersecurity

Research Enginner - Cybersecurity

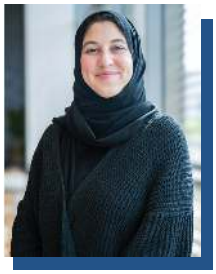


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UC San Diego/KAUST

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Program Administrator, Pre-University programs



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Business and Finance MSc.

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Tarek Shehata

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Manager, Pre-University Programs

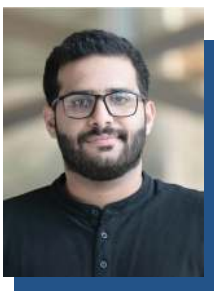


Venu Kas

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Doctor of Philosophy in Biochemistry

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Program Administrator



Artificial Intelligence Specialization

2025


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University of Toronto - Summer Internship - Artificial Intelligence



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Al-Baha University

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Princess Nourah Bint Abdul Rahman University

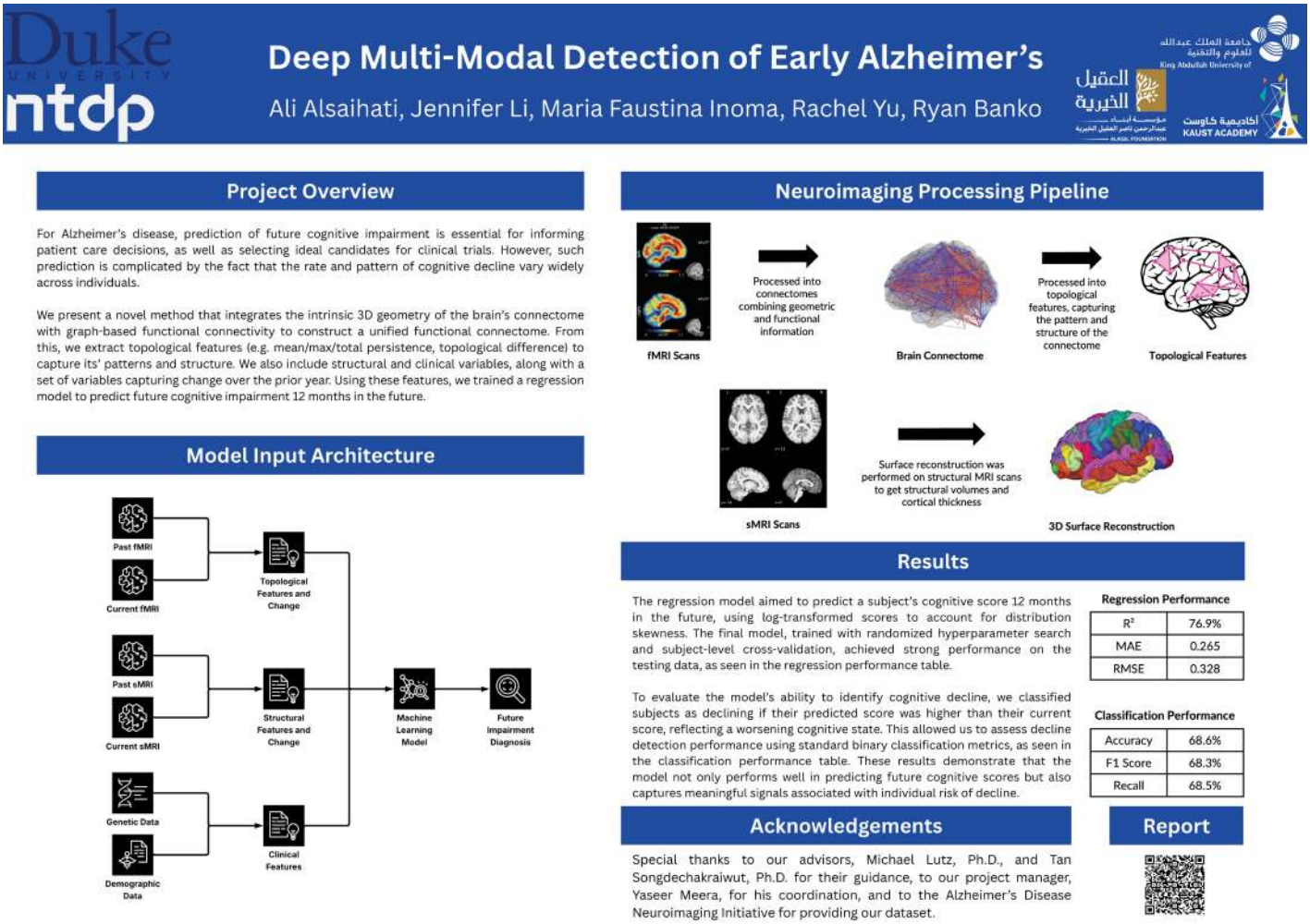
AI For Sports Summer School - King Abdullah University of Science and Technology

ARTIFICIAL INTELLIGENCE PROGRAM

The application of deep learning to Alzheimer's disease (AD) research using MRI is a rapidly evolving field, with existing studies serving primarily as proof of concept. This Data+ project aims to contribute to the development of a deep learning model that integrates MRI-based topological biomarkers for the early detection of AD. Led by Tananun Songdechakraiwut (Computer Science) and Michael Lutz (Neurology), an interdisciplinary student team will focus on extracting subtle topological features from functional and structural MRI data, complementing these with established clinical biomarkers (e.g., amyloid-beta, tau, APOE genotype) to develop models that are more clinically relevant.

PROJECT MENTOR: Tan Songdechakraiwut

ARTIFICIAL INTELLIGENCE PROGRAM Ali Alsaihati.

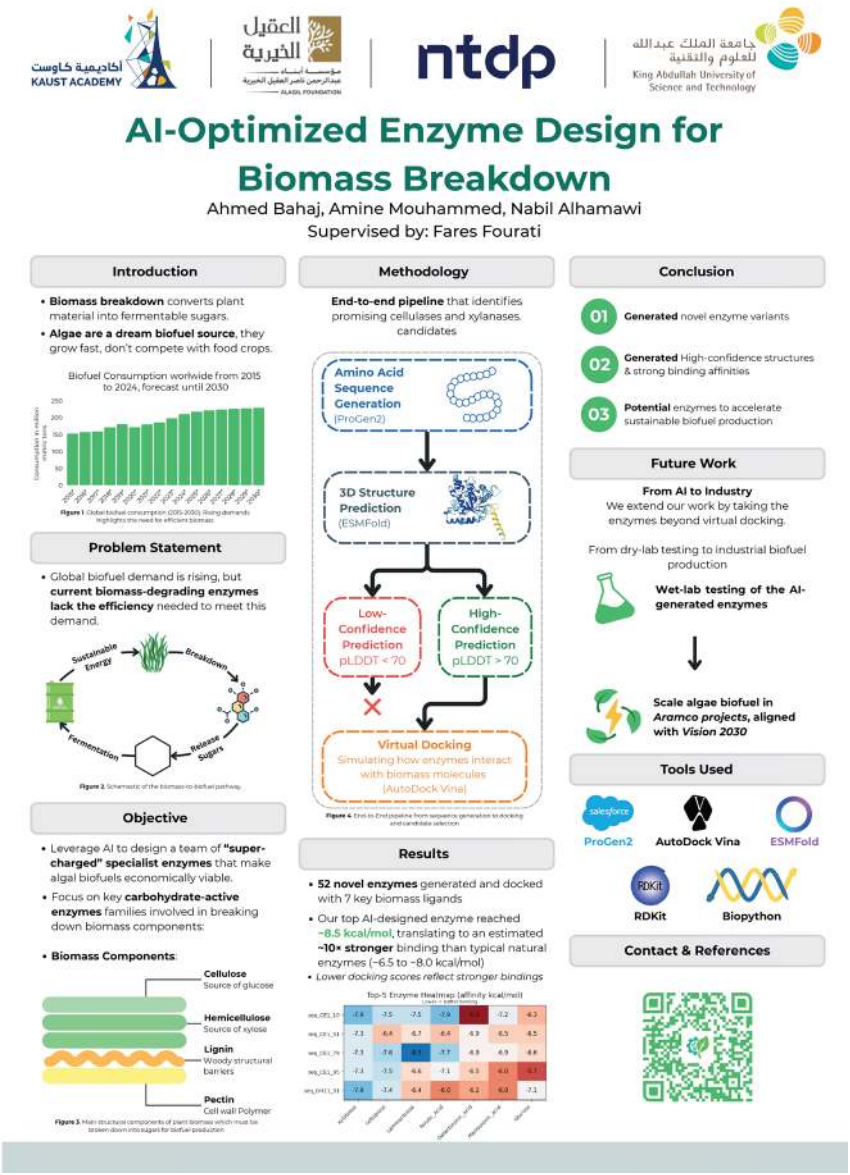


AI-OPTIMIZED ENZYME DESIGN FOR BIOMASS BREAKDOWN

Algae and aquatic plants are promising biofuel sources because they don't need farmland or freshwater and contain both sugars and oils. Unlike food crops, they avoid the food-vs-fuel conflict. But their biomass is hard to break down due to tough cell walls made of cellulose, lignin, and complex polysaccharides.Current enzymatic methods are slow and expensive — enzymes like cellulases struggle with the diverse and resistant structures in these organisms. This inefficiency adds around $0.50 per gallon of ethanol, making biofuels less competitive with fossil fuels.We are building an AI pipeline that generates novel enzyme sequences that can make the plant break-down more efficient. We will generate and evaluate those sequences using y-lab tools.

PROJECT MENTOR: Fares Fourati

PROJECT MEMBERS: Ahmed Omar Bahaj , Mouhamad Alim Alamine, Nabil Abdulkafi Alhamawi

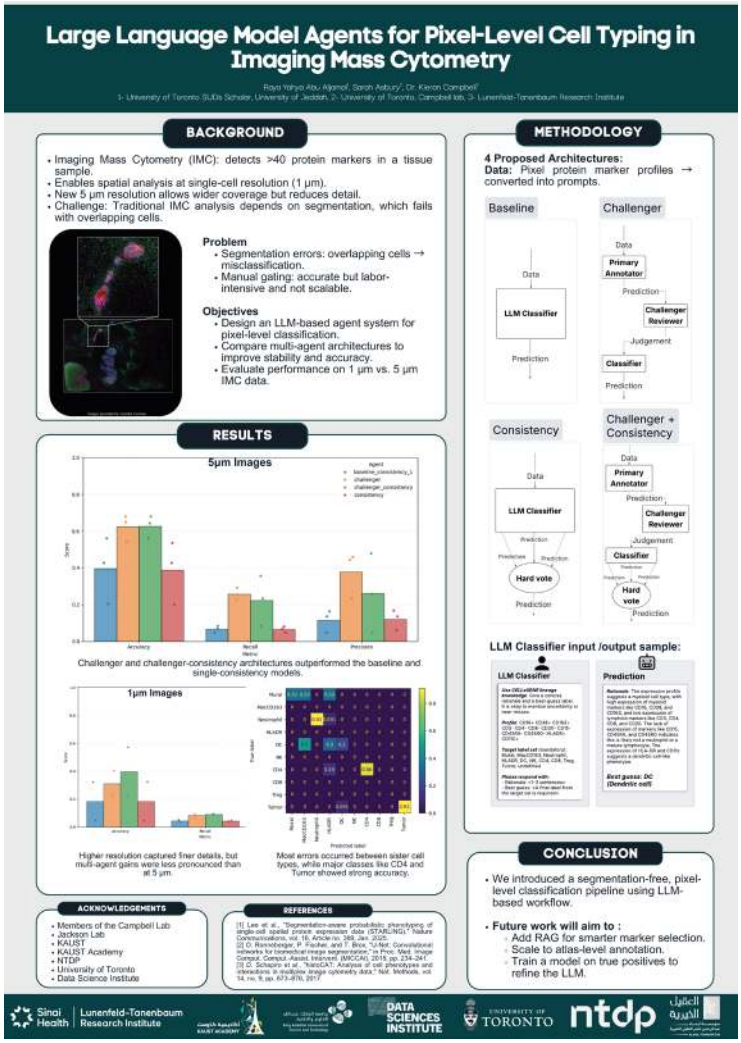


LARGE LANGUAGE MODEL AGENTS FOR PIXEL-LEVEL CELL TYPE CLASSIFICATION IN IMAGING MASS CYTOMETRY

Imaging mass cytometry enables high-dimensional protein marker detection, providing insight to the spatial and cellular heterogeneity of human tissues. Recent advances in 5 micron resolution permit high throughput tissue processing, however, traditional cell segmentation methods fail to accurately segment lower resolution IMC images. To adess this limitation, we propose a novel computational framework that implements pixel-level cell classification for segmentation-independent analysis.Our approach leverages unsupervised clustering of individual pixels based on multi-dimensional antibody expression. We have previously shown that pixel clusters can be used to distinguish positive and negative marker expression across the antibody panel, enabling detection of binary expression signatures for each pixel. Now, we aim to develop an AI agent system to classify each pixel as belonging to a specific cell type from the CELLxGENE library, mixed cell types, or constituting background noise. The antibody expression profile from pure cell pixels will be used to deconvolve the cellular composition of mixed pixel populations and remove background noise. The integration of context-aware agent systems provides a scalable and interpretable approach for biological annotation of complex, high-dimensional pixel-level spatial proteomics data.

PROJECT MENTOR: Kieran Campbell

PROJECT MEMBERS: Raya Yahya Abu Aljamal

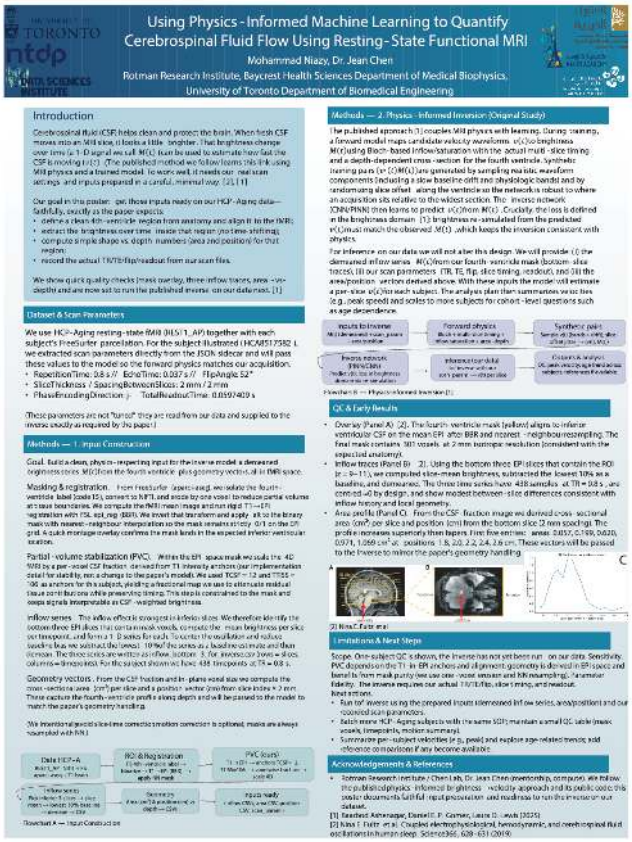


VALIDATION OF AI-GENERATED CEREBROSPINAL FLUID FLOW FROM RESTING-STATE FMRI DATA: THE EFFECT OF AGE

Cerebrospinal fluid (CSF) flow helps wash metabolic waste from the brain, which is directly related to brain health, and is known to slow with aging and in Alzheimer's disease. Disruptions in CSF flow have been linked to impaired clearance of neurotoxins such as beta-amyloid, which build up in Alzheimer's disease and may play a key role in early disease progression. Yet the current golden standard scan for measuring it, the phase-contrast MRI (PC-MRI), requires cost, time, and specialized hardware and personnel. A recent study solved this restriction by showing that the the inflow-based brightness changes seen in fast resting-state fMRI can be converted into quantitative, true CSF velocity curves using physics-informed neural network (PINN). Our project will put that method to the test on resting-state fMRI scans from the Human Connectome Project – Aging (HCP-A), covering mid-life through late adulthood, and compare its output to other flow measurements for validation. We will also examine the original model's assumptions, such as fixed CSF T1, plug-flow shape, heart-rate near 1 Hz, constant proton density, and minimal respiratory influence, to learn which ones must be adjusted, and how, for data under different environments and conditions to get comprehensible results. After some pre-processing, which includes standard slice-timing, motion, and distortion correction, we will mask the bright CSF voxels, port the published Bloch formula + PINN code, and run targeted sensitivity checks by varying each assumption in turn. We expect to reproduce the key findings from the original study, including strong agreement with PC-MRI (correlation around 0.9 and low bias), and to replicate the reported decline in peak CSF speed of about 0.02 mm/s per decade. The outcome will be a validated, low-cost pipeline for large aging cohorts that shows how to adapt the model across sites; an important step toward using fast, routine fMRI for accessible CSF monitoring in Alzheimer's research.

PROJECT MENTOR: Jean Chen

PROJECT MEMBERS: Mohammad Rami Niazy

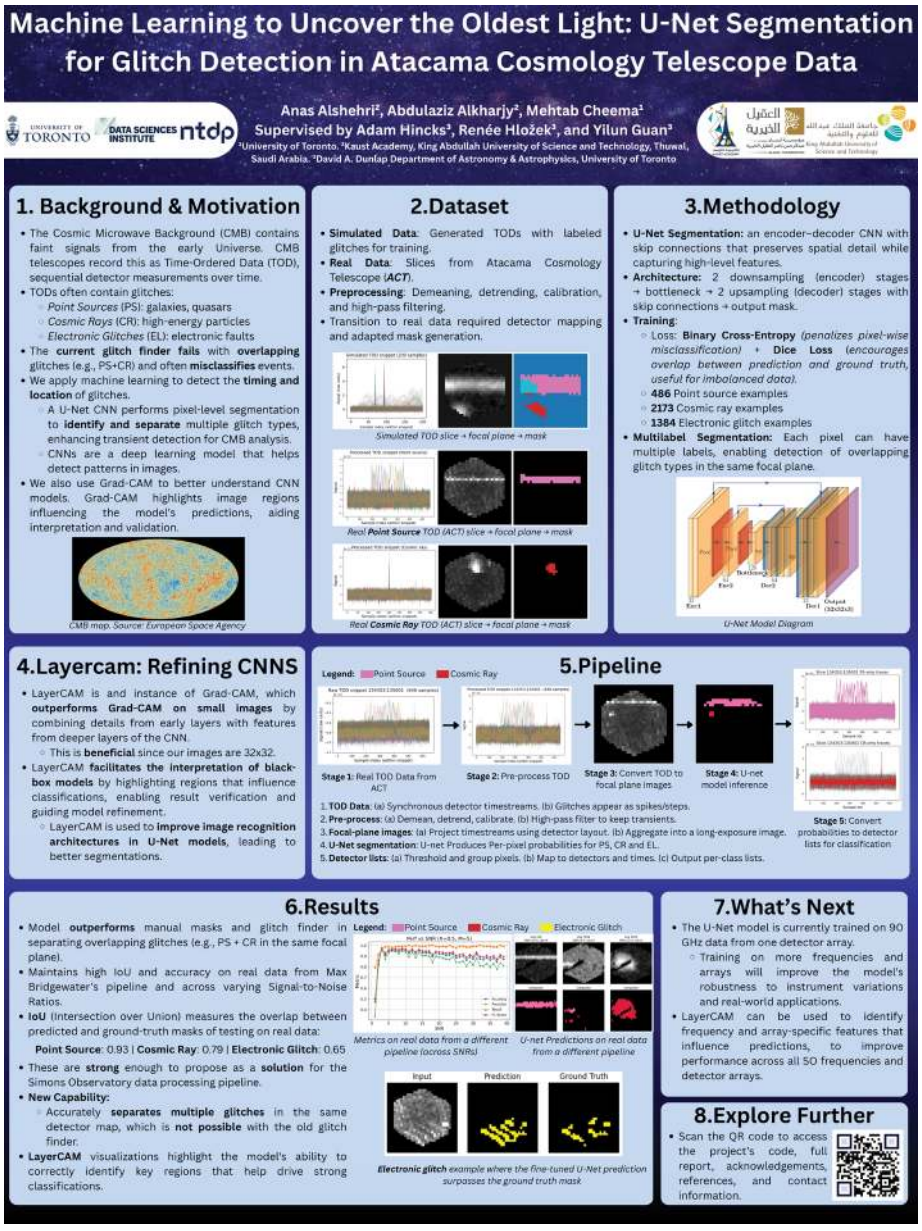


MACHINE LEARNING TO UNCOVER THE OLDEST LIGHT: U-NET SEGMENTATION FOR GLITCH DETECTION IN ATACAMA COSMOLOGY TELESCOPE DATA

The project develops and benchmarks advanced deep-learning modules that automatically clean and reconstruct the multi-terabyte timestreams recorded by the Simons Observatory and its precursor, the Atacama Cosmology Telescope. By suppressing instrumental noise and classifying foreground galaxies and stars, these models generate high-fidelity CMB maps while flagging potential astrophysical transients such as flaring stars and gamma-ray bursts. The work integrates convolutional, attention-based, and multi-modal techniques into the observatory's production data-processing pipeline, laying the groundwork for scalable, real-time analysis of petabyte-scale cosmological data.

PROJECT MENTOR: Adam Hincks

PROJECT MEMBERS: Abdulaziz Saad Alkharjy , Anas Abdulrahman Alshehri

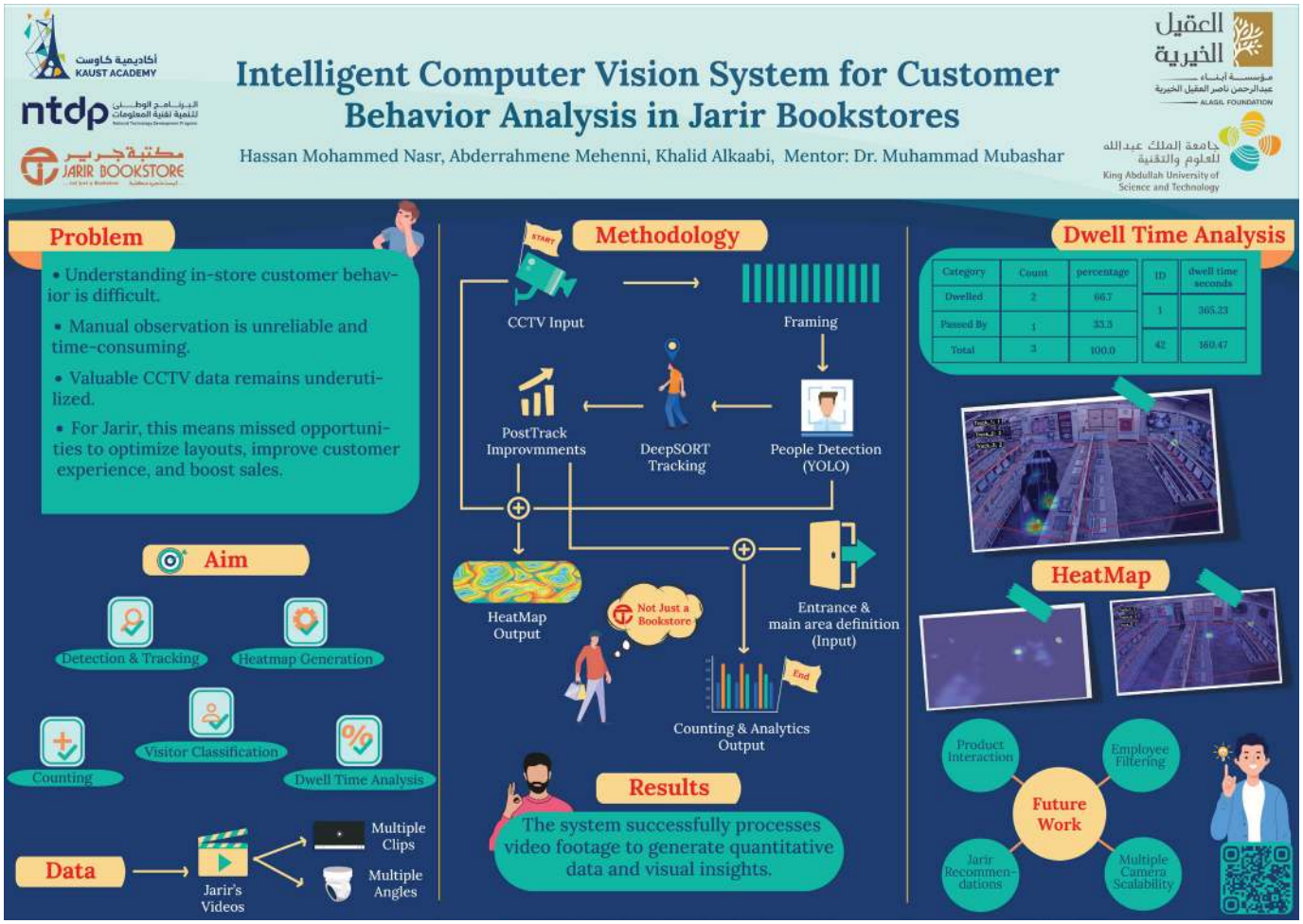


INTELLIGENT COMPUTER VISION SYSTEM FOR CUSTOMER BEHAVIOR ANALYSIS IN JARIR BOOKSTORES

The objective of this project is to analyze customer interactions by detecting and tracking both individuals and products within Jarir stores. Through advanced detection and analytical techniques, the system aims to provide insights into customer behavior and engagement patterns.

PROJECT MENTOR: Muhammad Mubashar

PROJECT MEMBERS: Abderrahmene Mehenni , Hassan Mohammed Nasr, Khalid Abdulaziz M Alkaab



DEVELOPMENT AND CHARACTERIZATION OF A "HIGH-VOLTAGE ION GENERATOR" DEVICE FOR WATER CAPTURE FROM HUMID AIR

References: an article explaining the concept (MIT): https://dspace.mit.edu/bit-stream/hand... and a video (YT "Plasma Channel") on building it: https://www.you-tube.com/watch?v=G2brxBRnRH4 Project objective: to design and build a prototype of such a device (ideally suited for possible use in desert environment), to test the feasibility of the process inside a controlled enclosure (with known humidity) and to measure its efficiency (energy used / water condensed).Background: electronic engi-neering, basic CAD modeling

PROJECT MENTOR: Carlo Fonda and Marco Baruzzo

PROJECT MEMBERS: Dina Alshehri

Development and characterization of a "high-voltage ion generator" device for water capture from humid air

Dina Alshehri
International Centre for Theoretical Physics

Background

Water scarcity: Over 1 billion people lack safe drinking water.

Fog harvesting: Traditional mesh collectors only capture ~1–2% of droplets because of aerodynamic limits.

New approach: Use electrostatic forces (via corona discharge) to charge and guide droplets to a collector, improving efficiency.

Experimental setup

The system consists of a high-voltage ion emitter and a grounded mesh collector placed inside a controlled enclosure. A humidifier simulates fog by producing fine water droplets directed toward the collector. A sealed electrical box contains the high voltage supply and is designed for safety, only requiring a power source. Two output wires connect to the emitter and ground, and a digital multimeter monitors voltage. When corona discharge occurs, the emitter ionizes the air. Fog droplets gain charge and are pulled toward the mesh by the electric field. Water droplets collected on the mesh are measured to evaluate system performance under different voltages and mesh types.

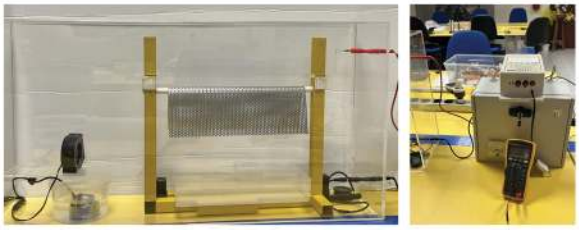


Figure 1. Fog collection setup with mesh and emitter (left) and enclosed high-voltage power system with multimeter (right)

Testing and Results

Initial trials without applying voltage showed no water collection. Once the voltage exceeded the corona discharge threshold (~12kV), droplets were visibly drawn to the mesh and water began to collect immediately.

Mesh Comparison (20 kV, 20 min):

- Mesh A: Lowest yield
- Mesh B: Moderate yield
- Mesh C: Highest yield (~50 g of water collected)

Voltage Dependence (Mesh C):

- 18 kV: Water collected at a reduced rate
- 20 kV: Peak performance
- 22 kV: No major improvement due to voltage saturation



Figure 2. Mesh A (top), Mesh B (middle), and Mesh C (bottom) used in fog collection tests.

Conclusions

The electrostatic fog collection system proved significantly more effective than passive methods. Applying high voltage enabled droplet attraction and water capture, with performance improving up to 20 kV. Mesh geometry had a clear impact, with Mesh C collecting ~50 g in 20 minutes. Results confirm that electric fields can greatly enhance fog harvesting efficiency and justify further testing under real environmental conditions.

Acknowledgments

I would like to thank Mr. Carlo Fonda and Mr. Marco Baruzzo for their guidance and support throughout this work, and the team at ICTP for providing the resources and experimental space.

References

Damak, M., & Varanasi, K. K. (2018). Electrostatically driven fog collection using space charge injection. Science Advances, 4(6), eaao5323. https://doi.org/10.1126/sciadv.aao5323

PROPAGATED GRADIENT BASED LEARNABLE DYNAMIC COMPRESSION AND ENERGY OPTIMISATION FOR EDGE AI ON MICROCONTROLLERS

ML models demand substantial computation, memory, and energy resources, hindering their deployment on edge devices with limited hardware. To tackle these constraints, we introduce a state-of-the-art technique, “S More Than You Need,” a propagated-gradient-based learnable dynamic compression method that obtains a subnetwork that performs as well as the full network, reducing size by 35× to 88× without loss of accuracy. Our method guides the gradient toward convergence, providing optimal accuracy and compact size. We reinforce our work with long-term solutions such as motion sensors to extend battery life and reduce computational load, achieving up to 90% energy savings, and lightweight communication protocols such as MQTT and LoRa. Additionally, we assess our methods on several microcontrollers, providing reliable performance across models such as LeNet, ResNet, MobileNet, and LightNN.

PROJECT MENTOR: Rytis Paškauskas

PROJECT MEMBERS: MOHAMMED S. ALZIYAD

Propagated Gradient Based Learnable Dynamic Compression and Energy Optimisation for Edge AI on Microcontrollers

MOHAMMED S. ALZIYAD
Supervised by Dr. Rytis Paskauskas

Abstract

ML models demand substantial computation, memory, and energy resources, hindering their deployment on edge devices with limited hardware [1]. To tackle these constraints, we introduce a state-of-the-art technique, “S More Than You Need,” a propagated-gradient-based learnable dynamic compression method that obtains a subnetwork performing as well as the full network, reducing size by 35× to 88× without loss of accuracy. Our method guides the gradient toward convergence, providing optimal accuracy and compact size. We reinforce our work with long-term solutions such as motion sensors to extend battery life and reduce computing load, and lightweight communication protocols such as MQTT and LoRa. Additionally, we assess our methods on several microcontrollers, providing reliable performance.

Future work

In future work, we aim to extend this approach to algorithms such as RNNs and Transformers to broaden its applicability. We will also focus on improving the robustness of the loss function and addressing the challenge of local minima to enhance model convergence.

Energy Optimisation

In power consumption optimization, we use sensors such as motion sensors and recharge the battery with a solar panel to extend the life of the microcontroller.



Figure 1. Mini PIR motion detector used for motion sensing and power optimization.

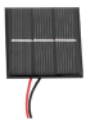


Figure 2. Solar panel used for recharging the microcontroller battery.

Methodology

Our approach modifies traditional neurons and loss functions, empowering them over the neural network.

- SNeurons: We introduce a term that acts as a binary gate, enabling the network to deactivate redundant neurons and identify an optimal subnetwork:

$$y = f(\sum_{i=1}^{n} w_i x_i + b) * H(\sigma(S))$$

- SLoss: We extend the original loss function by adding a sparsity-inducing term. During training, this loss encourages the reduction of both neuron count and task error:

$$L_{total} = L_{original} * (\frac{1}{n}\sum_{i=1}^{n} H(\sigma(S_i))) + L_{original}$$



Figure 3. SNeuron includes a term that acts as a binary gate, selecting the state of the current neuron and allowing the gradients to activate beneficial neurons.

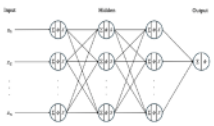


Figure 4. SNeural network works to minimize the loss function and number of neurons.

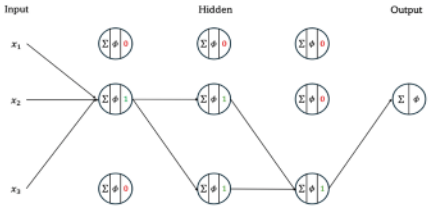


Figure 5. SNeural network used to find the optimal subnetwork of a neural network

Results

The table below shows the performance of S compression on various deep learning architectures.

Network	Accuracy	Parameters		Compression Rate	
LeNet	98.13%	44,426	170 KB		
LeNet via S	98.08%	3477	13 KB	13x	92.2%
LeNet via S	95.25%	505	1.97 KB	88x	98.86%
GN	99.9%	3,719	14.53 KB		
GN via S	99.9%	168	0.66KB	22x	95.48%
LightNN	81.09%	1,186,986	2319 KB		
LightNN via S	80.17%	214,190	418 KB	6x	81.95%

Table 1. Compression results on benchmarks

References

[1] S. S. Saha, S. S. Sandha, and M. Srivastava, “Machine Learning for Microcontroller-ClassHardware: A Review,” arXiv preprint arXiv:2205.14550, 2022.

[2] S. Heydari and Q. H. Mahmoud, “Tiny Machine Learning and On-Device Inference: A Survey of Applications, Challenges, and Future Directions,” Sensors, vol. 25, no. 10, p. 3191, 2025.

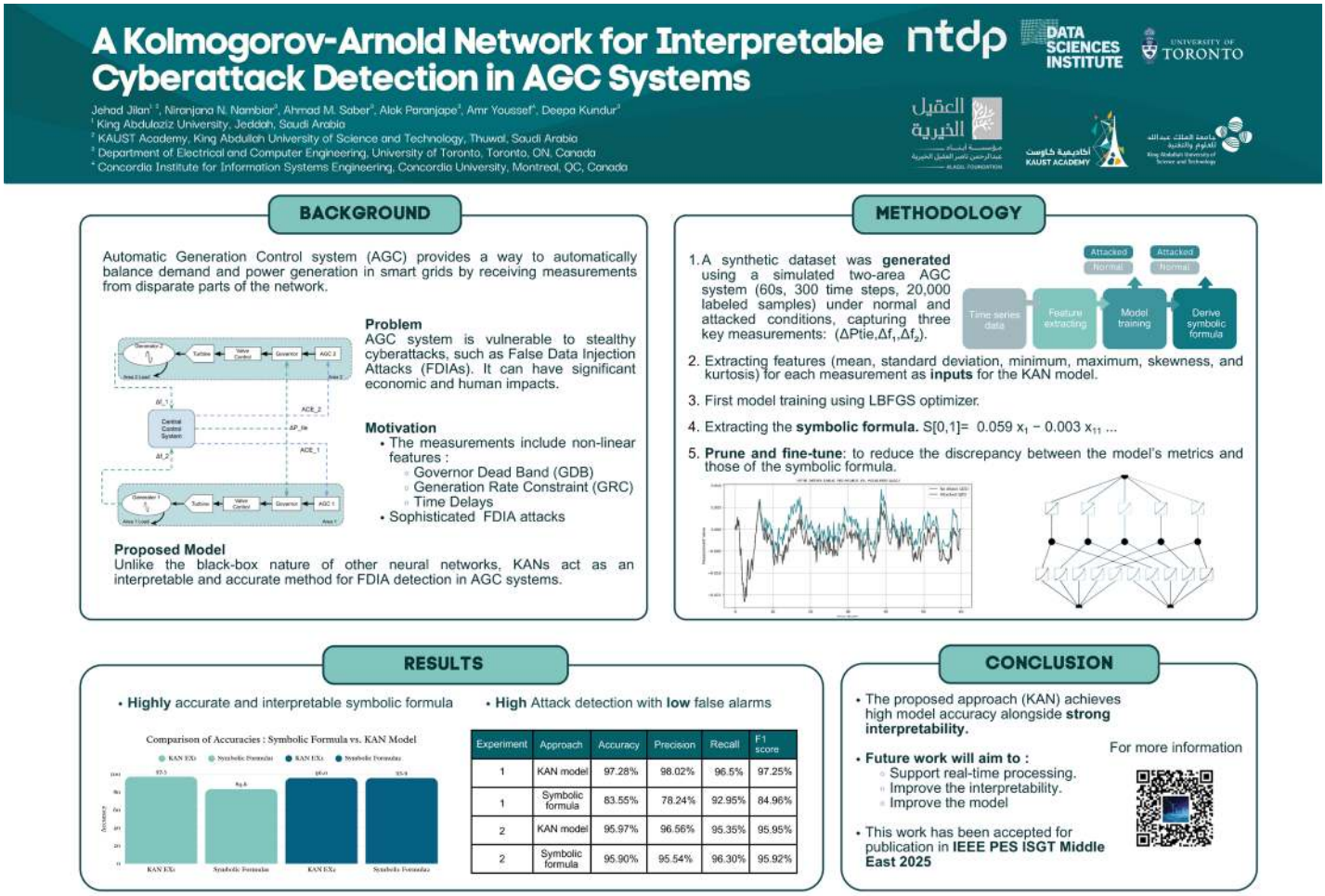
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A KOLMOGOROV-ARNOLD NETWORK FOR INTERPRETABLE CYBERATTACK DETECTION IN AGC SYSTEMS.

This project aims to explore the potential of large language models (LLMs) to adess critical challenges in smart grids, such as cyberattack detection and energy forecasting. LLMs excel not only in accuracy but also in generating explainable insights, making them valuable for complex decision-making in energy systems. The project will focus on developing LLM-based frameworks tailored to smart grid applications, emphasizing explainability to enhance trust and transparency in model predictions. Key tasks include designing models for detecting cyber threats and forecasting energy demand, as well as evaluating their ability to provide clear, actionable explanations for their outputs. Interns will gain hands-on experience in deploying and fine-tuning LLMs, applying cuttingedge AI solutions to real-world energy challenges, and enhancing cybersecurity and operational efficiency in smart grids.

PROJECT MENTOR: Deepa Kundur

PROJECT MEMBERS: Jehad Adel Jilan



CHATBOT WITH SIGN LANGUAGE RECOGNITION

Recognize sign language gestures as queries and respond. Possibly in Arabic.

PROJECT MENTOR: Muhammad Mubashar

PROJECT MEMBERS: Khamees Ebraheem Khamees Abdulla Al Hammadi, Khaled Mohammed Ali Abualrougha Alzaabi, Ohud Yahya Khubrani, Roudha Abdallah Sultan Mohammed Alalawi, Rauda Abdulqader Barakt Kal Bel Raeesi

KArSL Arabic Sign Language Chatbot

Khalid Al Zaabi, Rouda Al Alawi, Rouda Abdulqader, Ohoud Khubrani, Khamees Al Hammadi
Supervised by: Muhamed Mubasher

Abstract

Globally, millions of people suffer from hearing impairments, making daily communication a major challenge Traditional chatbots and voice assistants rely on audio, which excludes the deaf community. This project introduces an AI-based chatbot that can understand spoken words through lip-reading from images, enabling more inclusive and accessible communication.

Objectives

- Develop a real-time Arabic sign language recognition system.
- Achieve accuracy above 90% for the 502 KArSL sign vocabulary.
- Create an intuitive web-based interface accessible to all users.
- Implement both Arabic and English text output with confidence scores.
- Provide a foundation for future Arabic sign language applications.



Methodology

The system captures 30-frame sign sequences using a web camera and preprocesses them to 64×64 resolution. These sequences are processed by a 3D CNN trained on the KArSL-502 dataset, which includes 502 signs across 11 categories. Predictions are generated in real time and displayed as the top six results in both Arabic and English with confidence scores.

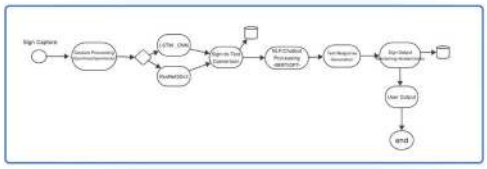


Figure (1) System Workflow.

Result

The 3D CNN model achieved 94.38% test accuracy and 96.63% Top-5 accuracy on the KArSL-502 dataset. Real-time performance was optimized with a <0.5s response time, processing 30-frame sequences at 30 FPS. The system supports 502 Arabic signs across 11 categories, displaying predictions in Arabic and English with confidence scores.

Metric	Accuracy (%)	Baseline Comparison
Training Accuracy	99.94	Excellent (>95%)
Validation Accuracy	95.50	Very Good (>90%)
Test Accuracy	94.38	Very Good (>90%)
Training Top-5	100.00	Perfect
Validation Top-5	97.69	Excellent
Test Top-5	96.63	Excellent

Figure (2) Model performance across different dataset splits.



Figure (3) The System.

Limitations

- High computational cost managed via cloud GPUs.
- Dataset inconsistencies and signer variability required robust augmentation.
- Users preferred dual-language feedback with confidence scores.
- Browser video capture issues resolved with fallback mechanisms.

Conclusion and Future work

Our KArSL system achieved 94.38% accuracy on 502 Arabic signs, enabling real-time recognition with dual-language output. Future work includes continuous sentence recognition, improved robustness to lighting, model compression for mobile deployment, and expanding vocabulary for broader accessibility.

Refrences

1] Hamzah Luqman. "An Efficient Two-Stream Network for Isolated Sign Language Recognition Using Accumulative Video Motion". In: IEEE Access 10 (2022), pp. 93785 93798.

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MORAQEB: A DISTILLED VLM ON SURVEILLANCE VQA

Distilling and fine tuning a VLM to achieve SoTA metrics on certain benchmark data-sets in the area of surveillance VQA

PROJECT MENTOR: Tanveer Hussain

PROJECT MEMBERS: Abdulelah Ali Alturki,Anas Ali Hakami,Anas Mousa Aldadi Haifa Almakhdhoub,Joori Abdullah Alsaif,Raghad Ali Alsuhaibani

Report

Moraqeb: A Distilled VLM on Surveillance VQA

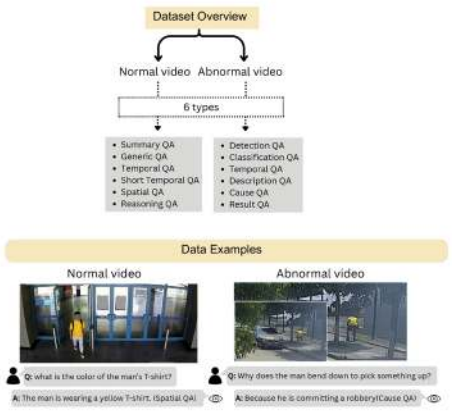
Anas Aldadi, Anas Hakami, Abdulelah Alturki, Raghad Alsuhaibani, Joori Alsaif, Haifa Almakhdhoub, **Supervised by:** Dr. Tanveer Hussain

Abstract

- **Video Vision-Language Models** (**VLMs**) with **Visual Question Answering** (**VQA**) can offer richer scene understanding in surveillance by enabling natural-language queries about dynamic scenes.
- Current research direction in Large VLMs achieves state-of-the-art results; however, deployment for **real-world surveillance systems** can be expensive and slow, due to their size, latency, or reliance on large GPU cluster.
- **Aim**: Through this project, we aim to train a large Vision Language Model and distill it into a lightweight model suitable for real-world Video Question Answering (VQA) applications.

Dataset

This project uses the Surviellance VQA-589K dataset



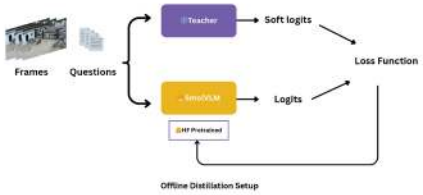
Methodology

1- Data Preprocessing : Selected the NWPU subset from SurveillanceVQA and combined videos, tracking data, and QA pairs into one set, standardized for frame extraction, QA alignment, and tracking integration.

2- Teacher Signals: The data has been produced in stages by the following models: LLaVA-Video7B-Qwen2, Qwen-Turbo, and Qwen-Max.

3- Student Model Initialization: SmolVLM2-500M-Video-Instruct, initialized with pretrained weights.

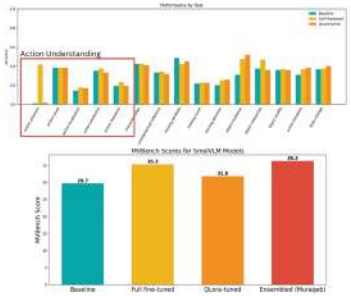
4- Offline Distillation Training: Trained the student offline on NWPU videos with QA pairs, using cross-entropy on softened labels to align predictions with teacher outputs.



5- Evaluation: Evaluated on a held-out NWPU split with generated QA pairs. Measured accuracy, latency, and compute usage, and benchmarked on MVBench and Sur-VQA.

Results & Discussion

- Our model **Muraqeb** achieves a 6.6% gain over the original student model in mean accuracy.
- Muraqeb delivers faster inference, making it practical for resource constrained surveillance enviroments.



- Muraqeb achieves score of 36.3% in mean accuracy, and 10.2% improvement in action understanding.

Future Work & Limitations

- Try online distillation for stronger student models, Refine loss function to better mimic teacher outputs.
- Train longer to boost performance on challenging tasks.
- Explore continual learning for dynamic environments.

Conclusion

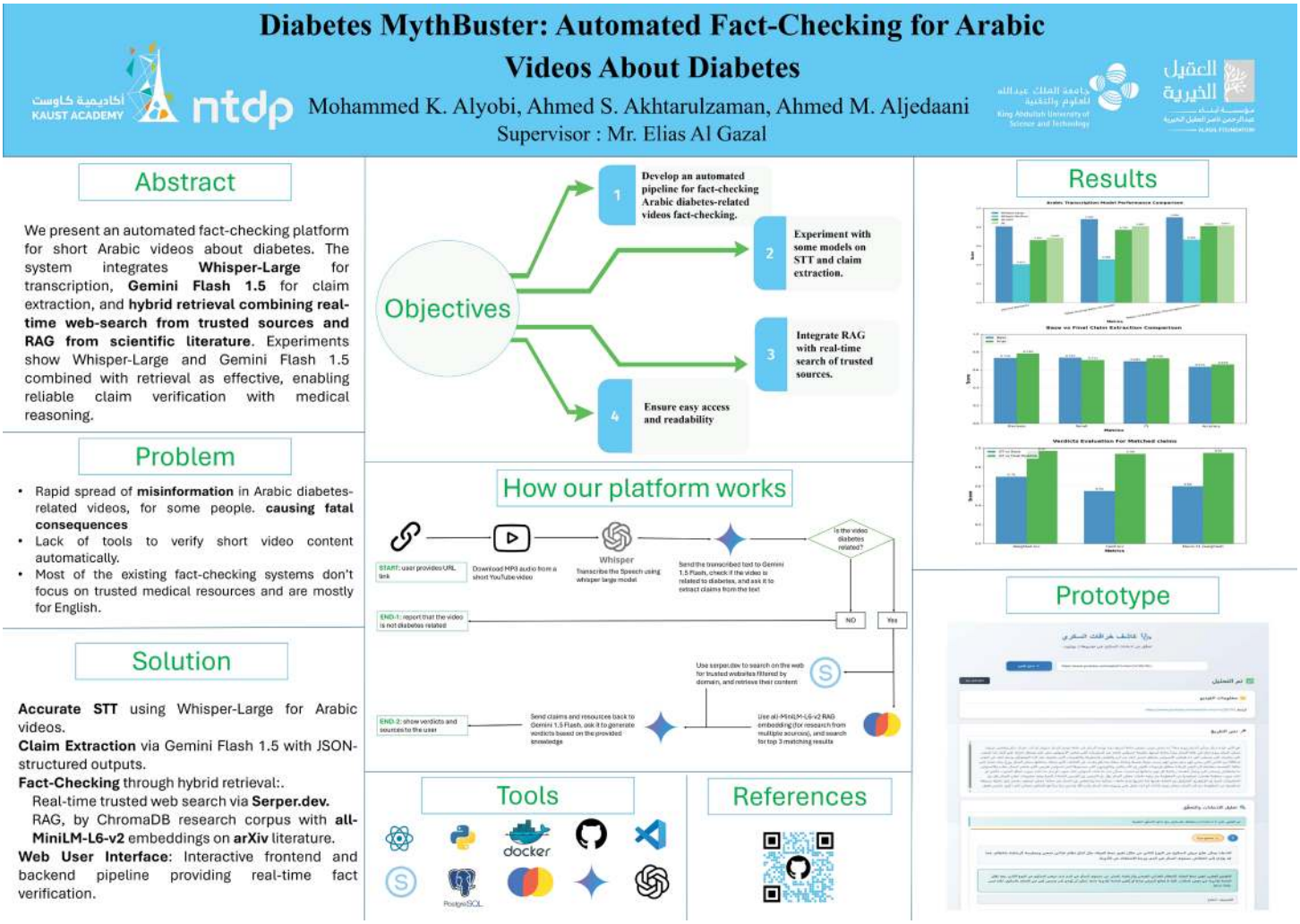
The substantial improvement Muraqeb achieved suggest that exploring different distillation techniques is a promising approach for reducing VLM sizes, GPU memory requirement, and increasing latency. This will make many video VQA tasks be cheaper, and more accessible enabling much more users to utilize these tools.

DIABETES MYTHBUSTER

This project develops an intelligent pipeline to fact-check spoken claims in Arabic medical videos, with a focus on diabetes-related content. The system automatically extracts audio, transcribes speech, and identifies factual claims. These claims are then verified using (web search and/or RAG) and large language models (LLMs), enabling real-time assessment of medical information based on trusted online sources.

PROJECT MENTOR: Elias Al Ghazal

PROJECT MEMBERS: Ahmad Meshaal Aljedaani,ahmed Saleh Ahmed Akhtarulzaman, Mohammed Khalid Alyobi

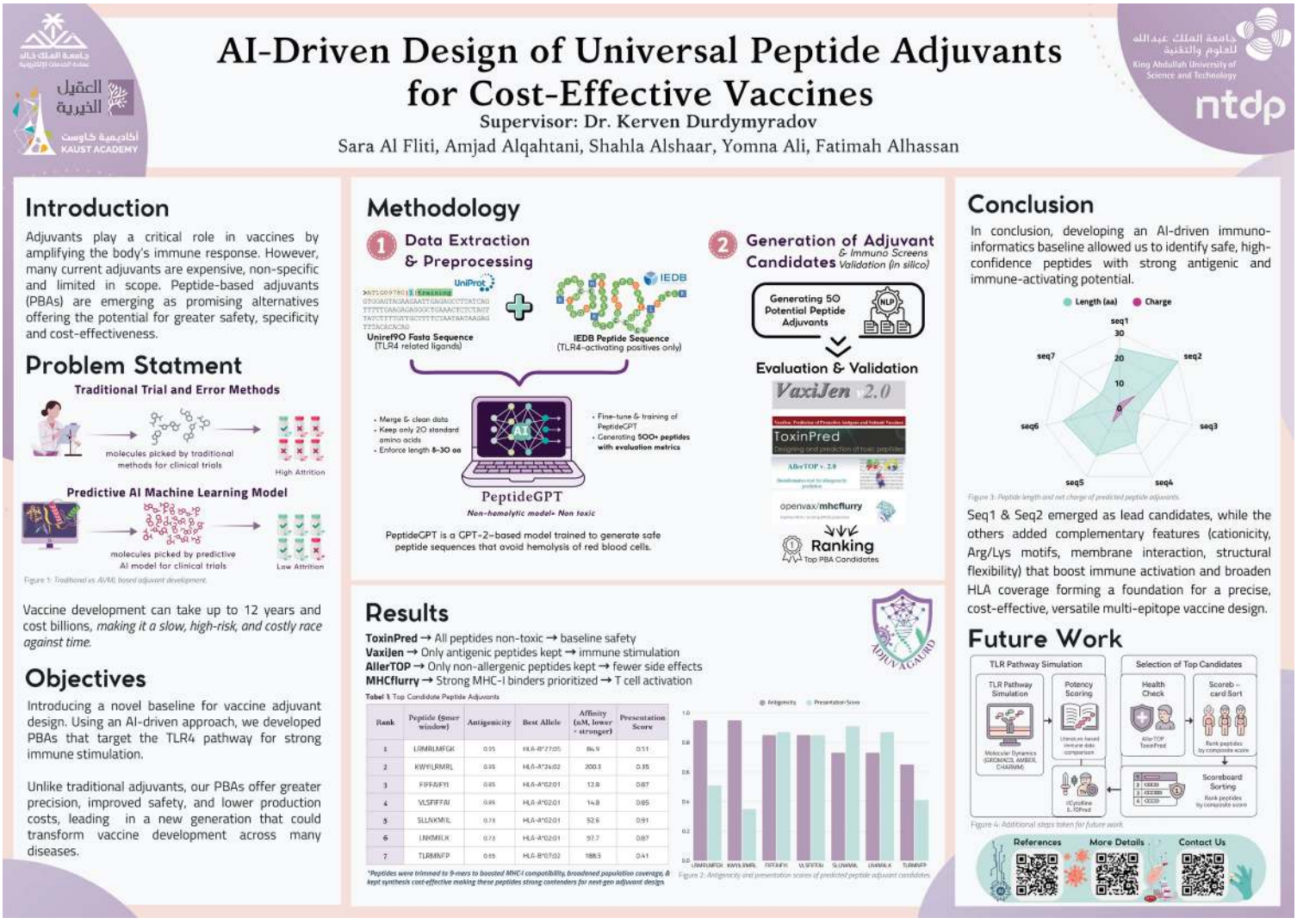


AI-DRIVEN DESIGN OF UNIVERSAL PEPTIDE ADJUVANTS FOR COST-EFFECTIVE VACCINES

This project aims to develop an AI-driven platform for the design of novel peptide adjuvants that enhance vaccine efficacy. By leveraging publicly available immunological data and machine learning techniques, the platform seeks to reduce development costs by over 80% and improve vaccine accessibility, particularly in low-resource and underserved regions.

PROJECT MENTOR: Kerven Durdymyradov

PROJECT MEMBERS: Amjad Jaber Alqahtani,Fatimah Abdulaziz Nasser Alhassan Sara Al Fliti, Shahla Assem Alshaar , Yomna Mohammad Elmohammady Ali

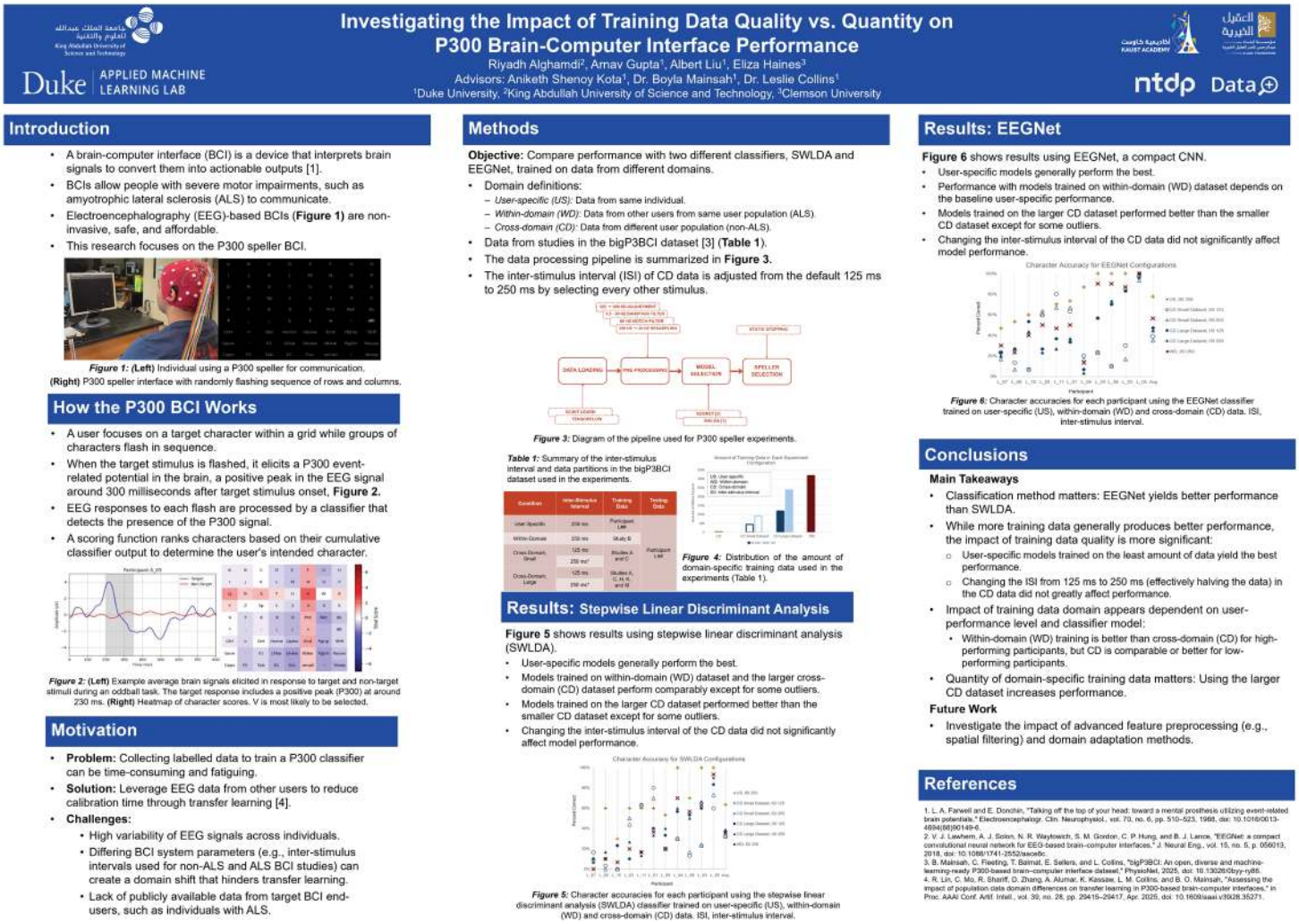


EXPLORING NOVEL MACHINE LEARNING TECHNIQUES FOR BRAIN-COMPUTER INTERFACE (BCI) APPLICATIONS

A team of researchers associated with the Applied Machine Learning Laboratory will lead a team of students in developing novel machine learning techniques that will be used for improving brain computer interfaces (BCIs) using electroencephalography (EEG) data. Students will learn how to pre-process EEG data, extract EEG features, and train machine learning algorithms for character selection in a spelling interface that allows "locked in" individuals, like Stephen Hawking, to communicate with the outside world. In addition to developing machine learning

PROJECT MENTOR: Aniketh Shenoy Shenoy Kota, Boyla Mainsah, Leslie M Collins

PROJECT MEMBERS: Riyadh Abdullah Alghamdi



Investigating the Impact of Training Data Quality vs. Quantity on P300 Brain-Computer Interface Performance

Riyadh Alghamdi[2], Arnav Gupta[1], Albert Liu[1], Eliza Haines[3]
Advisors: Aniketh Shenoy Kota[1], Dr. Boyla Mainsah[1], Dr. Leslie Collins[1]
[1]Duke University, [2]King Abdullah University of Science and Technology, [3]Clemson University

Duke APPLIED MACHINE LEARNING LAB

Introduction

- A brain-computer interface (BCI) is a device that interprets brain signals to convert them into actionable outputs [1].
- BCIs allow people with severe motor impairments, such as amyotrophic lateral sclerosis (ALS) to communicate.
- Electroencephalography (EEG)-based BCIs **(Figure 1)** are non-invasive, safe, and affordable.
- This research focuses on the P300 speller BCI.

Figure 1: **(Left)** Individual using a P300 speller for communication. **(Right)** P300 speller interface with randomly flashing sequence of rows and columns.

How the P300 BCI Works

- A user focuses on a target character within a grid while groups of characters flash in sequence.
- When the target stimulus is flashed, it elicits a P300 event-related potential in the brain, a positive peak in the EEG signal around 300 milliseconds after target stimulus onset, **Figure 2.**
- EEG responses to each flash are processed by a classifier that detects the presence of the P300 signal.
- A scoring function ranks characters based on their cumulative classifier output to determine the user's intended character.

Figure 2: **(Left)** Example average brain signals elicited in response to target and non-target stimuli during an oddball task. The target response includes a positive peak (P300) at around 230 ms. **(Right)** Heatmap of character scores. V is most likely to be selected.

Motivation

- **Problem:** Collecting labelled data to train a P300 classifier can be time-consuming and fatiguing.
- **Solution:** Leverage EEG data from other users to reduce calibration time through transfer learning [4].
- **Challenges:**
  - High variability of EEG signals across individuals.
  - Differing BCI system parameters (e.g., inter-stimulus intervals used for non-ALS and ALS BCI studies) can create a domain shift that hinders transfer learning.
  - Lack of publicly available data from target BCI end-users, such as individuals with ALS.

Methods

Objective: Compare performance with two different classifiers, SWLDA and EEGNet, trained on data from different domains.

- Domain definitions:
  - *User-specific (US):* Data from same individual.
  - *Within-domain (WD):* Data from other users from same user population (ALS).
  - *Cross-domain (CD):* Data from different user population (non-ALS).
- Data from studies in the bigP3BCI dataset [3] **(Table 1)**.
- The data processing pipeline is summarized in **Figure 3.**
- The inter-stimulus interval (ISI) of CD data is adjusted from the default 125 ms to 250 ms by selecting every other stimulus.

Figure 3: Diagram of the pipeline used for P300 speller experiments.

Table 1: Summary of the inter-stimulus interval and data partitions in the bigP3BCI dataset used in the experiments.

Condition	Inter-Stimulus Interval	Training Data	Testing Data
User-Specific	250 ms	Participant Left	
Within-Domain	250 ms	Study B	
Cross-Domain, Small	125 ms 250 ms	Studies A and C	Participant Left
Cross-Domain, Large	125 ms 250 ms	Studies A, C, H, S, and M	

Figure 4: Distribution of the amount of domain-specific training data used in the experiments (Table 1).

Results: Stepwise Linear Discriminant Analysis

Figure 5 shows results using stepwise linear discriminant analysis (SWLDA).

- User-specific models generally perform the best.
- Models trained on within-domain (WD) dataset and the larger cross-domain (CD) dataset perform comparably except for some outliers.
- Models trained on the larger CD dataset performed better than the smaller CD dataset except for some outliers.
- Changing the inter-stimulus interval of the CD data did not significantly affect model performance.

Figure 5: Character accuracies for each participant using the stepwise linear discriminant analysis (SWLDA) classifier trained on user-specific (US), within-domain (WD) and cross-domain (CD) data. ISI, inter-stimulus interval.

Results: EEGNet

Figure 6 shows results using EEGNet, a compact CNN.

- User-specific models generally perform the best.
- Performance with models trained on within-domain (WD) dataset depends on the baseline user-specific performance.
- Models trained on the larger CD dataset performed better than the smaller CD dataset except for some outliers.
- Changing the inter-stimulus interval of the CD data did not significantly affect model performance.

Figure 6: Character accuracies for each participant using the EEGNet classifier trained on user-specific (US), within-domain (WD) and cross-domain (CD) data. ISI, inter-stimulus interval.

Conclusions

Main Takeaways

- Classification method matters: EEGNet yields better performance than SWLDA.
- While more training data generally produces better performance, the impact of training data quality is more significant:
  - User-specific models trained on the least amount of data yield the best performance.
  - Changing the ISI from 125 ms to 250 ms (effectively halving the data) in the CD data did not greatly affect performance.
- Impact of training data domain appears dependent on user-performance level and classifier model:
  - Within-domain (WD) training is better than cross-domain (CD) for high-performing participants, but CD is comparable or better for low-performing participants.
- Quantity of domain-specific training data matters: Using the larger CD dataset increases performance.

Future Work

- Investigate the impact of advanced feature preprocessing (e.g., spatial filtering) and domain adaptation methods.

References

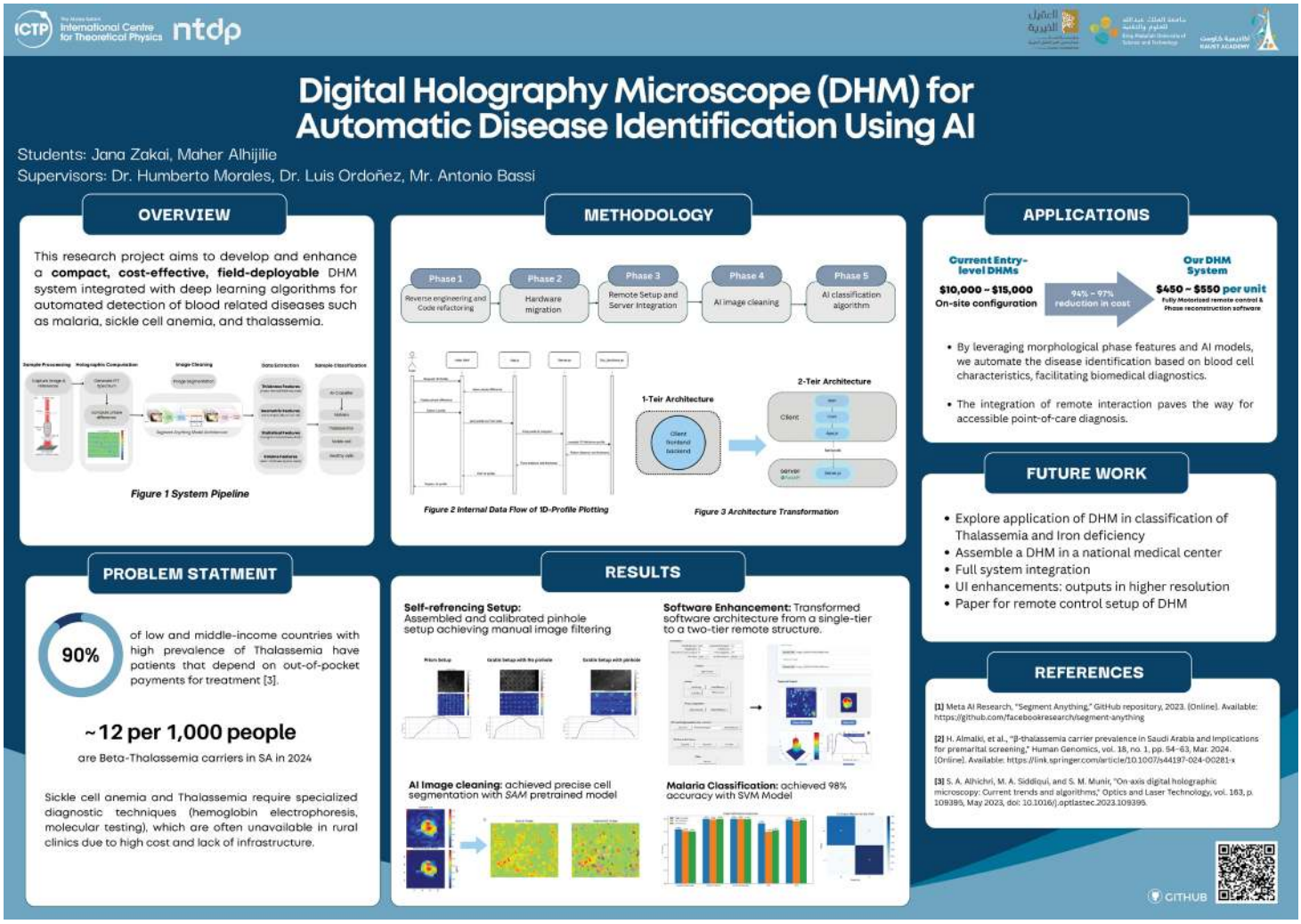
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DIGITAL HOLOGRAPHY MICROSCOPE (DHM) FOR AUTOMATIC DISEASE IDENTIFICATION USING AI

By leveraging DHM, automated, high-precision and cost-effective diagnostic solutions can be developed for diseases affecting millions worldwide, enhancing healthcare accessibility in resource-limited settings. This project proposes the design, development, fabrication, testing, and validation of a compact, cost-effective, low-cost-per-test, field deployable DHM coupled to a trained ML model for remote label-free automated point-of-care disease diagnosis. The features obtained from DHM can be used to train ML algorithms aiding in the detection of malaria, sickle cell anemia, and thalassemia.

PROJECT MENTOR: Humberto Cabrera

PROJECT MEMBERS: Jana Ghassan Zakai, Maher Saad Alhejaili

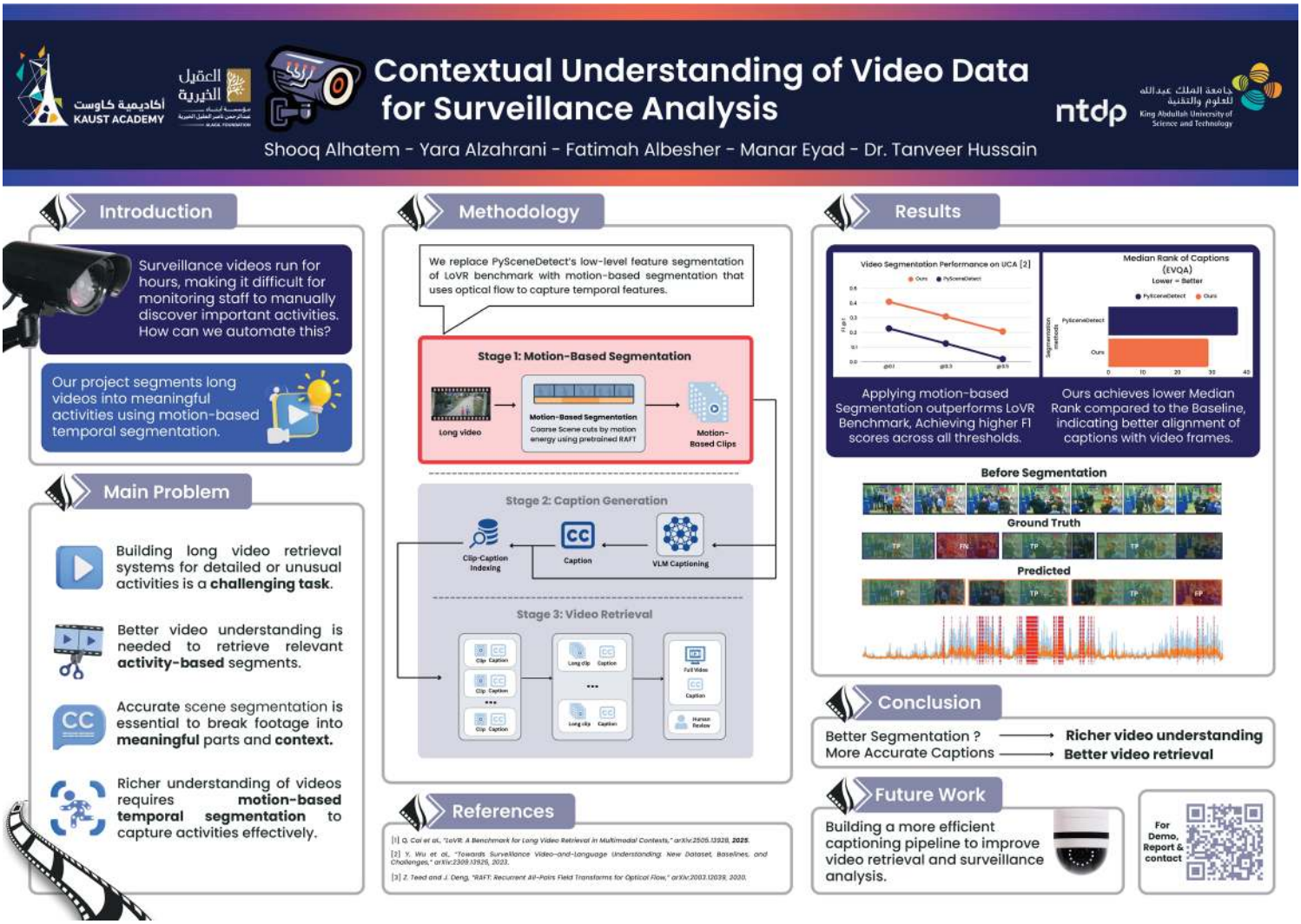


CONTEXTUAL UNDERSTANDING OF VIDEO DATA FOR SURVEILLANCE ANALYSIS

This project proposes a content-iven pipeline for analyzing surveillance videos by segmenting long streams into semantically meaningful, action-centered clips. Leveraging motion cues and object-level understanding, the system enables efficient indexing and retrieval of relevant events using natural-language queries, supporting intelligent surveillance analysis..

PROJECT MENTOR: Tanveer Hussain

PROJECT MEMBERS: Shooq tareq alhatem, Fatimah Nasser Ali Albesher, Manar Eyad Abdulrahman Ali, Yara Alzahrani



AI-POWERED DISCOVERY OF COUNTEREXAMPLES IN DISCRETE MATHEMATICS

This project uses reinforcement learning to discover counterexamples in discrete mathematics, the aim is to automate the search process and assist in identifying flaws in mathematical conjectures.

PROJECT MENTOR: Raymond Sun (under the supervision of Fan Wei)

PROJECT MEMBERS: Yasir Abdullah Alhasaniyyah

AI-Powered Discovery of Counterexamples in Combinatorics

Yasir Alhasaniyyah, Iurii Beliaev, Robert Sun, Thomas Kidane, Kevin Wang, Kate Newbold
Fan Wei
Duke University / KAUST Academy

Project Overview

Our research leverages **machine learning and computational search** to tackle **long-standing open problems in mathematics**. By reframing conjectures as optimization or search problems, we explore vast possibility spaces to hunt for elusive **counterexamples**.
We focus on:
- **Sidorenko's Conjecture**
- **Second Neighborhood Conjecture**
- **EFX vs MM allocations**

Our methods (Reinforcement Learning, Adaptive Monte Carlo Search, Evolutionary Search) yield **new insights**, computational frameworks, and verified counterexamples in fair division.

Research Problem

- **Sidorenko's Conjecture:** Every bipartite graph H satisfies $t(H,G) \geq t(K_2,G)^{|E(H)|}$. Open for certain graphs (e.g. Möbius ladders).
- **Second Neighborhood Conjecture:** In every oriented graph, at least one vertex has $|N^{++}(v)| \geq |N^{+}(v)|$.
- **Fair Division (EFX vs MM):** Investigate compatibility between **Envy-Freeness up to any item (EFX)** and the **Maximin (MM) allocation**.

Methodology

We translate abstract conjectures into computational search tasks:
Reinforcement Learning (RL): Agents "build" candidate counterexamples step-by-step, guided by reward functions.
Adaptive Monte Carlo Search (AMCS): Fast local optimization with outer loops to escape local maxima.
Hybrid RL + AMCS: RL finds promising regions, AMCS refines them.
Evolutionary Search: Random valuation matrices evolved by mutation → identifies **hard cases** in fair division.

Results

Sidorenko's Conjecture
- **No counterexamples found** up to tested graph sizes.
- Hybrid RL+AMCS significantly outperformed RL or AMCS alone.
- Example: Hybrid reduced Sidorenko Gap to $6.08\ x\ 10^{-15}$ *vs* 10^{-8} with RL.
- Optimization shows matrices converge toward uniform structure → supporting evidence for conjecture's validity.

Second Neighborhood Conjecture
- Initial searches produced trivial sink vertices.
- Adjusted reward functions enforced higher out-degrees.
- Best-performing graphs:
  - Dense cores, sparse peripheries.
  - At least one vertex with a very large second neighborhood.
- Interactive **Streamlit app** highlights Seymour vertices (red) for exploration.

EFX vs MM Allocations
- **Found counterexamples** where MM ≠ EFX.
- Counterexamples persist even when all agents share the same ranking of items.
- Structural patterns:
  - **Competitive goods:** few items valued highly by multiple agents.
  - **Spiky preferences:** one agent with sharp peaks in valuations.
- **Distance metrics** (swap distance, Euclidean, Hamming) quantify "how far" MM allocations are from EFX.

Example of a Counterexample Valuation Matrix

	Item 1	Item 2	Item 3	Item 4	Item 5
Agent A	94	18	12	13	2
Agent B	95	11	12	14	13
Agent C	7	9	19	3	18

Only Relative MM Allocation	EFX Allocation (Optimized for Min)
Agent a: {2,3,4} (30.94% total utility)	Agent a: {2,4} (22.30% total utility)
Agent b: {1} (65.52% total utility)	Agent b: {1} (65.52% total utility)
Agent c: {5} (32.14% total utility)	Agent c: {3,5} (66.07% total utility)

Tools Developed

- **Graph homomorphism counting library** (DP + tree decomposition, extended to graphons).
- Graph attention networks (GATs) to **approximate homomorphism densities.**
- **Interactive graph editor** for Second Neighborhood Conjecture exploration.

Conclusions

- AI methods **reveal structural insights** into longstanding conjectures.
- Hybrid RL+AMCS: best approach for Sidorenko search.
- Evolutionary search: powerful for **fair division counterexamples**.
- Even when conjectures hold, AI tools help uncover *why* they are robust.

Future Work

- Use RL agents as **smarter hunters** for counterexamples.
- Develop **repair algorithms** to adjust MM allocations into EFX.
- Extend framework to other open conjectures in combinatorics.

Report

Host University

Duke UNIVERSITY

Sponsors

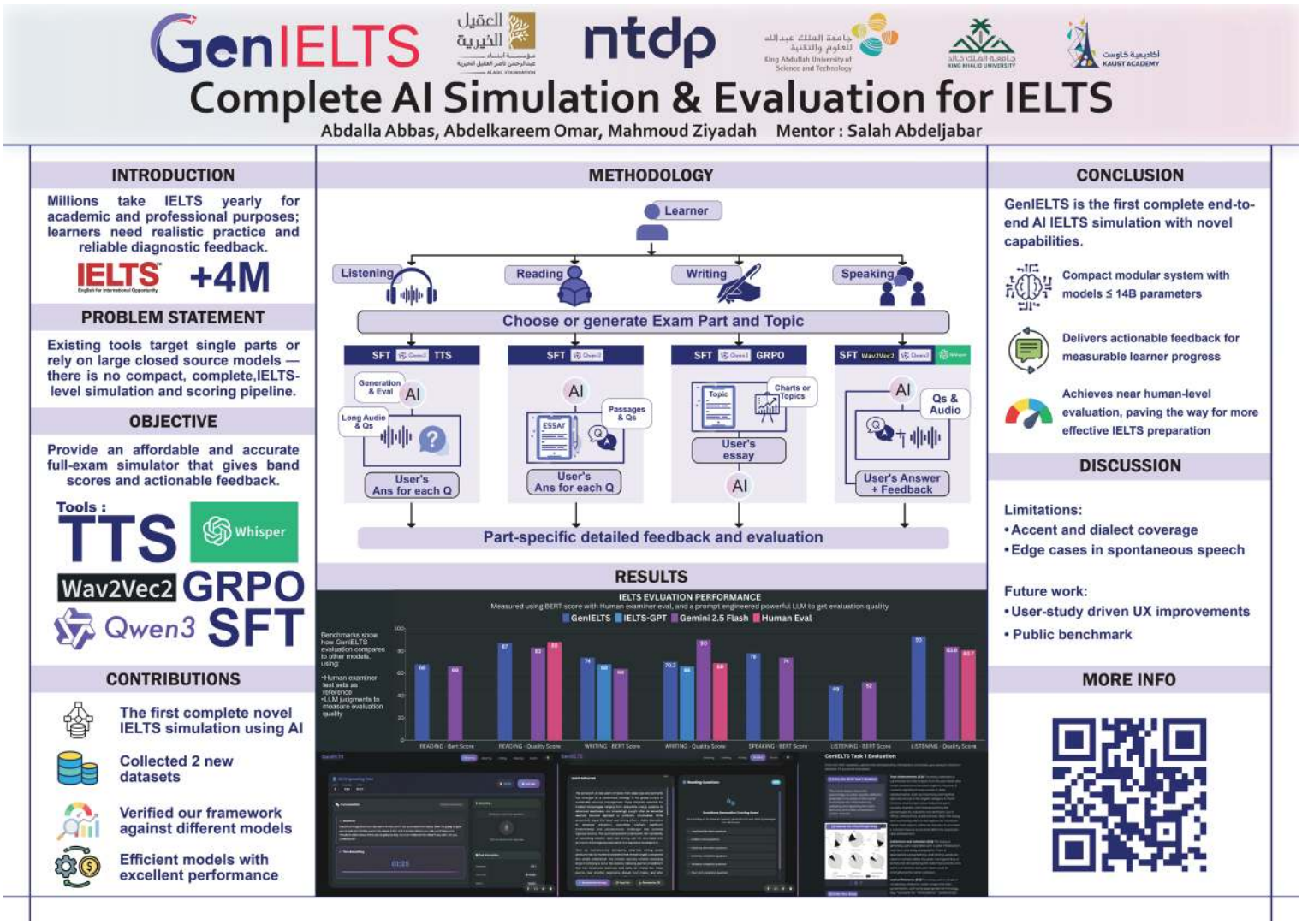
ntdp العقيل الخيرية

GENIELTS

AI aided education and language training to help students prepare for the IELTS exam

PROJECT MENTOR: Salah Abdeljabar

PROJECT MEMBERS: Abdalla Abbas Abdelrahman, Abdulkareem Abdulgadir Omer, Mahmoud Omar Ziyadeh

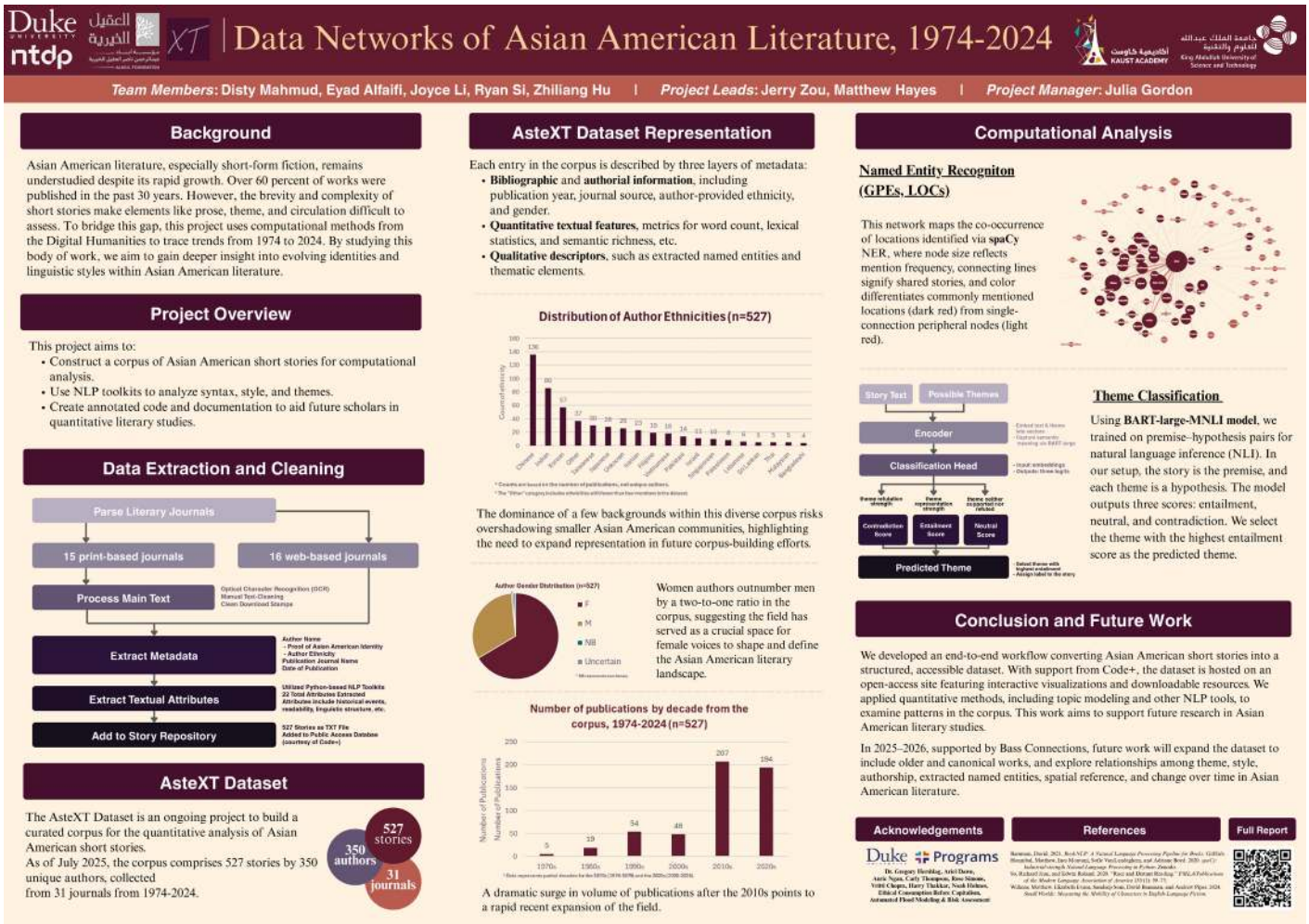


DATA NETWORKS OF ASIAN AMERICAN LITERATURE, 1974-2024

A team of students will collaborate with a doctoral fellow in Computational Humanities and the Asian American Studies Librarian to develop a statistics-based Natural Language Processing toolkit to study the linguistic styles of Asian American short stories published between 1974 and 2024. This toolkit will support historians, literary scholars, and humanities researchers in general who wish to conduct computational or quantitative literary research. The toolkit will include an annotated code bank that handles textual data and Natural Language Processing, documentation of best practices in quantitative literary research, and case studies. The team will design and create this toolkit by combining a foundational understanding of this body of literature with Natural Language Processing techniques gained over the summer. The work of this team may result in the release of a major open-access program or software, research website, or publication.

PROJECT MENTOR: Zhihui (Jerry) Zou

PROJECT MEMBERS: Eyad Ahmed Alfaifi

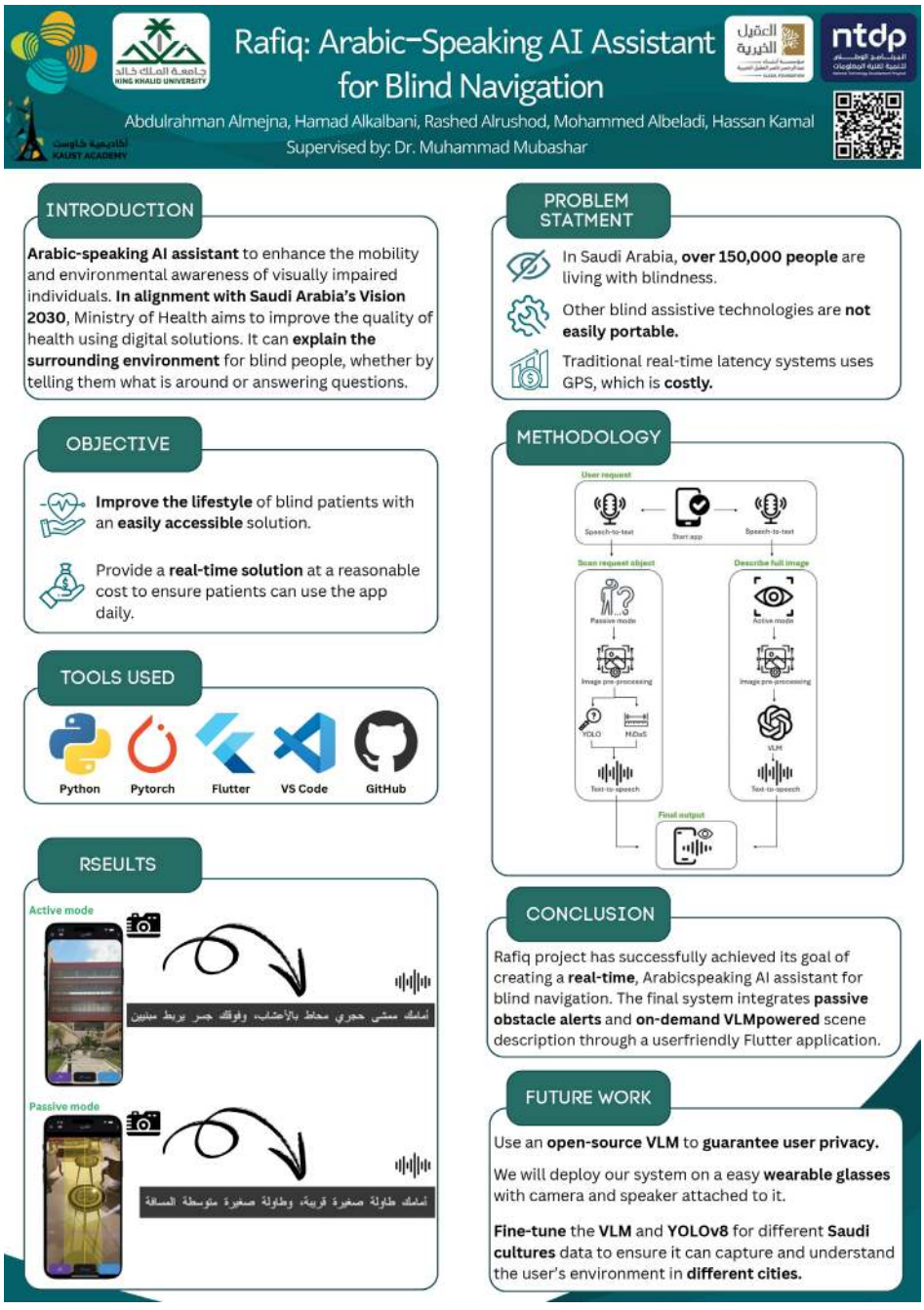


ACCESSIBILITY ASSISTANT FOR THE VISUALLY IMPAIRED

Chatbot which uses camera and microphone input to describe surroundings, read signs, and respond to commands.

PROJECT MENTOR: Muhammad Mubashar

PROJECT MEMBERS: Abdulrahman Mohammed Almejna, Hamad Mohammed Alkalbani, Hasan Shahid Kamal, Mohammed Yusif Al Belad, Rashed Mubarak Alrushud.



INTERPRETABLE MULTITASK LEARNING WITH KOLMOGOROV–ARNOLD NETWORKS FOR MENTAL HEALTH COMORBIDITY PREDICTION.

Mental health disorders often co-occur, a phenomenon known as comorbidity, posing significant challenges to accurate diagnosis and personalized treatment. Traditional machine learning approaches for comorbidity prediction frequently operate as black-box models, limiting their clinical applicability due to a lack of interpretability. This project aims to adess this gap by developing an interpretable multitask learning framework using Kolmogorov–Arnold Networks (KANs) for predicting mental health comorbidities. By integrating KANs into a multitask learning setting, the proposed framework will simultaneously predict multiple mental health conditions (e.g., depression, sleep, anxiety) while capturing their shared underlying patterns and specific risk factors.

PROJECT MENTOR: Mai Ali

PROJECT MEMBERS: Farah Ahmad Alshiha

INTERPRETABLE MENTAL HEALTH

Multitask Learning with Kolmogorov–Arnold Networks for Mental Health Comorbidity Prediction

Farah Alshiha – Department of Electrical & Computer Engineering – University of Toronto
Supervisors: Prof. Deepa Kundur and Mai Ali – Department of Electrical & Computer Engineering

BACKGROUND

Depression affects around 15% of individuals aged 10–19 and often co-occurs with other mental health disorders. Traditional predictive models like the Multi-layer Perceptron (MLP) face **interpretability challenges** and often **overlook shared patterns** across related conditions. This is where KANs come in.



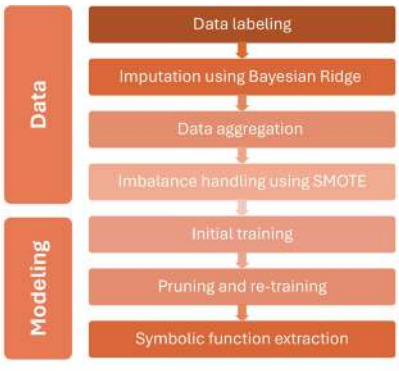
The black box problem

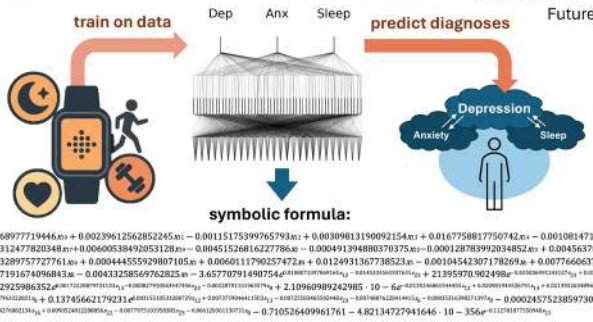
OBJECTIVE

1. Preprocess two Fitbit datasets from the NetHealth Project including longitudinal activity and sleep measures
2. Develop a Multitask Kolmogorov– Arnold Network (KAN)
3. Predict depression while jointly modeling anxiety and sleep disturbance, using the loss function:

$$\mathcal{L}_{\text{total}} = \mathcal{L}_M + \lambda(\mathcal{L}_{A_0} + \mathcal{L}_{A_0})$$

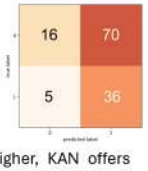
METHODOLOGY





RESULTS

	Single Task	Multitask
MLP	0.660	0.683
KAN	0.503	0.532



While MLP **balanced accuracy** is generally higher, KAN offers three formulas for all tasks, showing what features played an important role in its decision-making. The top three important features for depression were minutes after waking up, time out of bed, and sedentary minutes

CONCLUSION

Why the low accuracy? This is largely due to the imbalance in the dataset, but KANS are promising for the future of XAI.

Future studies can focus on the following:

- Different KAN library implementations
- Better processed datasets

With symbolic formulas extracted from KANs, clinical practice will involve more trust and accountability in justifiable diagnoses.

ACKNOWLEDGMENTS

This project is supported by the KAUST Academy and ntdp. A special thank you to my supervisors for their guidance.

REFERENCES

Z. Liu *et al.*, "KAN: Kolmogorov-Arnold Networks," *arXiv (Cornell University)*, Apr. 2024, doi: https://doi.org/10.48550/arxiv.2404.19756.

BUILDING HONEYPOTS TO TRACK AI WEB SCRAPERS

Building tools to analyze web scraping at scale based on analysis of Duke's web logs. Investigating the time-scale of AI data scraping and influence of different scrapers by planting content "honeypots" online. Using machine learning techniques like clustering and classification to identify spoofing bots.

PROJECT MENTOR: Emily Wenger

PROJECT MEMBERS: Hamza K. Ayfan

Building Honeypots to Track AI Web Scrapers

Researchers: Hamza, Eva, Adonias, James, and Zini
Project Manager: Cindy Gao

Problem Setting

Scrapers: Bots or users that parse websites to extract data.

Spoofers: Bots or users that lie about their online identity.



* **Lookup** IP owner info in the American Registry for Internet Numbers.

Goal: to analyze scraper behavior, detect spoofing instances and collect ground truth data.

Methodology:

EDA → Honeypots → Classification → Conclusion

About The Data:



1. Exploratory Data Analysis

Goal: Identify patterns in bot behavior

Method: HDBSCAN – density-based algorithm

Results: We found a user agent string that had a misspelling of the **"Mozilla"** token, suggesting that this was **manually** entered. After informal research, we concluded this user agent belongs to a **malicious bot**. Using this as our first labeled spoofer, we used it to enrich our classification.



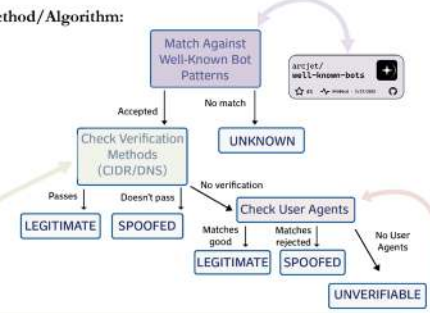
Mozlila/5.0 (Linux; Android 7.0; **SM-G892A** Bulid/NRD90M; wv) AppleWebKit/537.36 (KHTML, like Gecko) Version/4.0 **Chrome/60.0.3112**

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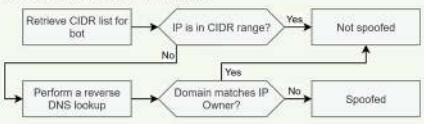
2. Honeypots

Goal: Collect ground truth data on spoofing with honeypot sites, logging hits with metadata such as IP, ASN, and user-agent.

Method/Algorithm:



CIDR/DNS Check Breakdown:



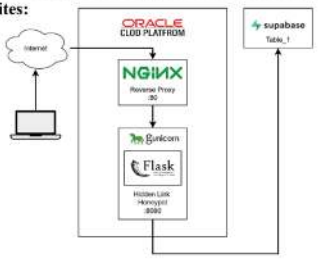
User Agent Matching Test Breakdown:

$$F = \{\text{products, urls, domains, tokens}\}$$
$$w_{product} = 0.5,\ w_{url} = 0.4,\ w_{domain} = 0.4,\ w_{token} = 0.2$$
$$J_f = \left|S_f^{(1)} \cap S_f^{(2)}\right| / \left|S_f^{(1)} \cup S_f^{(2)}\right|$$

where $S_f^{(1)}$ and $S_f^{(2)}$ are sets of tokens of the test and known UAs respectively.

$$score = \frac{\Sigma_{f \in F}\ w_f \cdot J_f}{\Sigma_{f \in F, S_f^{(1)} \neq \emptyset, S_f^{(2)} \neq \emptyset}\ w_f}$$

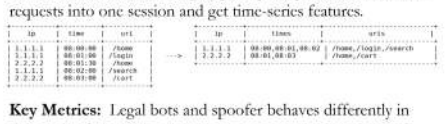
Hosting Sites:



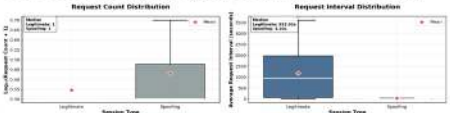
3. Classification

Goal: We built binary classification model to detect spoofer.

Time Series Dataset: We grouped by **IP**, process consecutive requests into one session and get time-series features.



Key Metrics: Legal bots and spoofer behaves differently in time series features (e.g., requests_counts, avg_time_interval).

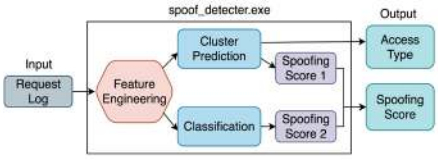


Results: We used XGBoost and reached 95.12% recall rate and 100% precision rate.

Model	Recall	Precision
Random Forest	88.41%	100%
XGBoost	**95.12%**	**100%**
Gradient Boosting	95.73%	96.91%

4. Conclusion

For our final deliverable, we combined our research into a **Command Line Interface (CLI) application**. It takes in a CSV file of request logs and assigns each log a spoofing probability score and access type label using our pretrained clustering and classification models.



For our next steps, we want to continue refining our model's performance in terms of accuracy and efficiency.

Acknowledgements

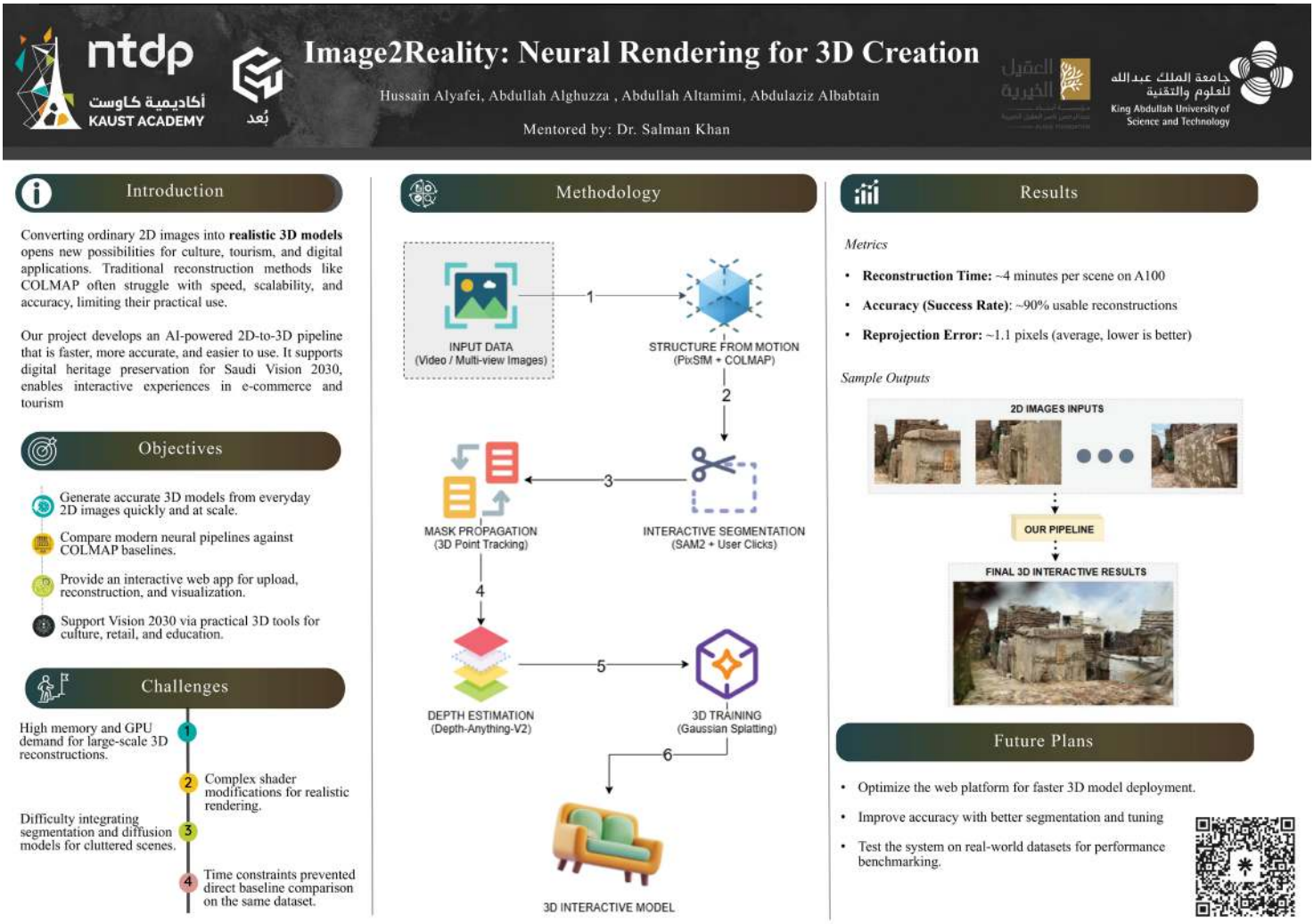
Special thanks to: Dr. Emily Wenger, Gregory Herschlag, Daniel Cid, and Github Arcjet for aiding us.

2D-TO-3D IMAGE RECONSTRUCTION USING AI

Our project uses AI to convert 2D images into 3D models. We combine neural rendering and photogrammetry tools like COLMAP and OpenSplat to generate realistic 3D outputs from single-view images. This is aimed at enhancing e-commerce, cultural heritage preservation, and digital experiences in initiatives like NEOM and Saudi Vision 2030.

PROJECT MENTOR: Salman Khan

PROJECT MEMBERS: Abdulaziz Fahad Albabtain, Abdullah Hamad Alghuzza, Abdullah Majed Altamimi, Hussain Saleh Mohammed Mohsen

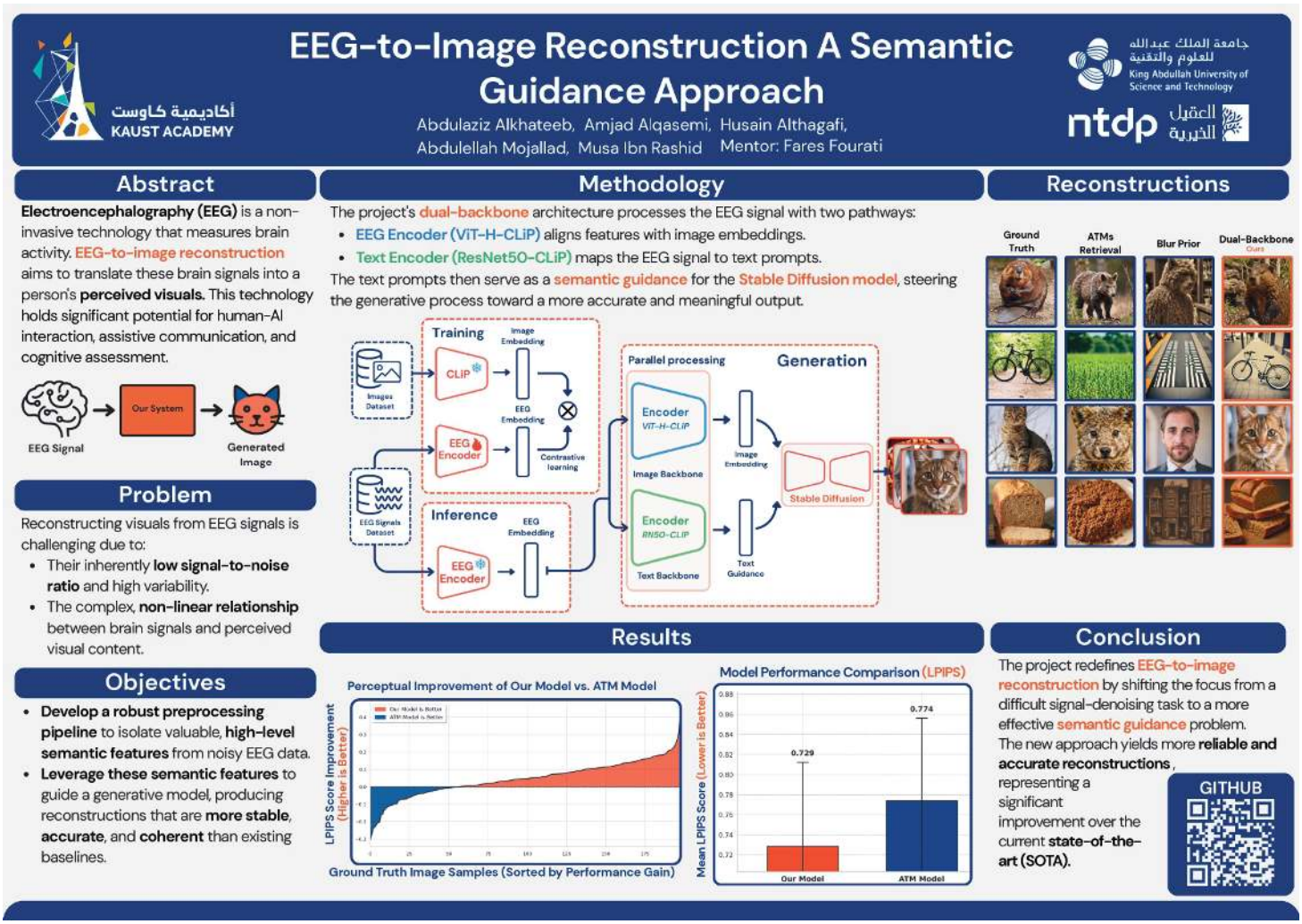


EEG (BRAIN WAVES) TO IMAGE RECONSTRUCTION

In this project, we harness recent breakthroughs in brain‑signal decoding and generative diffusion models to translate raw electroencephalography (EEG) recordings into photorealistic images. Using the newly released Alljoined1 dataset—currently the largest publicly available collection of time‑locked EEG responses to natural images—we aim to build a reliable "thought‑to‑image" pipeline that scales beyond the limitations of current models.

PROJECT MENTOR: Fares Fourati

PROJECT MEMBERS: Abdulaziz Alkhateeb, Abdulellah Mazen Mojalled, Husain Althagafi, Musa Ibn Rashid, Amjad Abdulatif Alqasemi



FORECASTING HEAVY RAINFALL IN THE SOUTHEASTERN U.S. USING DEEP LEARNING

A group of students, guided by climate science and environmental engineering professors, will use deep learning models to enhance flash flood predictions in the Southeastern United States. They will study extreme weather events that contribute to flooding and learn to identify these events using satellite and radar imagery. By applying their findings, the students will develop and refine deep learning models to improve flash flood risk predictions. Their work aims to create a more cost-efficient and accurate method for forecasting short-term heavy rainfall events.

PROJECT MENTOR: Yan Pan

PROJECT MEMBERS: Maan Mohammed Abdullah Adam

Forecasting heavy rainfall in the Southeastern US using deep learning

Suhaib Mansour[1], Zijin Ye[2], Maan Adam[3], Yan Pan[4]

[1] Duke University, Durham, NC; [2] Carnegie Mellon University, Pittsburg, PA; [3] Kaust University, Thuwal, Saudi Arabia; [4] Nicholas School of the Environment, Duke University, Durham, NC

Introduction

Heavy rainfall is a significant threat in the Southeastern U.S. Some characteristics of heavy rainfall events, such as spatial development during their life cycles, are challenging to precisely forecast. This region experiences high precipitation variability and frequent convective storms, making accurate forecasting and early warning essential.

Our Project Aims To use radar and satellite imagery to develop a deep learning model that is cost-efficient, generalizable, and precise. We plan to accurately forecast extreme rainfall events in the near future (nowcasting).

Data and Methods

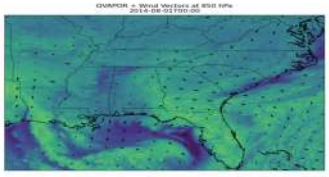
Dataset and Preprocessing:

Data: Reflectivity (**dBZ**) and drop-size distribution (**ZDR**) collected from MRMS (Multi-Radar, Multi-Sensor, Zhang et al., 2016)

Event Selection: Heavy rainfall days were identified using NOAA's CPC dataset (Climate Prediction Center)

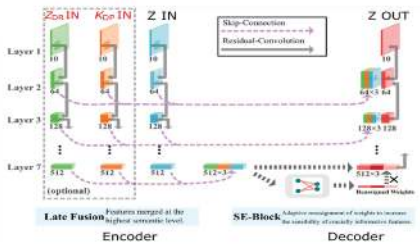
Temporal Resolution: dBZ every 2 min, ZDR every 5 min

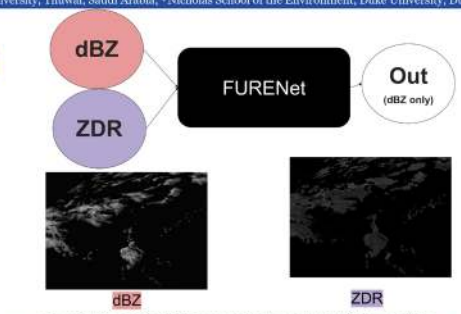
Preprocessing: Radar frames were converted to PNG images



FURENet Model (Pan et al., 2021):

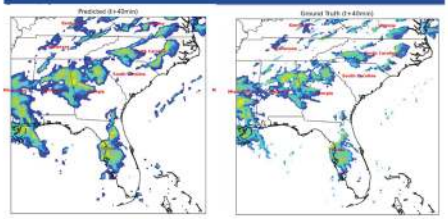
The model used in this project is a version of **U-Net**, specialized for our project. Unlike standard U-Net models, **FURENet can capture both spatial and temporal patterns of extreme weather events.** It learns from high impact rainfall days, making it more accurate and reliable for predicting intense precipitation.





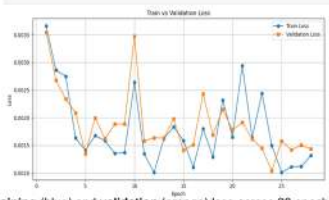
The model takes in dBZ and ZDR images as inputs and outputs a dBZ image prediction

Results



Predicted reflectivity in 40 minutes

Actual reflectivity in 40 minutes



Training (blue) and **validation** (orange) loss across 28 epochs. Both curves drop sharply through epoch 5, then plateau with minor fluctuations. Early stopping at epoch 25, where validation loss bottoms out, helps prevent overfitting, yielding a final validation loss of approximately 0.0010 and demonstrating strong generalization.

Statistics for 40 minute forecast

	dBZ threshold = 15	dBZ threshold = 35
Probability of detection (Hit rate)	.843	.664
False alarm rate	.138	.344
Heidke Skill Score (comparison to random forecast)	.846	.657

Data available for training	Train with only heavy rain days with 3 month dBZ	Train with all days from 3 month dBZ data	Train with only heavy rain days data with 3 month dBZ and ZDR
Evaluation Score	53%	50%	76%

Conclusions

The **FURENet** deep learning model demonstrates promise for precipitation nowcasting in southeastern US. The model successfully generates 40-minute rainfall nowcasting, achieving meaningful accuracy in summer precipitation forecasting. The use of deep learning techniques adds to traditional methods, particularly by capturing the complex relationships in atmospheric processes.

Highlights :

- Achieved **76%** accuracy with manageable false alarm rate
- Demonstrates skills in capturing the **spatial and intensity patterns** of rainfall evolution
- Successfully integrated **multi-sensor radar data** for enhanced prediction accuracy

Summary and Next steps

Some challenges with our project

- **Storage and Computation Resources**
- **Accuracy**: Predictions fall off for longer forecasts (>1hr), this is to be expected somewhat but it could be improved

Next Step

- Gather data from more years and more seasons
- Add more parameters (KDP, wind vectors, water vapor…)

References

- Pan, X., Lu, Y., Zhao, K., Huang, H., Wang, M., & Chen, H. (2021). Improving nowcasting of convective development by incorporating polarimetric radar variables into a deep-learning model. Geophysical Research Letters, 48(21), e2021GL095302.
- Zhang, J., Howard, K., Langston, C., Kaney, B., Qi, Y., Tang, L., ... & Kitzmiller, D. (2016). Multi-Radar Multi-Sensor (MRMS) quantitative precipitation estimation: Initial operating capabilities. Bulletin of the American Meteorological Society, 97(4), 621-638.

LORA MESH NETWORK TESTBED

There are several mesh architectures based on LoRa but there are no studies that compare them scientifically. The project is about establishing a testbed to compare-different LoRa mesh solutions.

PROJECT MENTOR: Marco Zennaro, Moez Altayeb

PROJECT MEMBERS: Abdullah Almanei

A Testbed for LoRa Mesh Networks

Abdullah Almanei
International Centre for theoretical Physics ICTP

The Project

LoRa mesh networks promise long-range, low-power connectivity, yet reproducible comparisons are rare. We present a protocol-agnostic testbed and measurement pipeline that evaluates any LoRa mesh under controlled conditions. By instrumenting Meshtastic and our novel protocol, LoRa QTree, with identical hardware, traffic, and roles, we isolate protocol behavior through KPIs like PDR, airtime, hop distribution, churn, and energy.

Methodology

The methodology involved a multi-step workflow:

1) Define a shared on-air test header and repeatable traffic patterns, and instrument Meshtastic and MeshCore to emit them.
2) Enforce EU duty-cycle with a lenient token bucket and per-node TX queue, fixing common PHY params (freq/BW/SF/CR/tx-power).
3) Run a receive-only gateway to log all frames, then normalize raw logs to CSV/JSON with timestamps, RSSI/SNR, hops, and battery.
4) Compute PDR, hop profile, airtime utilization, and energy proxies across controlled topologies and link conditions.

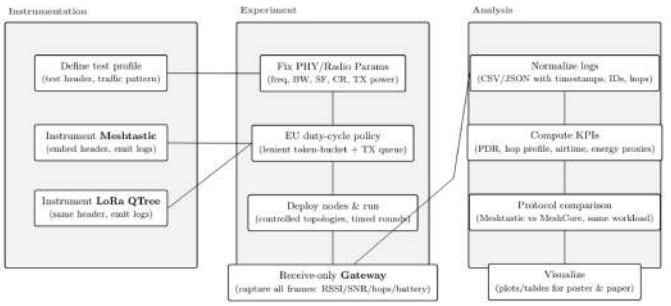
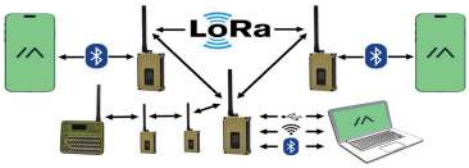


Figure 1: End-to-end pipeline for a protocol-agnostic LoRa mesh testbed. A single test specification drives both Meshtastic and LoRa QTree; experiments run under fixed PHY and duty-cycle rules; the gateway captures all traffic; analysis normalizes logs and computes comparable KPIs.

Results

Using identical radios, channel plan, and traffic, our pipeline reveals stack-level contrasts. For reliability, both stacks maintain stable PDR on short paths, but under higher hop counts Lora QTree avoids spurious "node vanished" purges, sustaining delivery. For airtime, token-bucket scheduling ensures responsiveness to control traffic within the 1% duty-cycle, absorbing bursts like concurrent JOINs without starving data. Routing depth distributions correlate with RSSI and parent reports, while the energy proxy tracks airtime, showing steeper voltage decline in heavy relays. Crucially, Meshtastic integration required only targeted TX/RX and logging changes, proving the pipeline's portability for and non-invasiveness.



Conclusion

We released an open, reproducible pipeline consisting of instrumentation, firmware, gateway logging, and analysis scripts that measure LoRa mesh protocols under identical workloads. Both Meshtastic (instrumented) and LoRa QTree (this work) run the same test profiles and produce directly comparable KPIs. All resources (code, flasher, configs, and analysis notebooks) are open-source, enabling the community to build a shared testbed for comparing LoRa mesh networks and to extend it with new protocols and scenarios.

Acknowledgments

I would like to express my deepest gratitude to my supervisors, Dr. Moez Altayeb and Salah Abduljabar, for their invaluable guidance and support

Github resources

GITHUB

PSID DATA TO STUDY NUMERICAL LITERACY ACROSS GENERATIONS IN U.S. HOUSEHOLDS

This project explores numerical literacy across generations in the United States using the Panel Study of Income Dynamics (PSID), a comprehensive longitudinal dataset. Due to the dataset's size and complexity, we use AI to optimize performance and processing. The study examines how family structure, income shifts, and changes in socioeconomic status, such as becoming richer or poorer, are linked to numeracy across generations.

PROJECT MENTOR: Michael Boutros

PROJECT MEMBERS: Omar Ali Omar Bin Talib, Aws Hazzaa Alsaedi

Studying Numerical Literacy Across Generations in United States Households

Aws Alsaedi[1], Omar Bintalib[1], Prof. Michael Boutros[2]

[1]Kaust Academy, King Abdullah University of Science and Technology, Thuwal, Saudi Arabia

[2]Department of Economics, University of Toronto, Canada

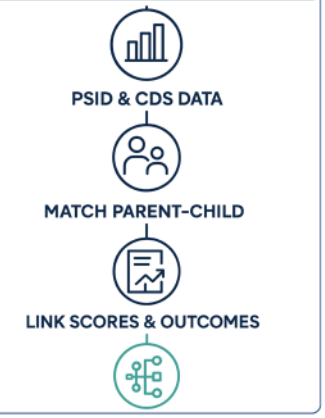
Background

Numerical literacy, the ability to understand and work with numbers is essential for sound **financial decisions** and long-term **wealth building**. Most research focuses on **adults**, overlooking how these skills develop in **childhood** or transfer between generations. The link between **childhood numerical ability** and **adult wealth** remains unclear. Our work uses national **PSID & CDS** data to explore this connection in a multi-generational context.

Hypothesis/Objectives

We expect **numerical literacy** to **persist** within individuals **over time** and to be passed from **parents** to **children**. We investigate whether stronger **childhood skills** lead to improved **adult wealth outcomes**. Using **statistical** and **machine learning methods**, we also identify the key factors predicting intergenerational literacy.

Methods



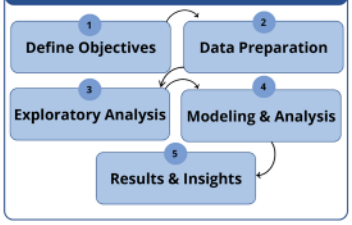
Data

PSID → **6-question** numerical literacy test (0–6 score) for parents.
CDS → standardized child assessment (0–120 score) for children.

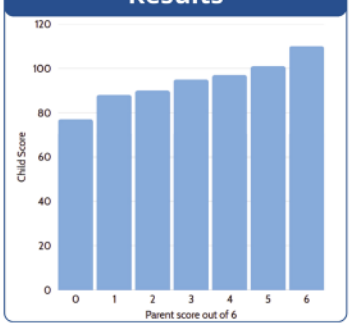
Why these exams?

- Used in past **economic research** for **financial/numerical literacy**.
- **Comparable** across **survey years**.
- Simple and objective scoring.

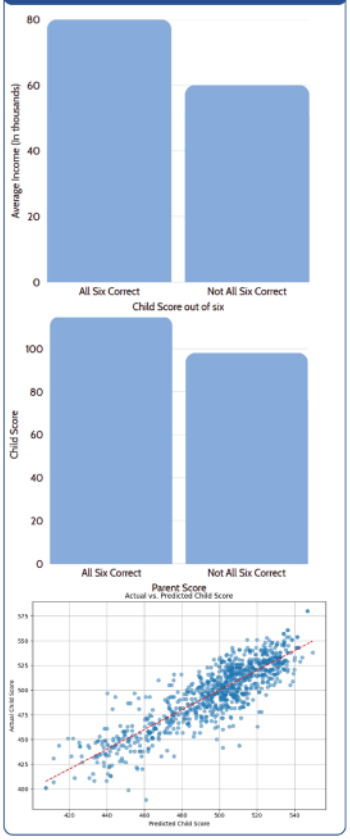
Pipeline



Results



Results



Tools

python · GitHub · PyTorch

Conclusion

Numerical literacy endures over time and is **transmitted** across generations. Stronger early life numeracy is associated with better **adult wealth outcomes**. Family context, especially **parental income**, spending habits, and **educational** expectations, emerges as a key predictor, underscoring the role of the home environment in shaping **financial** security.

Future Directions

- We aim to extend our analysis to more **PSID** waves, add richer **socioeconomic** indicators, and explore advanced ML techniques to improve predictions.
- Longer-term, we will expand to study **wealth mobility** and compare findings across different countries.

Acknowledgements

Supported by the **Data Sciences Institute, University of Toronto, and KAUST Academy**.
Thanks to **Prof. Michael Boutros** for mentorship and to the **PSID & CDS** teams for data access.

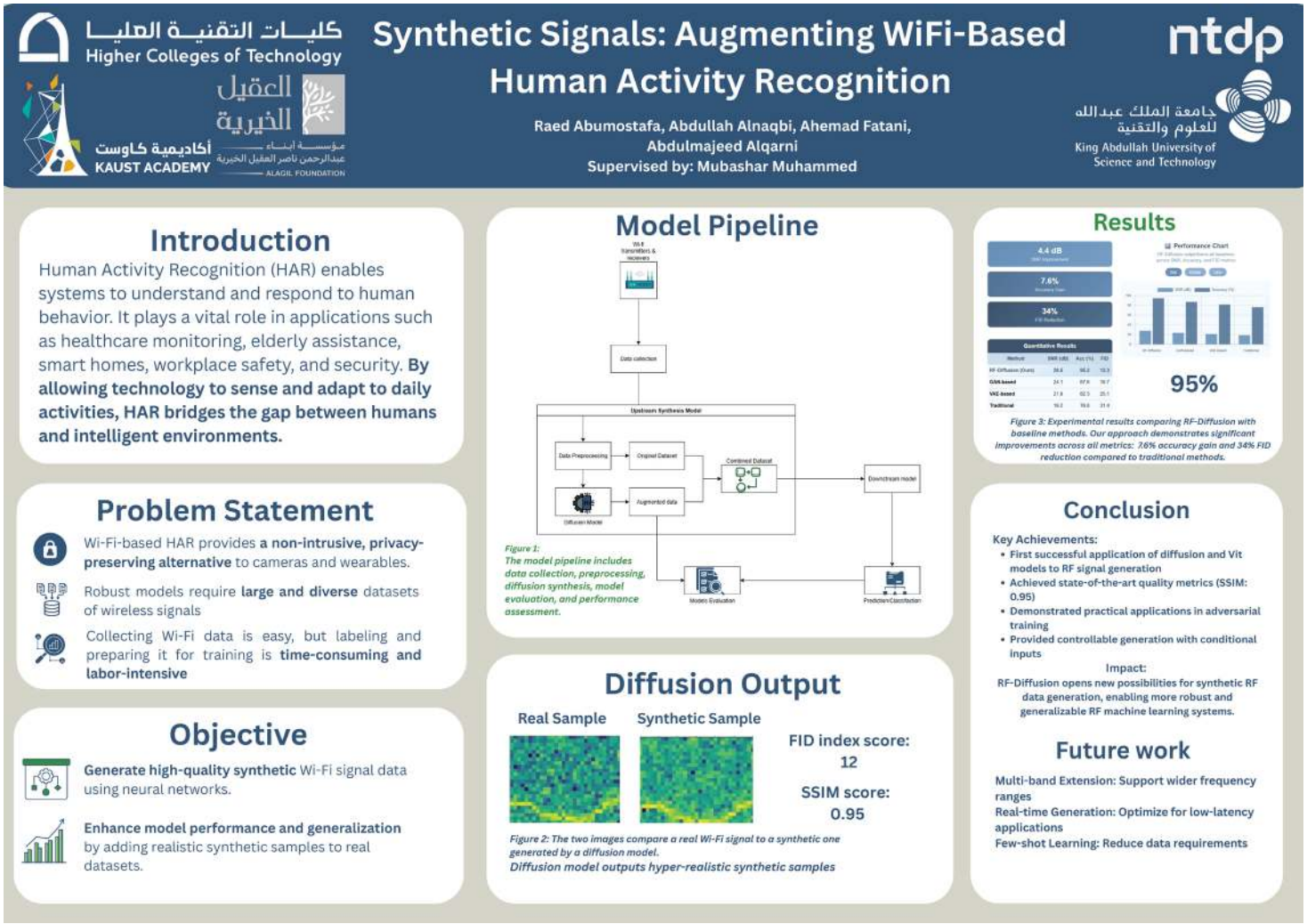
Resources & Contacts

WIFI HUMAN ACTIVITY RECOGNITION

This project explores how we can recognize human activities (like walking, sitting, or falling) using only WiFi signals, specifically Channel State Information (CSI). When a person moves, it affects how WiFi signals behave — and by learning from these changes, we can try to classify the activity taking place.The main challenge in this field is that most available datasets are small and not diverse, which makes models perform poorly on new users or environments or domains. While current approaches use self-supervised learning (SSL), transfer learning, or few-shot learning to adapt across domains, they still struggle when the source data lacks variety.Our project focuses on using diffusion models to generate synthetic CSI data, aiming to increase dataset diversity and improve model generalization.

PROJECT MENTOR: Muhammad Mubashar

PROJECT MEMBERS: Ahmed Farid Fatani, Abdulmajed Mohammad AlQarni, Raed Abdulrahim Abumostafa, Abdullah Ali Alnaqbi



PREDICTING MICROBIAL GROWTH TO UNDERSTAND BIOLOGICAL RESILIENCE

This Data+ project aims to improve microbial growth prediction using custom analytics, enhancing the MicroNet web app for better data visualization and statistical modeling. Students will beta-test the tool, extend its models, and analyze data to advance applications in health, food safety, and microbiome research.

PROJECT MENTOR: Braden Scherting

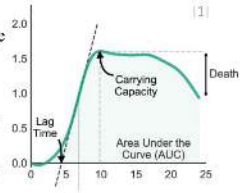
PROJECT MEMBERS: Abdulrahman Mohammed H Alalyani

MicroNet: A Web App for Analyzing Microbial Growth with Gaussian Processes

Team Members: Fan Xu, Ziqi Li, James Peng, Uzoma Uwazurike Jr., Abdulrahman Alalyani

Background

Microbial growth is measured with optical density (OD): the more microbes present, the more light will be absorbed. These OD values are plotted across time to make **growth curves**, a representation of how microbial populations change over time. Traditionally, these curves have been modelled parametrically.



[1]

Traditional Models vs Gaussian Processes

Traditional sigmoidal functions rely on underlying assumptions about microbial growth that may not hold under stressed conditions [2].

Enter **Gaussian Process regression** (GP), a dynamic, nonparametric model that can fit complex patterns

$$\ln OD(t) \sim N(\mu(t), \Sigma) \qquad \sigma_{ij} = k(t_i, t_j)$$ [1]

$$k(t_i, t_j) = \sigma_{RBF}^2 exp\left(-\frac{(t_i - t_j)^2}{2l^2}\right) + \sigma_{noise}^2 \cdot \delta_{i=j}$$

Advantages	Limitations
No underlying assumptions	Computational complexity
Uncertainty estimates	Kernel selection

AMiGA and MicroNet

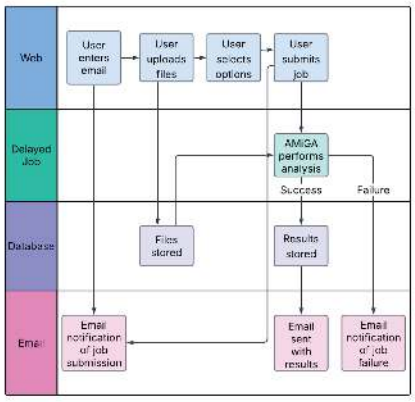
- **AMiGA:** Python package developed by Midani et al.
  - Models microbial growth data using GP methods.
- **MicroNet:** Web App built on top of AMiGA
  - More accessible to researchers w/o coding knowledge and experience

Further Studies

- Additional testing and debugging of features and interface
- Giving users additional configuration options
- Deploying application to Duke servers and online hosting

Methods, Results, and Discussion

How does MicroNet Work?

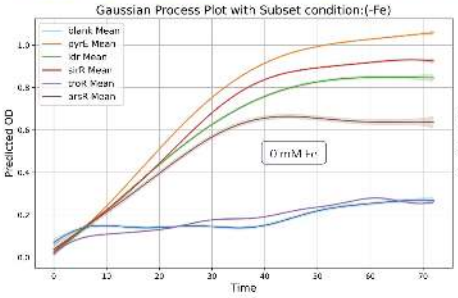


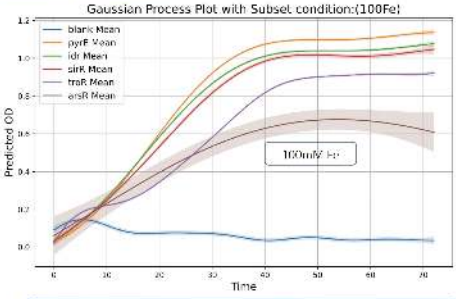
MicroNet features:

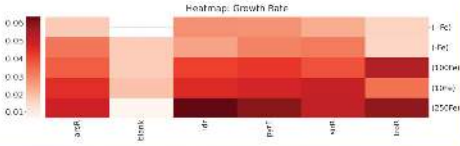
- Plot raw growth data by well
- Fit growth curves as GP models and generate growth parameters
- Test for significant differences between curves and parameters
- Generate visualizations for analysis



A Case Study into the Iron Metabolism of Archaea *H. volcanii*







- Evaluation of *H. volcanii* wild-type (WT) and KO mutant strains growth in different iron levels [3]
- **Our analysis with MicroNet shows that the TroR knockout strain performs poorly in low iron,** indicating the importance of the TroR gene as a homeostatic regulator of iron metabolism

References

1. Midani, F. S., Collins, J., & Britton, R. A. (2021). AMiGA: Software for Automated Analysis of Microbial Growth Assays. mSystems, 6(2), e00562-21. https://doi.org/10.1128/mSystems.00508-21
2. Tonner, P. D., Darnell, C. L., Engelhardt, B. E., & Schmid, A. K. (2017). Detecting differential growth of microbial populations with Gaussian process regression. Genome research, 27(2), 320–333. https://doi.org/10.1101/gr.210286.116
3. Martinez-Pastor, M., Sukchar, S., Hwang, S., Buckley, R. K., Sahoo-Kotecki, A. J., Maupin-Furlow, J. A., & Schmid, A. K. (2024). TroR is the primary regulator of the iron homeostasis transcription network in the halophilic archaeon Haloferax volcanii. Nucleic acids research, 52(1), 135–146. https://doi.org/10.1093/nar/gkad997

Acknowledgements

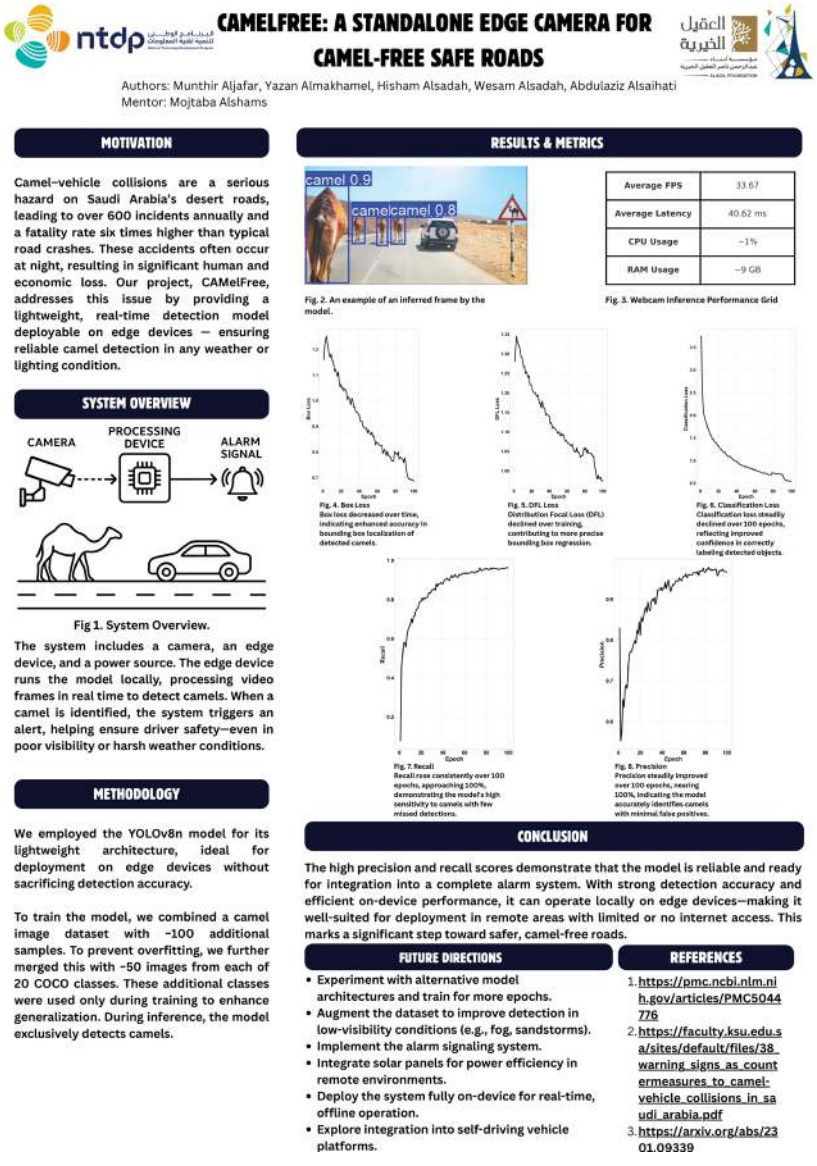
Thank you to our Project Manager Braden Scherting and Project Lead Dr. Amy Schmid for their guidance and support throughout the summer!

CAMELFREE: A STANDALONE EDGE CAMERA FOR CAMEL-FREE SAFE ROADS.

Summary: If the students are interested in pursuing this project, I will lend them a Raspberry pi along with its camera. The camera will feed the image into the edge device in real-time to run it through an Object Detection (OD) DNN model. Students can interactively show their system during posters session. Applications: security survielance cameras (intruders detection), real-time people faces recognizer, industry safety systems ... etc. Proof-of-concept: Preliminary system was tested and real-time detection was observed. Yolo model was ran on a raspberry pi 4 and results were displayed on screen. Extensions students can do: Students will get the system on and running as a first stage. Next stages may include using compressed models to have smaller computation latency, simulate an edge compute paradigm where they will simulate the performance across the communication hierarchy.

PROJECT MENTOR: Mojtaba AlShams

PROJECT MEMBERS: Abdulaziz Alsaihati, Hisham Alsadah,Munthir Aljafar, Wesam Alsadah, Yazan Almakhamel



CAMELFREE: A STANDALONE EDGE CAMERA FOR CAMEL-FREE SAFE ROADS

Authors: Munthir Aljafar, Yazan Almakhamel, Hisham Alsadah, Wesam Alsadah, Abdulaziz Alsaihati
Mentor: Mojtaba Alshams

MOTIVATION

Camel–vehicle collisions are a serious hazard on Saudi Arabia's desert roads, leading to over 600 incidents annually and a fatality rate six times higher than typical road crashes. These accidents often occur at night, resulting in significant human and economic loss. Our project, CAMelFree, addresses this issue by providing a lightweight, real-time detection model deployable on edge devices — ensuring reliable camel detection in any weather or lighting condition.

SYSTEM OVERVIEW

CAMERA
PROCESSING DEVICE
ALARM SIGNAL

Fig 1. System Overview.

The system includes a camera, an edge device, and a power source. The edge device runs the model locally, processing video frames in real time to detect camels. When a camel is identified, the system triggers an alert, helping ensure driver safety—even in poor visibility or harsh weather conditions.

METHODOLOGY

We employed the YOLOv8n model for its lightweight architecture, ideal for deployment on edge devices without sacrificing detection accuracy.

To train the model, we combined a camel image dataset with ~100 additional samples. To prevent overfitting, we further merged this with ~50 images from each of 20 COCO classes. These additional classes were used only during training to enhance generalization. During inference, the model exclusively detects camels.

RESULTS & METRICS

Fig. 2. An example of an inferred frame by the model.

Average FPS	33.67
Average Latency	40.62 ms
CPU Usage	~1%
RAM Usage	~9 GB

Fig. 3. Webcam Inference Performance Grid

Fig. 4. Box Loss
Box loss decreased over time, indicating enhanced accuracy in bounding box localization of detected camels.

Fig. 5. DFL Loss
Distribution Focal Loss (DFL) declined over training, contributing to more precise bounding box regression.

Fig. 6. Classification Loss
Classification loss steadily declined over 100 epochs, reflecting improved confidence in correctly labeling detected objects.

Fig. 7. Recall
Recall rose consistently over 100 epochs, approaching 100%, demonstrating the model's high sensitivity to camels with few missed detections.

Fig. 8. Precision
Precision steadily improved over 100 epochs, nearing 100%, indicating the model accurately identifies camels with minimal false positives.

CONCLUSION

The high precision and recall scores demonstrate that the model is reliable and ready for integration into a complete alarm system. With strong detection accuracy and efficient on-device performance, it can operate locally on edge devices—making it well-suited for deployment in remote areas with limited or no internet access. This marks a significant step toward safer, camel-free roads.

FUTURE DIRECTIONS

- Experiment with alternative model architectures and train for more epochs.
- Augment the dataset to improve detection in low-visibility conditions (e.g., fog, sandstorms).
- Implement the alarm signaling system.
- Integrate solar panels for power efficiency in remote environments.
- Deploy the system fully on-device for real-time, offline operation.
- Explore integration into self-driving vehicle platforms.

REFERENCES

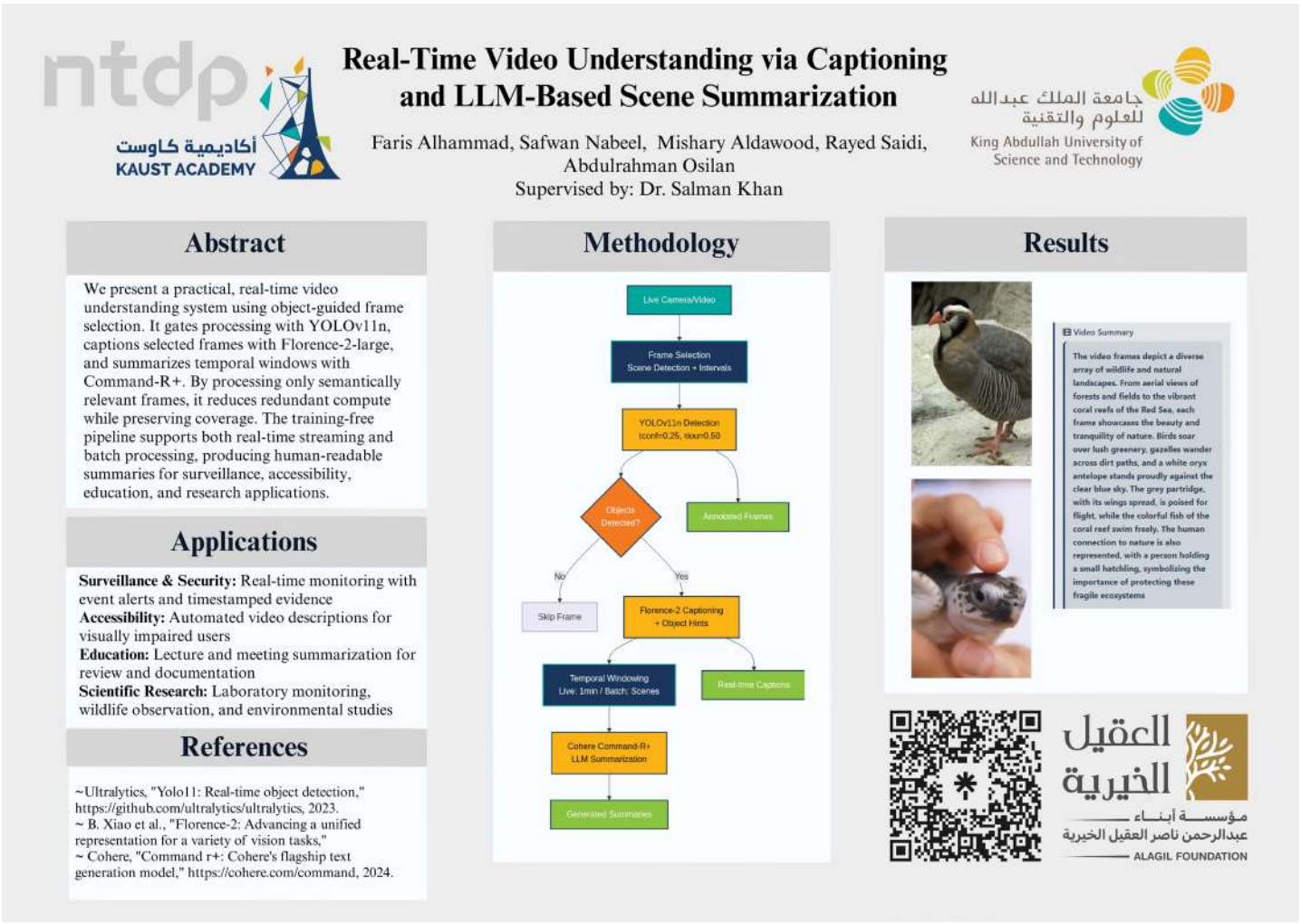
1. https://pmc.ncbi.nlm.nih.gov/articles/PMC5044776
2. https://faculty.ksu.edu.sa/sites/default/files/38_warning_signs_as_countermeasures_to_camel-vehicle_collisions_in_saudi_arabia.pdf
3. https://arxiv.org/abs/2301.09339

REAL-TIME VIDEO UNDERSTANDING VIA CAPTIONING AND LLM-BASED SCENE SUMMARIZATION

This project presents a real-time video interpretation system that captures live camera feeds, detects objects using YOLO, and generates natural language captions for key frames using multimodal models. These frame-wise captions are then aggregated and summarized every minute using large language models (LLMs), such as Cohere's command-r-plus, to produce a concise human-like scene description. The pipeline includes intelligent object detection, caption refinement, class-based statistics, and prompt-engineered summarization to transform raw video into structured and meaningful summaries, enabling downstream applications in surveillance, content moderation, and assistive technologies

PROJECT MENTOR: Salman Khan

PROJECT MEMBERS: Faris Mohammed Alhammad, Safwan Nabeel,Rayed Mustafa Saidi, Mishary Aldawood, Abdulrahman Osilan



DATA SCIENCE FOR OPTIMIZING CARDIOVASCULAR AND BRAIN HEALTH PROMOTION

Using Electric Health Record (EHR) data sources for public health analysis. We are currently studying dementia population characteristics using an EHR databases called Truveta.

PROJECT MENTOR: Jay Lusk

PROJECT MEMBERS: Ayman zaid Alrashidi

Decoding Dementia: Descriptive Epidemiology Using U.S. Linked Electronic Health Record and Claims Data, 2017–2024

Ayman Alrashidi, Harrison Kane, Doan Pham, Emma Zhang
Brian Mac Grory MB BCh BAO MHSc, Fan Li PhD, Jay Lusk MD MBA

Background

- Dementia is a progressive neurological condition affecting over 6 million people in the U.S., with cases projected to nearly double by 2060 [1].
- Limited access to data has hindered accurate analysis of dementia trends.

Table 1. Strengths and Weaknesses Methods of Previous Estimating Dementia Epidemiology

Data Source	Strengths	Limitations
Cohort Studies	Rich clinical details Longitudinal follow-up	Self-selection bias Limited generalizability High resource demands; 10 years of study to estimate one number
Medicare Claims	Large, national dataset Standardized coding	Only includes services paid by Medicare, missing other care Data lag; limited coverage (e.g., under 65 not eligible)

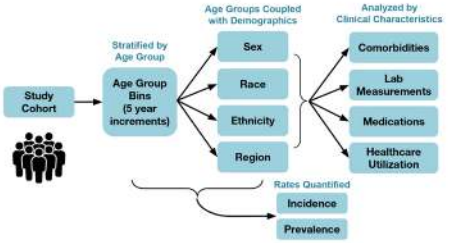
- Electronic health record (EHR) data addresses key limitations of previous approaches by offering a larger, more diverse patient population with clinical information.

Objectives

- Describe clinical and treatment profiles of dementia patients
- Estimate annual incidence and prevalence of dementia in the U.S. (2017–2024) using Truveta EHR-linked claims data

Methods

- Used Truveta, a retrospective nationwide database of de-identified EHR for 120M+ patients nationwide.



Dementia cases from January 2017 – December 2024, identified using validated claims-based algorithms:

- Dementia defined using a validated algorithm [2]
- Sensitivity analysis with broader definitions [3-4]

Dementia Clinical Profiles

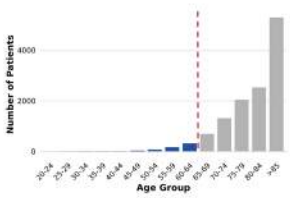


Figure 1. Demographic Characteristics of the Dementia Cohort

- 5.3% of cases were diagnosed before age 65 (Figure 1).
- This population has been historically underrepresented in claims-based studies due to Medicare age eligibility restrictions.

Clinical data highlights key dementia risk factors:

- 22.4% of patients had an anticholinergic burden (ACB) [5] ≥ 5, indicating preventable medication-related risk (Figure 2A).
- 74.7% of patients had an Elixhauser Comorbidity Score [6] ≥ 15 at diagnosis, underscoring high comorbidity burden (Figure 2B).

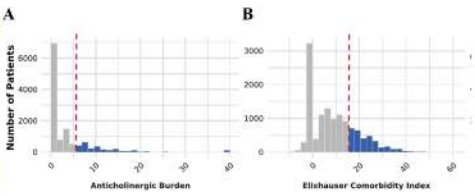


Figure 2. Index Summary of Dementia Cohort. (a) Anticholinergic Burden (b) Elixhauser Comorbidity Index

Dementia Trend Estimates

- Incident dementia cases decreased after 2020, while prevalent dementia cases increased. This trend suggests that dementia patients are living longer than they used to (Figure 3).

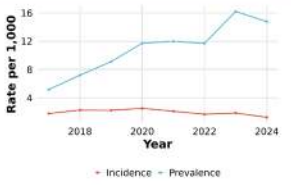


Figure 3. Age and Sex Standardized Incidence and Prevalence

- Patients who were male, Black or African American, Hispanic or Latino, or residing in the West were more likely to receive an earlier dementia diagnosis (Figure 4).

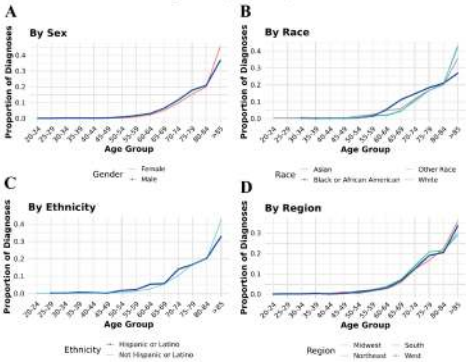


Figure 4. Stratified Density of Diagnosed Dementia Cases. (a) By Age Group and Gender (b) By Age Group and Race (c) By Age Group and Ethnicity (d) By Age Group and Region

Discussion

- We are the first to leverage comprehensive EHR data to provide a detailed clinical profile of dementia, including cases diagnosed before age 65.
- Many patients live longer with dementia, but early intervention is possible: 22% had modifiable medication risks that could be prevented with safer prescriptions.

Limitations:

- Data only from patient encounters with Truveta healthcare systems, encounters outside Truveta are not recorded.
- EHR data may underrepresent groups who are less likely to seek care or receive a timely diagnosis.

Future Direction

Future work will validate these findings using data from other EHR platforms, such as Epic Cosmos. We will apply the codelists developed in this study to other standardized, reproducible analyses of dementia and other public health topics.

References

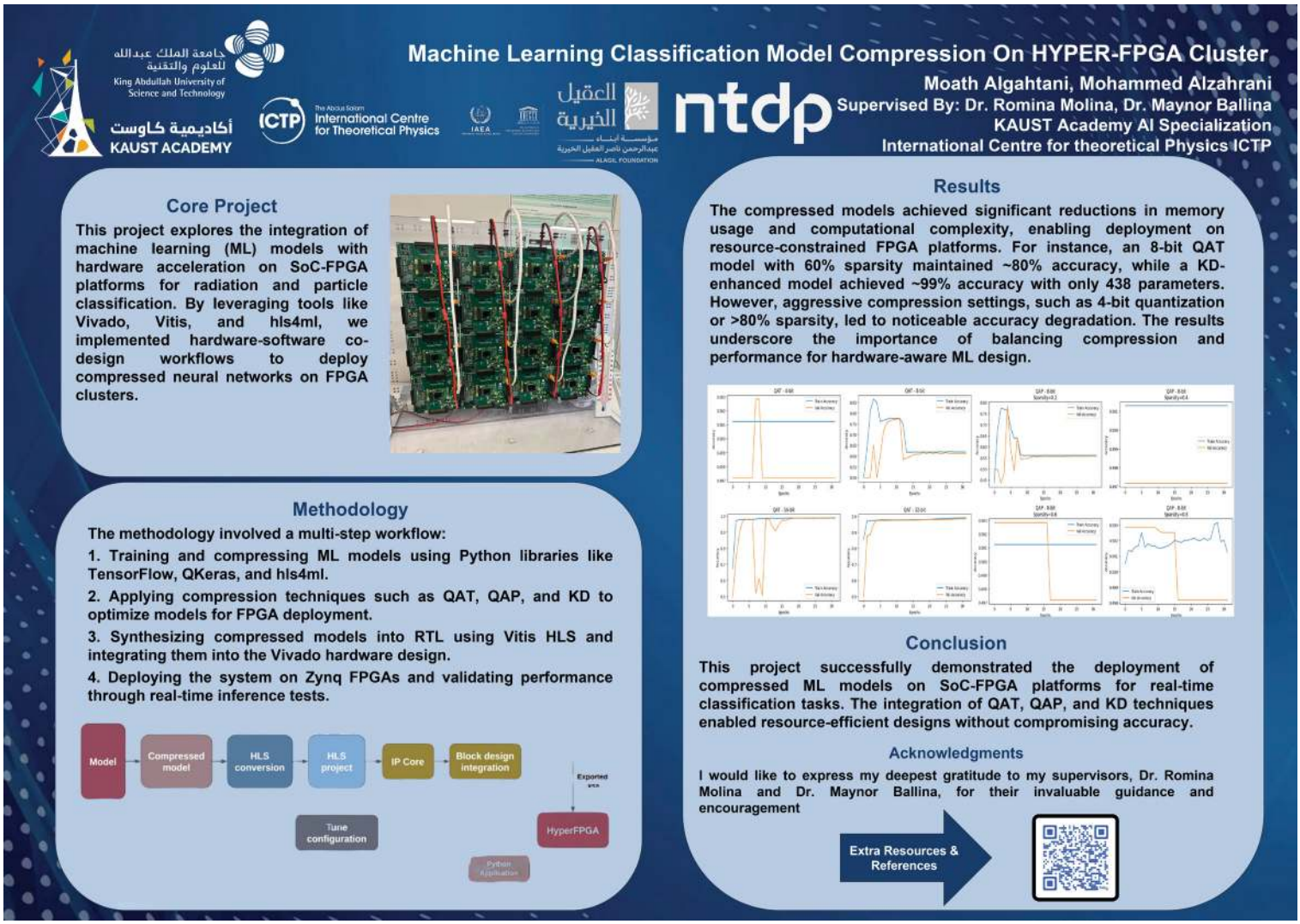
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MACHINE LEARNING MODEL COMPRESSION FOR RADIATION/PARTICLE CLASSIFICATION ON SOC-FPGA

SoC-FPGA technology is increasingly used for hardware acceleration of ML models thanks to its key advantages, including high parallelism, low power consumption, and low latency. However, mapping an ML architecture to a SoC-FPGA often requires the application of compression strategies to create a hardware design that effectively balances model performance, memory footprint, and inference time. This project focuses on employing an end-to-end workflow to map deep neural networks (DNNs) onto SoC-FPGAs for real-time classification of radiation and particles.

PROJECT MENTOR: Romina Molina and Maynor Ballina

PROJECT MEMBERS: Moath Ahmad Algahtani, Mohammed Hassan S Al-Zahrani

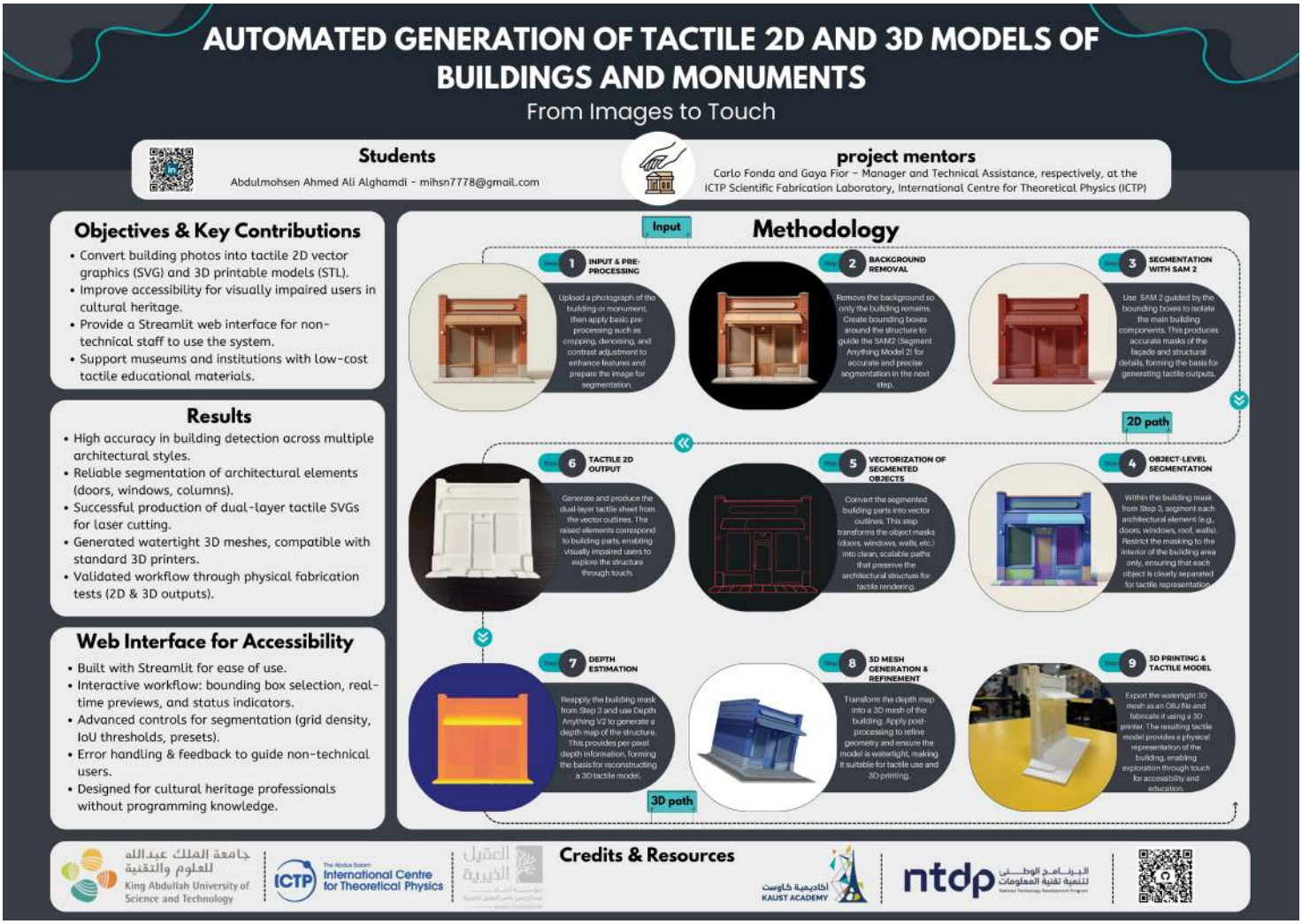


AUTOMATED GENERATION OF TACTILE REPRESENTATIONS OF BUILDINGS AND MONUMENTS FROM PICTURES

To develop and test a software tool that generates 3D models (for 3D printers) and/or 2D vector awings (for laser cutter production) starting from photos of buildings and monuments, as a cost-effective inclusive solution to facilitate the promotion of cultural heritage to visually-impaired people..

PROJECT MENTOR: Carlo Fonda

PROJECT MEMBERS: Abdulmohsen Ahmed Ali Alghamdi



JARIR-NLP: PERSONALIZED AI SALESMAN

The Jarir-NLP project introduces an AI-powered virtual assistant that helps online shoppers navigate Jarir's wide selection of computers and tablets. By simulating the role of an in-store salesperson, the assistant engages customers in natural conversation to recommend devices based on their specific needs, preferences, and budget.Built on a Agentic AI framework, the system combines real-time search with language generation to deliver accurate, up-to-date answers grounded in Jarir's product catalog. This ensures reliable guidance while offering a personalized, intuitive shopping experience that bridges the gap between online automation and human expertise.

PROJECT MENTOR: Salman Khan

PROJECT MEMBERS: Almaan Khan, Mohammed Rashad Mudhsh Ali, Baraa Tammam Zino,Muhammad Ammar Sohail

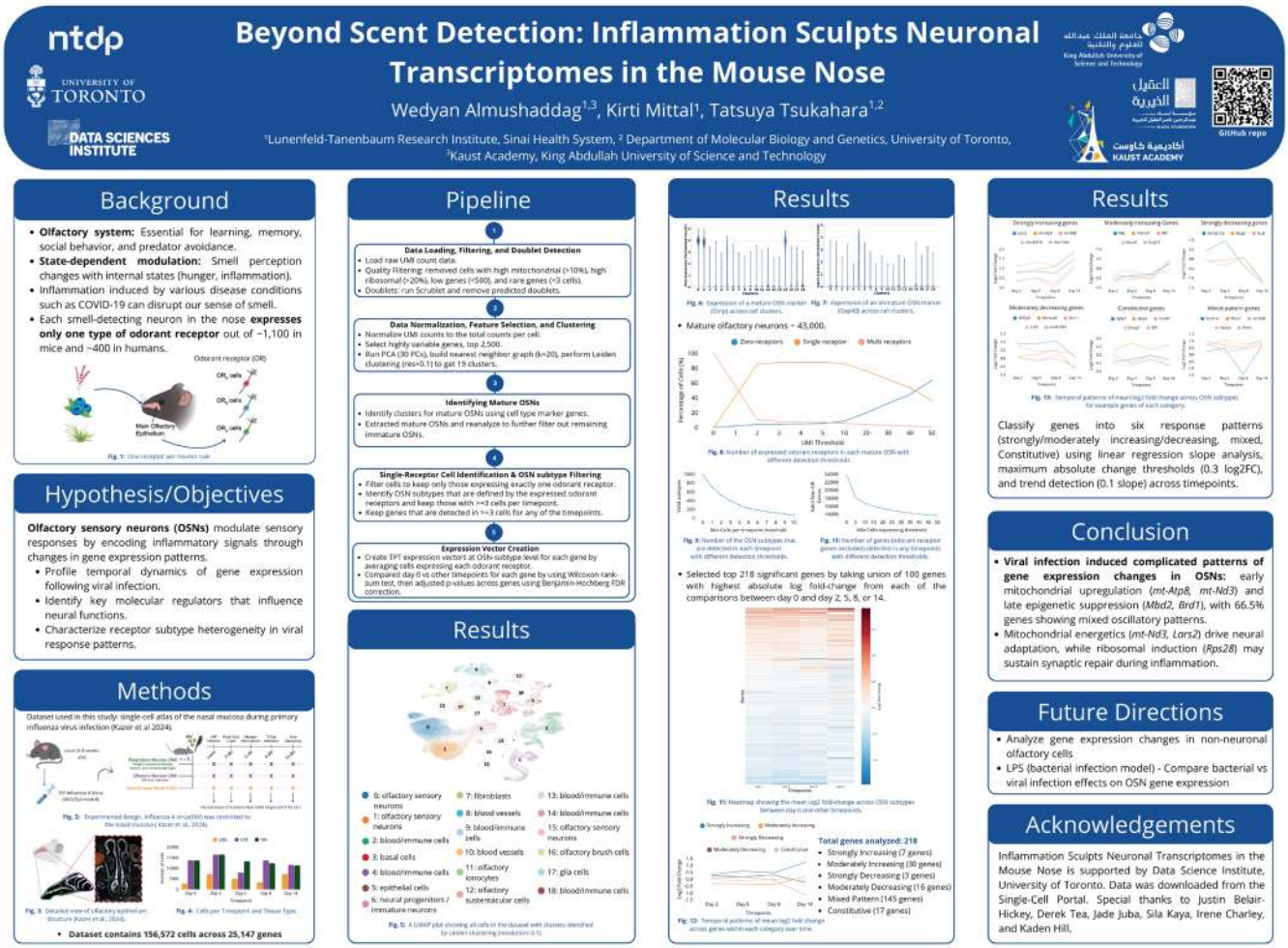


BEYOND SCENT DETECTION: INFLAMMATION SCULPTS NEURONAL TRANSCRIPTOMES IN THE MOUSE NOSE

We are constantly exposed to various sensory stimuli such as sight, sound, and smell. Although sensory systems detect and interpret these stimuli, our perception is influenced by internal states such as hunger, stress, and inflammation. However, it is still unclear how the signals that signify these states, such as hormones, peptide, and cytokines, are encoded in gene expression of individual neurons and modulate the patterns of neural responses to stimuli. To adess this question, our lab uses the mouse olfactory system as a model. Olfaction plays fundamental roles in many aspects of our life including learning and memory and detection of food and danger. In addition, it has been shown that odor processing is influenced by internal states even at the first step where sensory neurons in the nose detect odors. However, mechanisms through which individual neurons encode the internal states and modify responses to stimuli are still unknown. This SUDS project will primarily aim to quantitatively characterize the state-dependent changes in gene expression in the olfactory system by analyzing single-cell and bulk genomics datasets (RNA, epigenome, and protein) obtained from mice that are imposed changes in internal states such as hunger and inflammation..

PROJECT MENTOR: Tatsuya Tsukahara

PROJECT MEMBERS: Wedyan Fawaz Almushaddag



MICRO-COMPUTER TOMOGRAPHY USING CMOS IMAGE SENSORS

CMOS image sensors, initially designed for visible light imaging, are also sensitive to ionizing radiation, making them suitable for use as radiation detectors. Key advantages ofthese sensors include their low cost, ease of readout, ability to operate at room temperature, capability to perform X-ray spectral measurements, and high spatial resolution due to their small pixel pitch. This project focuses on utilizing and characterizing CMOS image sensors to acquire high-resolution X-ray images and perform tomographic reconstructions for various samples.

PROJECT MENTOR: Luis Garcia

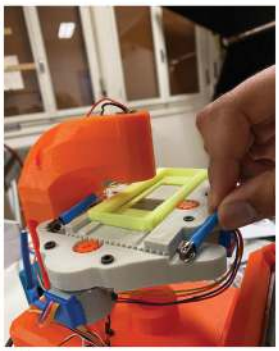
PROJECT MEMBERS: Fahad Hamzah Sultan

Precision Motion Controller (PMC) Development for Microscopes and Raspberry Pi Integration

Fahad Hamzah Sultan
KAUST Academy AI Specialization
International Centre for theoretical Physics ICTP

Core Project

This project focuses on the development of a C-based stepper motor driver and touchdown safety system for precise motion control in microscopy and mechatronics applications. By integrating limit switches, interruption pins, and hardware-level safety checks, the system ensures accurate multi-axis positioning while preventing motor overrun or damage. Additionally, mechanical protection components such as a Raspberry Pi casing and wire strainers were designed in Fusion 360 to improve cooling, integration, and wiring safety.



Methodology

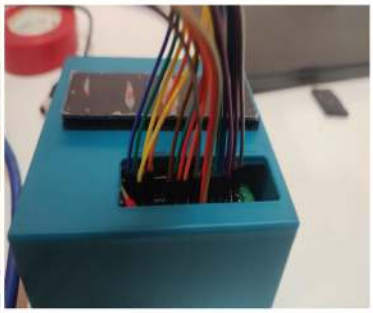
The methodology involved both hardware and software development:
1. Driver Development: Implemented motor control logic in C using WiringPi libraries for real-time GPIO control.
2. Safety Systems: Designed a touchdown function with limit switches and interruption pins to terminate motion during unsafe conditions.
3. Hardware Integration: Assembled circuits, managed power distribution, drilled, soldered, and connected all wiring to create a complete working setup.
4. Mechanical Design: Created and 3D-printed a Raspberry Pi casing and wire strainers to provide airflow for cooling and cable protection.



Results

The developed system achieved:
1. Precise multi-axis motion control of stepper motors with minimal error.
2. Reliable safety shutdown via touchdown and interruption pins.
3. Improved hardware durability, with custom wire strainers reducing cable strain and the Raspberry Pi casing preventing overheating.
4. Seamless hardware–software integration, validated through repeated test cycles.





Conclusion

This project successfully demonstrated the design and deployment of a low-cost, reliable stepper motor driver with built-in safety mechanisms. The integration of C-based control, hardware safeguards, and mechanical design elements provided a robust solution for laboratory and educational motion-control systems.

Acknowledgments

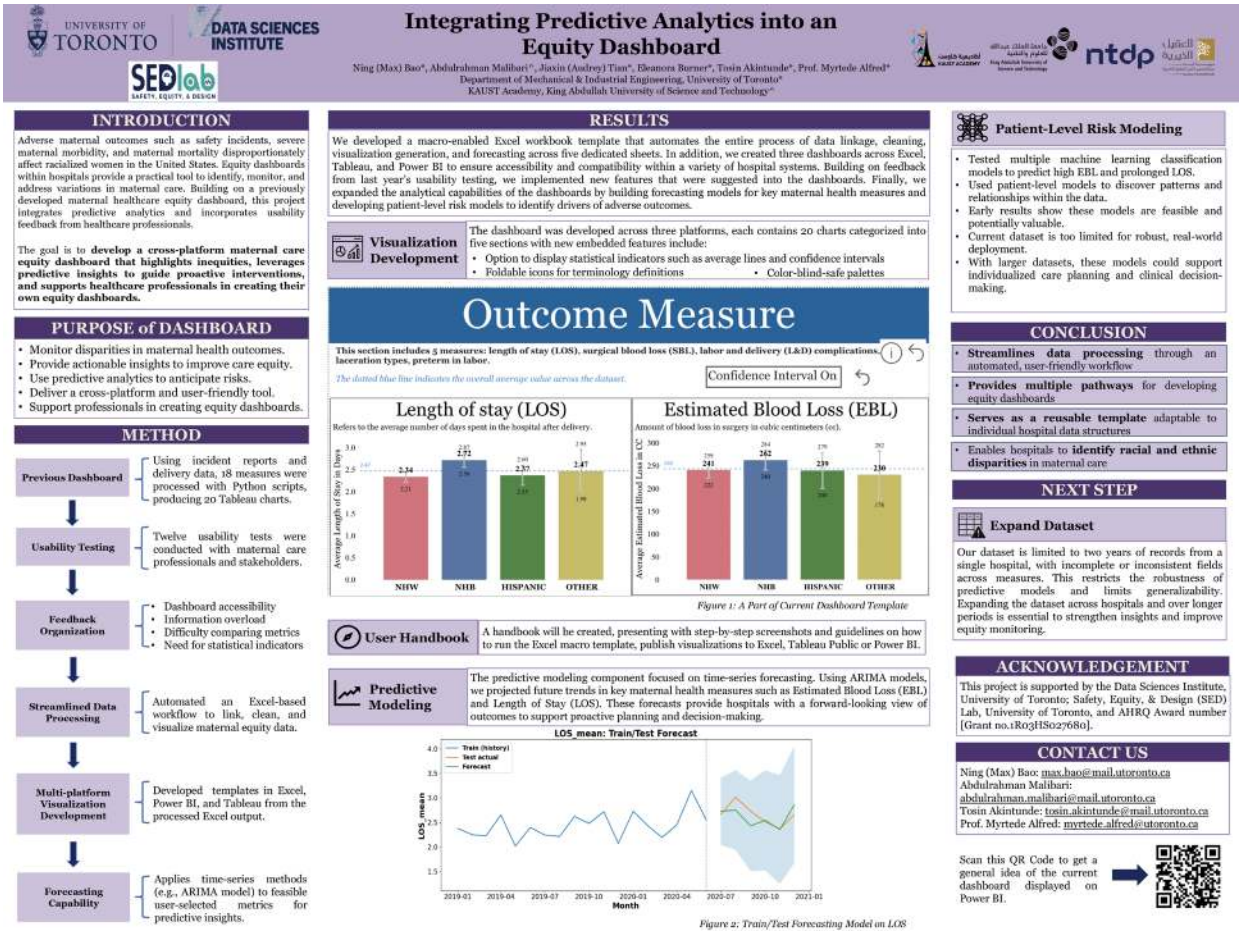
I would like to express my deepest gratitude to my supervisors, Dr. Luis Garcia and Mr. Antonio Passi, for their invaluable guidance and encouragement

INTEGRATING PREDICTIVE ANALYTICS INTO AN EQUITY DASHBOARD

The development an equity dashboard in hospitals has been proposed as a solution to facilitate the identification of variations in outcomes, encourage accountability, and support ongoing monitoring. Our research sought to develop an equity dashboard using data collected from the maternal care wards of a hospital in the US in 2019 and 2020. The data obtained were cleaned, and patient delivery data were linked to their demographic data using Microsoft Excel and Python. The data were then disaggregated by race/ethnicity and statistical analysis was performed to assess differences in the outcomes using R. Tableau Desktop was used to develop 18 visualizations of the measures. We are currently conducting usability testing. We could not complete the planned predictive modeling; however, we are working with our collaborators to obtain five years of data to incorporate predictive analytics in the next iteration. Once we validate its efficacy through user testing, we will disseminate our dashboard for implementation. **1) Develop predictive models of adverse events and outcomes based on patient characteristics and social vulnerability. Analyze feature importance for these predictions. 2) Develop an Excel Macro and content pack in Power BI that can generate comparable visualizations 3) Make dashboard publicly accessible through Tableau Public**

PROJECT MENTOR: Tosin Akintunde

PROJECT MEMBERS: Abdulrahman Malibari

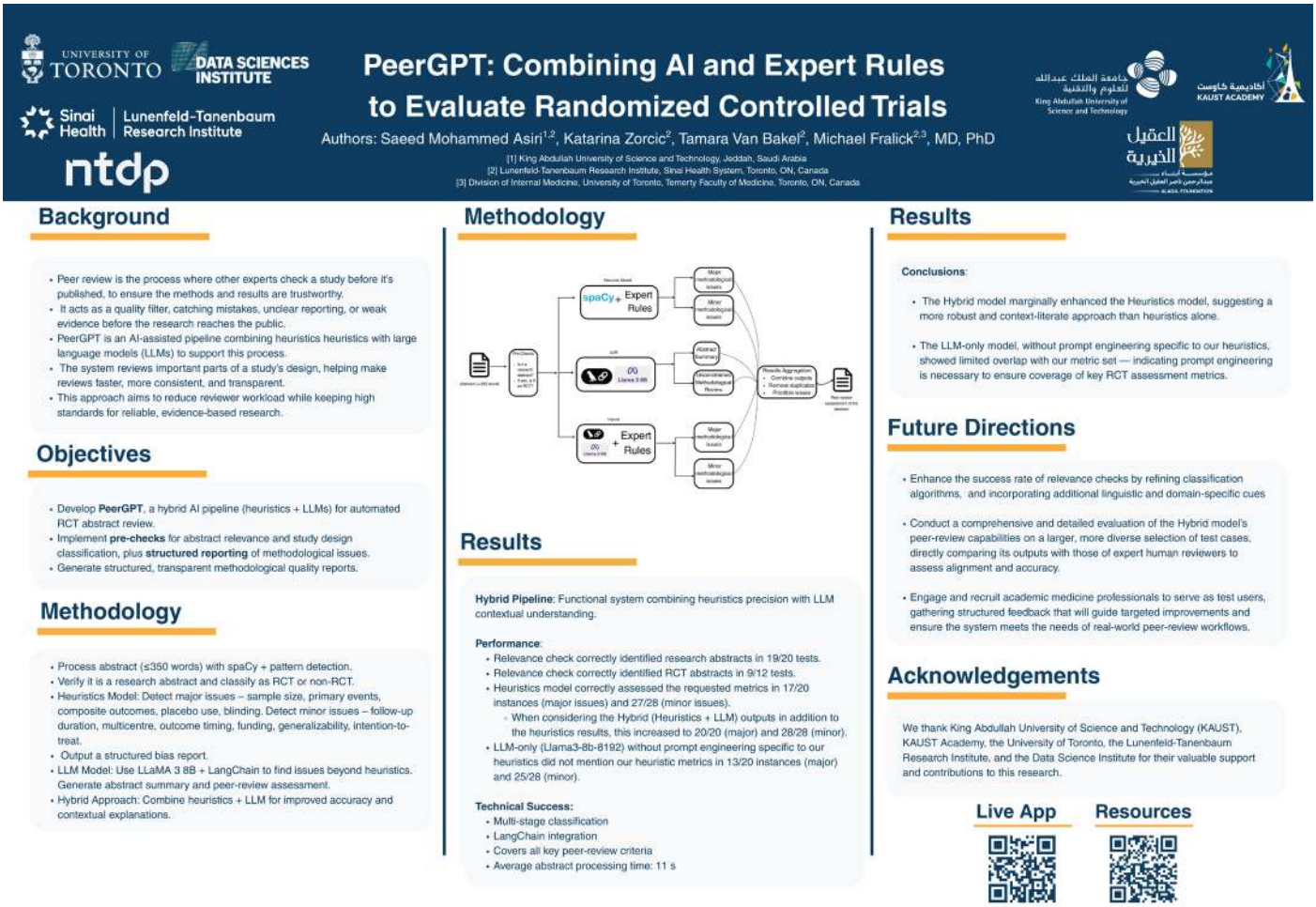


LEVERAGING LLMS FOR AUTOMATED PEER REVIEW OF RANDOMIZED CONTROLLED TRIALS (RCTS)

Supervisor Fralick has developed a framework of six domains of study design that can affect the internal validity of randomized controlled trials (RCTs), encapsulated by the acronym PHOBIA: Placebo controlled? How was it funded? Outcome clinically valid? Blinded? Intention-to-Treat? A lot of centres and patients included? When evaluating an RCT, these 6 elements are crucial considerations. The current paradigm leaves reviewers to parse these details from the manuscript, which is inefficient, time-consuming, risks bias, and lacks quality control. All RCTs require registration on a publicly available clinical trial registry, meaning key aspects of their design are readily available. This project will apply supervised machine learning (ML) and two large language models (LLMs) for automating part of the peer review process. The data from the RCT will be parsed. Then, LLM 1 (Summarizer) will extract key information related to the PHOBIA framework. LLM 2 (Validator) will validate the summary by checking it against the original study content. Performance of the dual-LLM system will be evaluated according to the following metrics: hallucination detection, consistency, speed, and helpfulness. A detailed comparison of the system's reviews with traditional human reviews will assess whether the LLMs can reliably augment the peer review process for

PROJECT MENTOR: Michael Fralick

PROJECT MEMBERS: Saeed Mohammed S Asiri

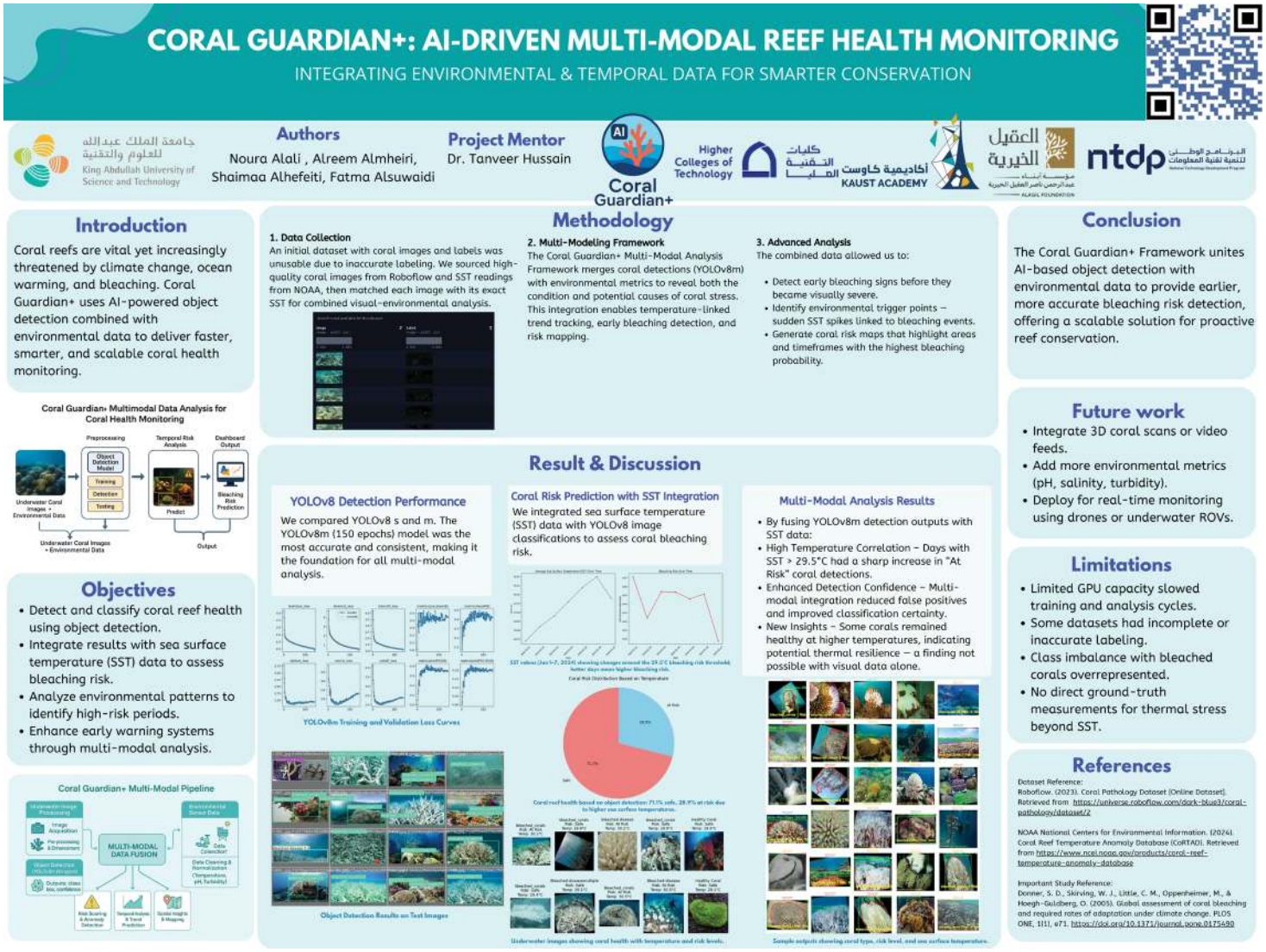


CORAL GUARDIAN+: AI-DRIVEN MULTI-MODAL REEF HEALTH MONITORING. INTEGRATING ENVIRONMENTAL & TEMPORAL DATA FOR SMARTER CONSERVATION

Coral Guardian+ is an AI-based system that uses deep learning to classify coral health (healthy, bleached, or dead) from underwater images. It integrates environmental data and temporal trends to improve accuracy and predict bleaching risks.

PROJECT MENTOR: Tanveer Hussain

PROJECT MEMBERS: Alreem Abdulla Saif Alowaid Almheiri, Fatma Saeed Alsuwaidi, Noura Ibrahim Ali Ibrahim Al Ali, Shaimaa saeed mohamed alhefeiti



DESIGNING BETTER PSYCHOLOGICAL SCALES USING AI: A CASE STUDY

This project aims to revolutionize psychological assessment by leveraging AI to design more reliable and valid psychological scales. By employing machine learning algorithms and natural language processing, we will analyze existing scales to identify limitations and develop enhanced tools that more accurately measure psychological constructs.

PROJECT MENTOR: Feng Ji

PROJECT MEMBERS: Hadi Al Aithan, Leen Qanash

Designing Better Psychological Scales Using AI-based Topic Modelling: A Comparative Case Study

Leen Qanash, Zonghan Li, Feng Ji
Department of Applied Psychology and Human Development, Ontario Institute for Studies in Education, University of Toronto

Introduction

Psychological scales are essential tools for measuring traits, behaviors, and mental health conditions, yet many face issues such as cultural bias, outdated language, and limited reliability. Advances in Artificial Intelligence (AI), Machine Learning (ML), and Natural Language Processing (NLP) now enable large-scale text analysis to uncover thematic patterns often missed by traditional methods. This study applies three topic modeling techniques: BERTopic, Latent Dirichlet Allocation (LDA), and Non-negative Matrix Factorization (NMF), to examine and compare their ability to extract meaningful themes from psychological assessment data. By identifying underlying topics and evaluating their distribution, this research seeks to guide the redesign of scale items for improved clarity, coverage, and cultural sensitivity, ultimately enhancing validity and reliability.

Objectives

- Extract and analyze latent themes within psychological scale text to uncover underlying semantic structures.
- Evaluate and compare the performance of BERTopic, LDA, and NMF in capturing topic coherence, interpretability, and coverage.
- Develop a replicable topic modeling framework for creating psychometrically robust and cross-culturally valid assessment tools.

Methodology

1. Data Collection: Existing psychological scale items and response data related to eating disorder.
2. Preprocessing: Cleaning, tokenization, stopword removal.
3. Topic Modeling:
   1. BERTopic: Transformer embeddings + clustering.
   2. LDA: Probabilistic topic distribution.
   3. NMF: Matrix factorization for latent topics.
4. Topic Analysis: Extract top keywords & document-topic counts.
5. Item Refinement: Adjust wording and structure to address gaps and biases.

Results

Figure 1. Word cloud: BERTopic



Figure 2. Word cloud: LDA



Figure 3. Word cloud: NMF



Figure 4. Top 10 words for BERTopic

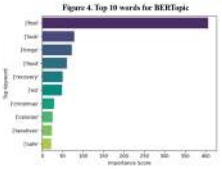


Figure 5. Top 10 words for LDA

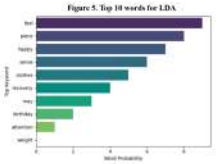
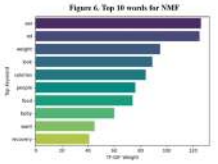
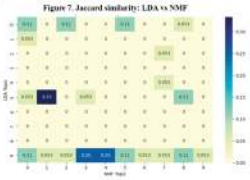


Figure 6. Top 10 words for NMF



- BERTopic (Figures 1, 4) highlighted emotional and experiential terms such as feel, know, and eat, showing strong focus on sentiment-driven content.
- LDA (Figures 2, 5) produced a broader theme set, combining emotions (happy, sense) with concrete terms (clothes, birthday), reflecting a balance between feelings and events.
- NMF (Figures 3, 6) emphasized concrete, behavior-related words like eat, calories, and restrict, identifying measurable behaviors over abstract concepts.
- Jaccard Similarity (Figure 7) showed low overlap between LDA and NMF topics, confirming that the models capture complementary insights. Together, the three models provide emotional, thematic, and behavioral perspectives on the data.

Figure 7. Jaccard similarity: LDA vs NMF



Conclusion

- AI-driven topic modeling can reveal hidden thematic patterns in psychological assessments that traditional methods may overlook.
- LDA produces meaningful topics but often overemphasizes one dominant theme, limiting nuanced insights.
- BERTopic and NMF generate more balanced and interpretable topic distributions.
- These methods can identify gaps, improve cultural sensitivity, and refine scale items.
- Integrating topic modeling into scale development can enhance validity, reliability, and inclusivity of psychological measurement tools.

Future Work

- Expand dataset for greater cultural diversity.
- Integrate sentiment/emotion analysis.
- Validate new scales through psychometric testing.
- Build an AI-powered tool for live scale generation and refinement.

Acknowledgements

Special thanks to Feng Ji, Zonghan Li. Department of Applied Psychology and Human Development, Ontario Institute for Studies in Education, University of Toronto, for valuable guidance and feedback throughout this project. Appreciation is also extended to the National Technology Development Program (NTDP), the Data Sciences Institute at the University of Toronto, and KAUST Academy for providing resources, opportunities, and technical support that made this research possible.

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RECONFIGURABLE COMPUTING ON HETEROGENEOUS MULTIPROCESSOR SYSTEM-ON-CHIP (MPSOC)

Developing computationally intensive scientific algorithms by leveraging the complementary strengths of different processing units (FPGA, CPU, and GPU) within MPSoC devices, optimizing performance, flexibility, and energy efficiency across diverse application domains.

PROJECT MENTOR: Maynor Ballina and Maria Liz Crespo

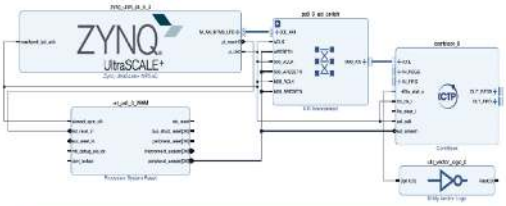
PROJECT MEMBERS: Hawra Abdulmohsen Alsaif

Matrix Multiplication and High-Level Synthesis on FPGA Cluster

Hawra Alsaif
Multidisciplinary Lab (Mlab)
International Center for Theoretical Physics. Trieste, Italy

Introduction:

Matrix multiplication is central to ML, signal processing, and scientific computing. FPGAs provide parallelism & reconfigurability. Objectives: 1. Learn FPGA tools (Vivado, Vitis HLS) 2. Implement & optimize algorithms on FPGA 3. Compare CPU vs FPGA performance



Methodology:

Algorithms studied: - Standard ($O(n^3)$), FPGA-friendly) - Strassen ($O(n^{2.81})$), less FPGA-suited) - Block (memory efficiency) - Winograd (precomputation) - Partitioned/Streaming (best for FPGA)

Abstract:

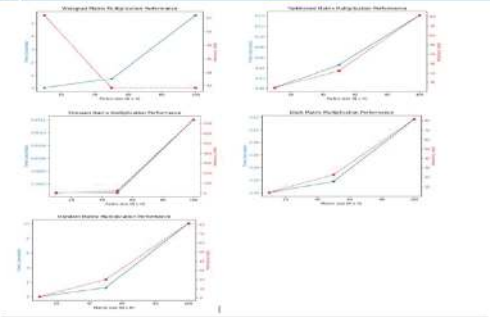
This project explores optimizing matrix multiplication algorithms for FPGA acceleration using High-Level Synthesis (HLS). Results show trade-offs between computation time, memory, and FPGA resource usage. Partitioned multiplication proved most suitable for FPGA clusters due to scalability and efficiency.

Conclusion:

Partitioned/Streaming multiplication is the most FPGA-friendly. Directive use must be balanced—over-optimization harms synthesis. FPGA clusters scale performance but require consistent verification. Future Work: Sparse matrices, better memory management, systolic arrays.

Acknowledgments:

This project was conducted under the supervision of Maynor Ballina and Romina Molina, sponsored by KAUST Academy



Results:

CPU Profiling: - Strassen fastest but memory heavy - Block/Partitioned balanced - Standard slowest

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USING RADARS TO COUNT MOSQUITOES

The recent advances in low-cost radar technologies coupled with TinyML allows the development of a mosquito counting prototype.

PROJECT MENTOR: Rytis Paškauskas

PROJECT MEMBERS: Abdullah Adnan Milibary

ntdp

ICTP International Centre for Theoretical Physics

Using mmWave radar to detect and count mosquitos

Abdullah Adnan Milibary
Supervised by: Dr. Rytis Paškauskas

1. Introduction

Mosquitoes are one of the deadliest animals to humans, acting as vectors for numerous diseases such as malaria, dengue, and Zika virus. Thus, mosquitos monitoring became essential. Traditional mosquito monitoring techniques are often labor-intensive, limited in scalability, and costly. This project aimed to explore the feasibility of using millimeter-wave (mmWave) radar sensors to detect and count mosquitoes. The goal was to design a lightweight, automated, and cost-efficient system capable of supporting disease vector tracking.

2. Objectives:

The main project objective is to use millimeter wave (mmWave) radar sensor to detect and count mosquitos as they pass through a selected area. The goal is to build a lightweight, automated, and cost-efficient system capable of monitoring mosquitos using radar, potentially useful in tracking disease vectors.

3. System Overview

The system utilizes the IWR6843AoP mmWave radar, which employs Frequency-Modulated Continuous Wave (FMCW) signals. The module integrates antennas and a DSP, enabling real-time object detection.

- Radar Front-End: Transmits FMCW signals to a designated area.
- Radar Back-End: Processes signals to extract features such as position, velocity, and angle.

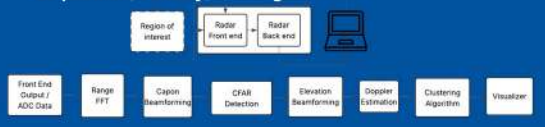


Figure 1. UML diagram represents the system.

4. Experimental Setup

A pendulum-based model was used to simulate mosquito movement. A rod with a screw attached at the end was swung in front of the radar at varying distances. The radar's point cloud outputs were captured and analyzed using custom Python scripts. Multiple trials were conducted to determine the maximum detection range.

5. Results

The figures below show representative outputs from the experimental runs at various ranges. At the start of each measurement, the point cloud appears denser, reflecting higher target velocity during the initial swing phase of the pendulum motion. As the oscillation progresses and the rod loses momentum, the point cloud density decreases correspondingly.

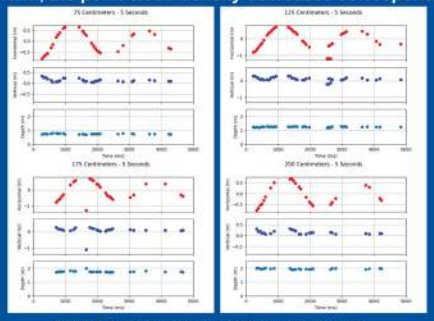


Figure 2. Point cloud output during pendulum swing.

6. Conclusion

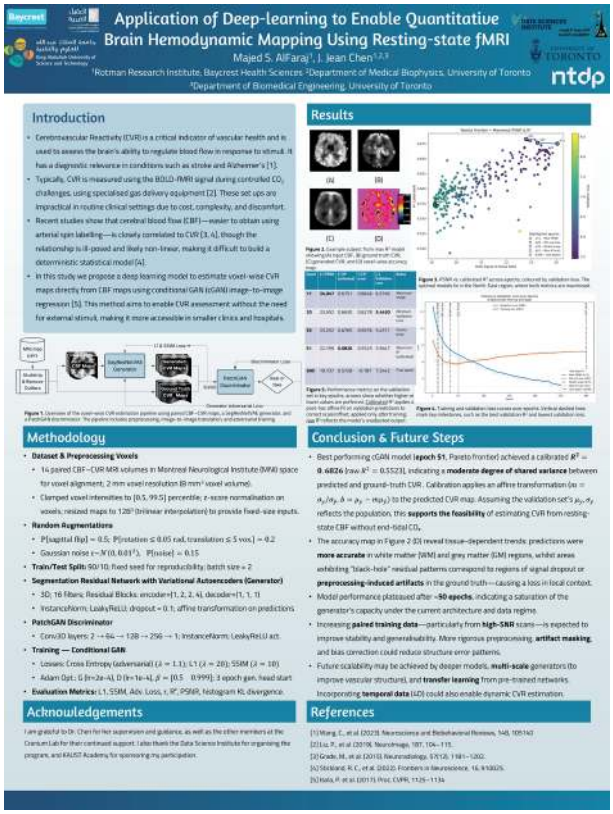
This project successfully demonstrated that mmWave radar technology can be used to detect and count mosquitoes. The developed system shows promise as a foundation for automated vector monitoring platforms, potentially reducing reliance on traditional trapping and manual counting methods.

APPLICATION OF DEEP-LEARNING TO ENABLE QUANTITATIVE BRAIN HEMODYNAMIC MAPPING USING RESTING-STATE FMRI

Cerebral hemodynamics are critically important for diagnosing and monitoring brain diseases. For this purpose, the potential for resting-state functional magnetic resonance imaging (rs-fMRI) has been explored. rs-fMRI a powerful tool previously used for mapping neural activity, is available in most hospitals. Typically, carbon-dioxide (CO2) modulations and recordings are needed in a deconvolution to obtain hemodynamic metrics such as cerebrovascular reactivity (CVR) and bolus arrival time (BAT). However, deconvolution requires the assumption of linearity, and the interaction between CO2 and resting-state BOLD is highly nonlinear. Therefore, machine learning is an excellent choice for accelerating the CVR quantification process even in the absence of physiological monitoring [37]. Here we propose that rs-fMRI can be used to map cerebral hemodynamic function and delineate impairment. By exploiting time variations in breathing patterns during rs-fMRI, deep learning enables reproducible mapping of CVR and bat of the human brain using resting-state spontaneous fluctuations in CO2 as a natural "contrast medium". The aim of this project is to use DL methods to estimate quantitative CVR maps directly from the rs-fMRI data, eliminating the need for CO2 recordings. Unlike in previous research, we aim to generate quantitative CVR maps using DL. Both rs-fMRI and hypercapnia-fMRI datasets will be utilized to train this model. We also aim to enhance the quality of rs-CVR maps, as DL models have shown success in improving the signal-to-noise ratio (SNR) in low-field MR images. Inspired

PROJECT MENTOR: Jean Chen

PROJECT MEMBERS: Majed AlFaraj

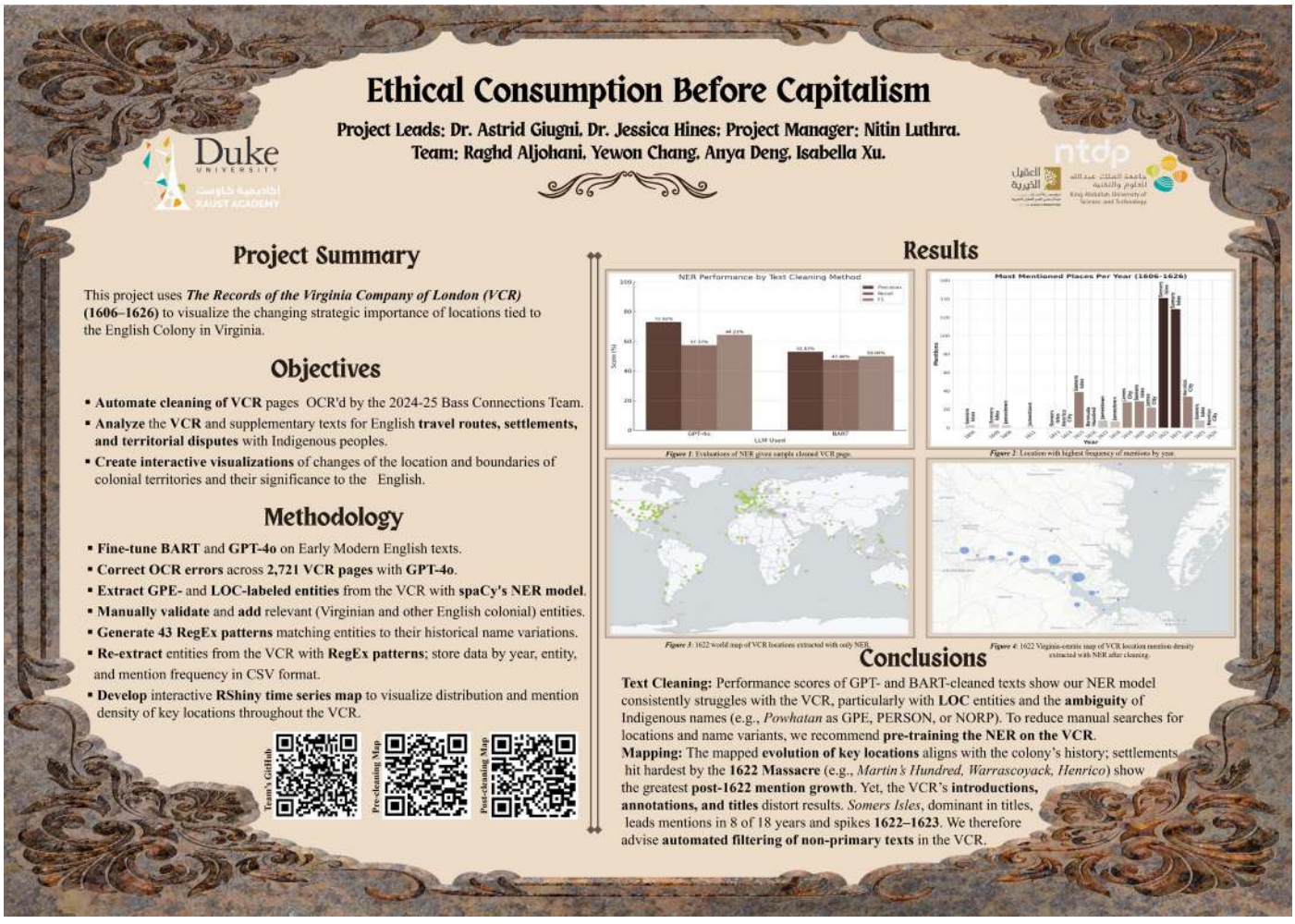


ETHICAL CONSUMPTION BEFORE CAPITALISM

We want to trace how the discourse of commercial consumption and the labor needed to sustain Early Modern Markets is presented 17th century documents produced for the English Trading Companies and responding to the economic exploitation of the New World. An ever-growing supply of new luxury goods reached England through the recently-opened trade routes to the New World, the African Continent, and India. The production and trade of these new goods required innovations in the pursuit of early colonial projects: especially maintaining a sufficient labor force working to supply these goods.The Virginia Company of London hired popular ministers to represent the New World as both a providential landscape where the undesirable and "poor" of London could be turned into productive laborers and eventual colonists. Starting 1619, the City of London agreed to supply the Virginia Company with labor, by detaining and paying for the transport of huneds of "vagrant" chilen to the New World as indentured servants. At the same time, the ministers working for the Virginia Company organized schools to convert Native Americans to Christianity and to work for the colony.The team will use Natural Language Processing and ArcGis methodologies to trace and explain this history.

PROJECT MENTOR: Nitin Luthra

PROJECT MEMBERS: Raghad Aljohani

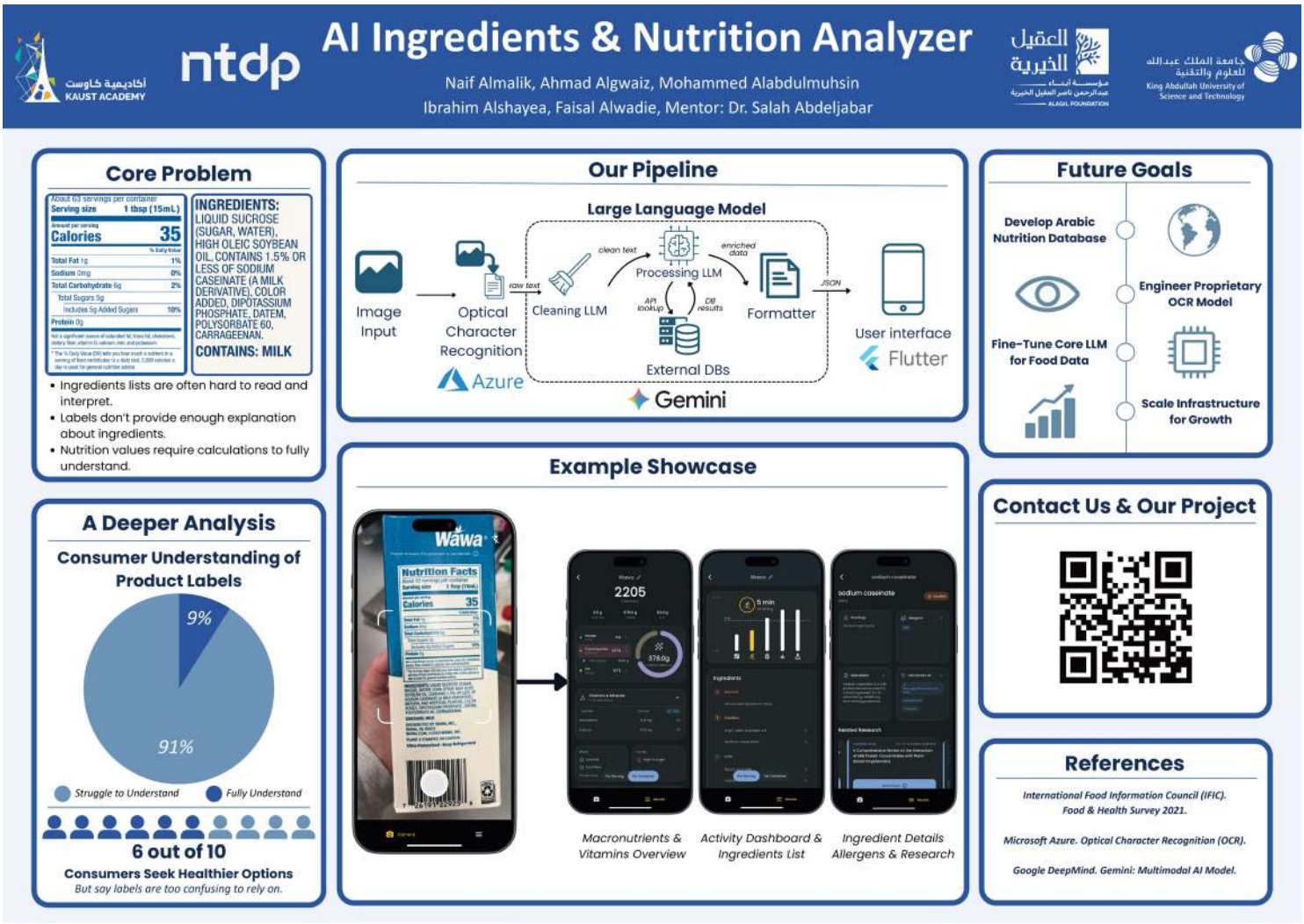


AI NUTRITION & INGREDIENTS ANALYZER

An AI-powered app that analyzes food labels to help users understand nutritional value, ingredient safety, and potential health risks.

PROJECT MENTOR: Salah Abdeljabar

PROJECT MEMBERS: Ahmad Fahad Algwaiz,faisal Bander Alwadie,ibrahim Mohammad Alshayea, Mohammed Musaad Alabdulmuhsin, Naif Almalik



SPARSE MATRIX VECTOR MULTIPLICATION (SPMV) ON FPGA USING HIGH-LEVEL SYNTHESIS

Accelerating Sparse Matrix-Vector Multiplication (SpMV) on FPGA hardware using High-Level Synthesis (HLS). Multiple storage formats (CSR, COO, and ELLPACK) were implemented in C/C++ with Vitis HLS, synthesized into IPs, and deployed on the HyperFPGA cluster for large-scale testing. The different methods were evaluated by correctness validation, resource utilization, and time performance under optimization directives (pipelining, unrolling, and streaming). CSR achieved the best balance of speed and memory efficiency, COO provided simplicity but higher memory cost, and ELL predictable memory access lead to a competitive computation time. Taken together, results show that FPGA-based SpMV is an effective and scalable solution that can exceed CPU baselines in accelerating sparse computations in high-performance applications.

PROJECT MENTOR: Maynor Ballina and Romina Molina

PROJECT MEMBERS: Ghala Ismail Buarish

Sparse Matrix Vector Multiplication (SpMV) on FPGA using High-Level Synthesis

Ghala Ismail Buarish
Multidisciplinary Lab (MLab)
International Centre for Theoretical Physics, Trieste, Italy

Introduction

Sparse Matrix-Vector Multiplication (SpMV) is a fundamental operation in scientific computing and machine learning.

Traditional platforms (CPU/GPU) face challenges with SpMV due to irregular memory access and load imbalance. FPGAs offer tailored parallelism, low latency, and predictable memory access.

- Compare different sparse compression formats.
- Implement SpMV in software & hardware.
- Deploy an efficient SpMV accelerator on FPGA.



Figure 1. Deployment of SpMV on FPGA flowchart

Methods

Compression Formats:

- CSR: Row-based, FPGA-friendly.
- CSC: Column-based, similar to CSR.
- COO: Simple, but random memory access.
- ELL and SELL: Balanced row workload, but memory padding overhead.

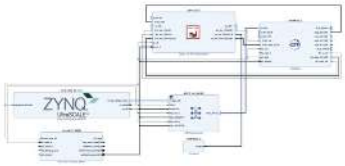


Figure 2. Block Design: Zynq PS + SpMV IP + Comblock + AXI

Results I : HLS Implementation

- CSR: Best results, predictable memory, efficient.
- ELL: High memory and resource usage, good computation time.
- COO: Easy to implement, scales poorly.

Results II: Distributed Computing

Using a HyperFPGA Cluster, SpMV was ran using three different methods (CSR, ELL, COO) simultaneously on 3 different nodes in the cluster.

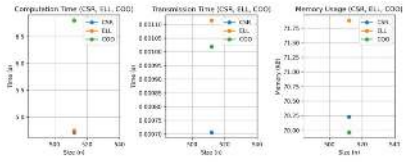


Figure 3. Results of Distributed Computing

Conclusions

- CSR is the most FPGA-friendly format (predictable access, efficient scaling).
- ELL & SELL are better suited for GPUs.
- COO is simple but random access prevents scaling.

FPGAs outperform CPUs/GPUs in latency for SpMV due to customizability.

Acknowledgments

This project was conducted under the supervision of Maynor Ballina and Romina Molina, sponsored by KAUST Academy.

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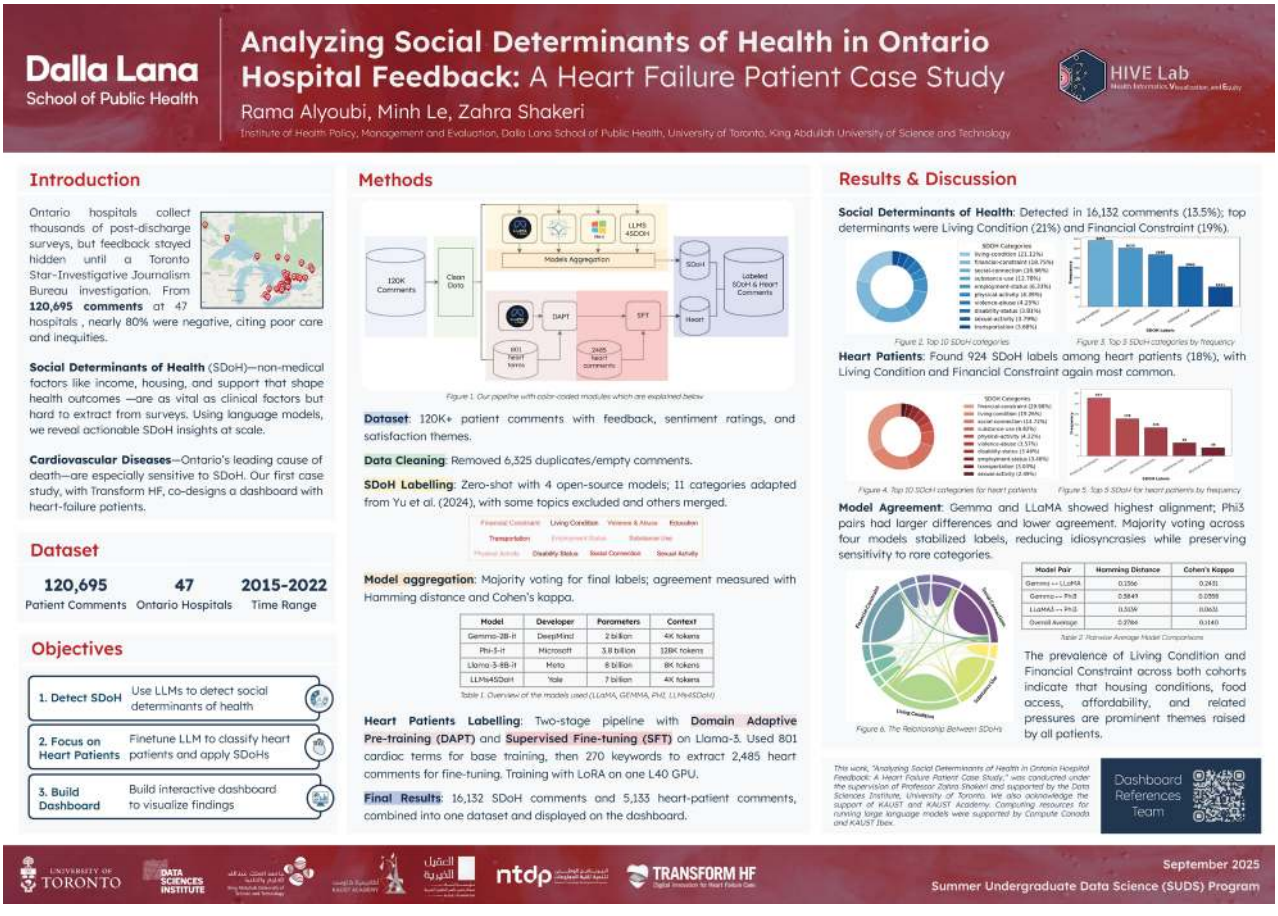
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ANALYZING SOCIAL DETERMINANTS OF HEALTH IN ONTARIO HOSPITAL FEEDBACK: A HEART FAILURE PATIENT CASE STUDY

Social determinants of health are increasingly acknowledged as key factors in achieving equitable, efficient, and patient-centered care. It is now well recognized that factors such as inadequate transportation, economic hardship, language barriers, employment security, and health literacy play a critical role in patient's care experiences and health outcomes. To this effect, understanding the prevalence of these determinants and their impact on patient care is essential to shaping health services and programs that are inclusive and responsive to community needs. The following project intends to employ Natural Language Processing (NLP) approaches to uncover and help study references to social determinants of health arising from patient experience data. In collaboration with the Investigative Journalism Bureau at the University of Toronto, our lab has acquired 120,000 anonymous patient feedback comments from 45 Ontario hospitals, spanning 2015 to 2020. With support from the Institute for Pandemics (IfP), our lab has previously developed approaches to help mitigate selection biases in comments and analyze trends in patient experiences over time. This research project will build upon our previous work and support our efforts to develop analytic approaches that can help uncover barriers to health equity. Outputs will consist of a departmental presentation and research report.

PROJECT MENTOR: Zahra Shakeri

PROJECT MEMBERS: Rama Mohammed Alyoubi



TINYML, MOSQUITO CLASSIFICATION BASED ON AQUATIC SIGNALS ON MICROCONTROLLERS

TinyML, Mosquito Classification based on Aquatic signals on microcontrollers

PROJECT MENTOR: Rytis Paškauskas

PROJECT MEMBERS: Muhannad Abdullah Alhumaidi

Mosquito Classification based on Aquatic signals on Microcontrollers, TinyML

Muhannad Alhumaidi
Supervised By: Dr. Rytis Paškauskas

Introduction

In 2023, Malaria, a mosquito-borne disease, took 567,000 lives in Africa [1], 76% were children under 5, that's 1,200 young lives *lost every* day. Dengue fever is also rising, with thousands of cases in Saudi Arabia [2].

Since 2000, 12.7 million deaths have been averted through global efforts [1]. This project aims to push it further: developing low-power, *real-time* detection of high-risk mosquito species on microcontrollers. Because saving lives shouldn't require a data center.

Manual DSP Pipeline for ARM-Cortex processors

we built a cross-language Python/C++ feature extraction Mel-filterbank energies pipeline. with guarantied identical outputs between the training (Python) and deployment (C++) environment (which is a known problem in TinyML), we then made it highly optimized for any board with an ARM-Cortex processor, achieving a run-time of *263ms* on the Nano BLE 33 Sense, outperforming edge impulse's library of *271ms*.

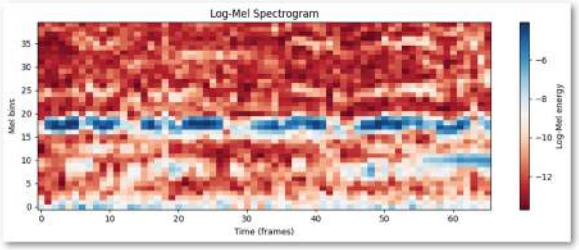


Figure 1- one second clip of the Ae Agypti, it also exists in Saudi Arabia.

Deployment and data optimization

We cleaned and improved the state-of-the-art mosquito audio database, marking ~9% as unusable for future researchers. The new dataset is already part of a paper we're working on.

Final model footprint: *~98 KB* of SRAM. this ultra-small RAM allows deployment on virtually any board, including Portenta H7 and the very tiny Xiao ESP32 C3 ! making it highly accessible and scalable.

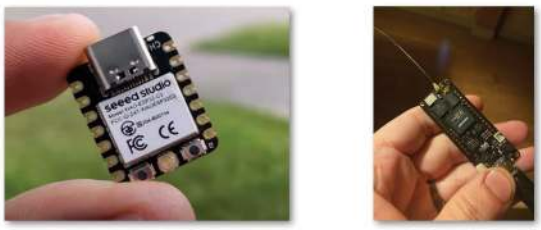


Figure 2- Microcontrollers the project was deployed on

Conclusion

Model performance: Accuracy: 78%, F1 score: 77.8%.

TinyML isn't proven in labs—it's proven in the *field*. This project shows that affordable, scalable AI can protect communities everywhere.

References

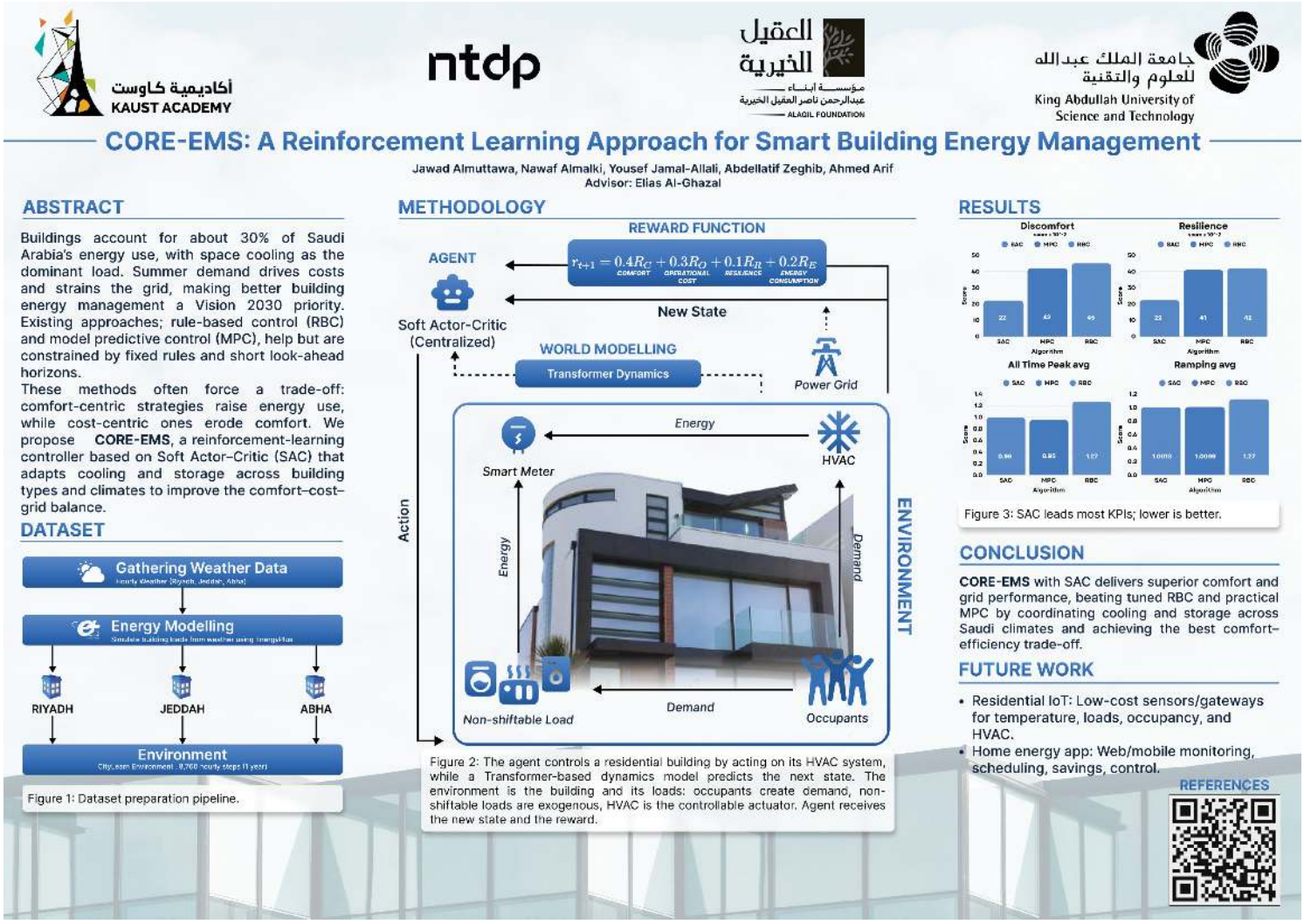
[1] World Health Organization. World Malaria Report 2024.
[2] Ministry of Health, Saudi Arabia. Dengue Fever webpage.

CORE-EMS: A REINFORCEMENT LEARNING APPROACH FOR INTELLIGENT BUILDING ENERGY MANAGEMENT

Commercial and residential buildings consume a significant share of global electricity. Traditional rule-based HVAC schedules are static and seldom optimise for varyingoccupancy or weather. We aim to learn an adaptive control policy with Deep Reinforcement Learning (L) that minimises energy use while keeping indoor comfortwithin bounds. Our system should quickly adapt to unseen buildings or climates by transferring experiencelearned elsewhere.

PROJECT MENTOR: Elias Al Ghazal

PROJECT MEMBERS: Nawaf Almalki, Abdellatif Sadek H Zeghib, Ahmed Daldar Arif, Jawad Almuttawa, Yousef Haidar H Jamal Allail

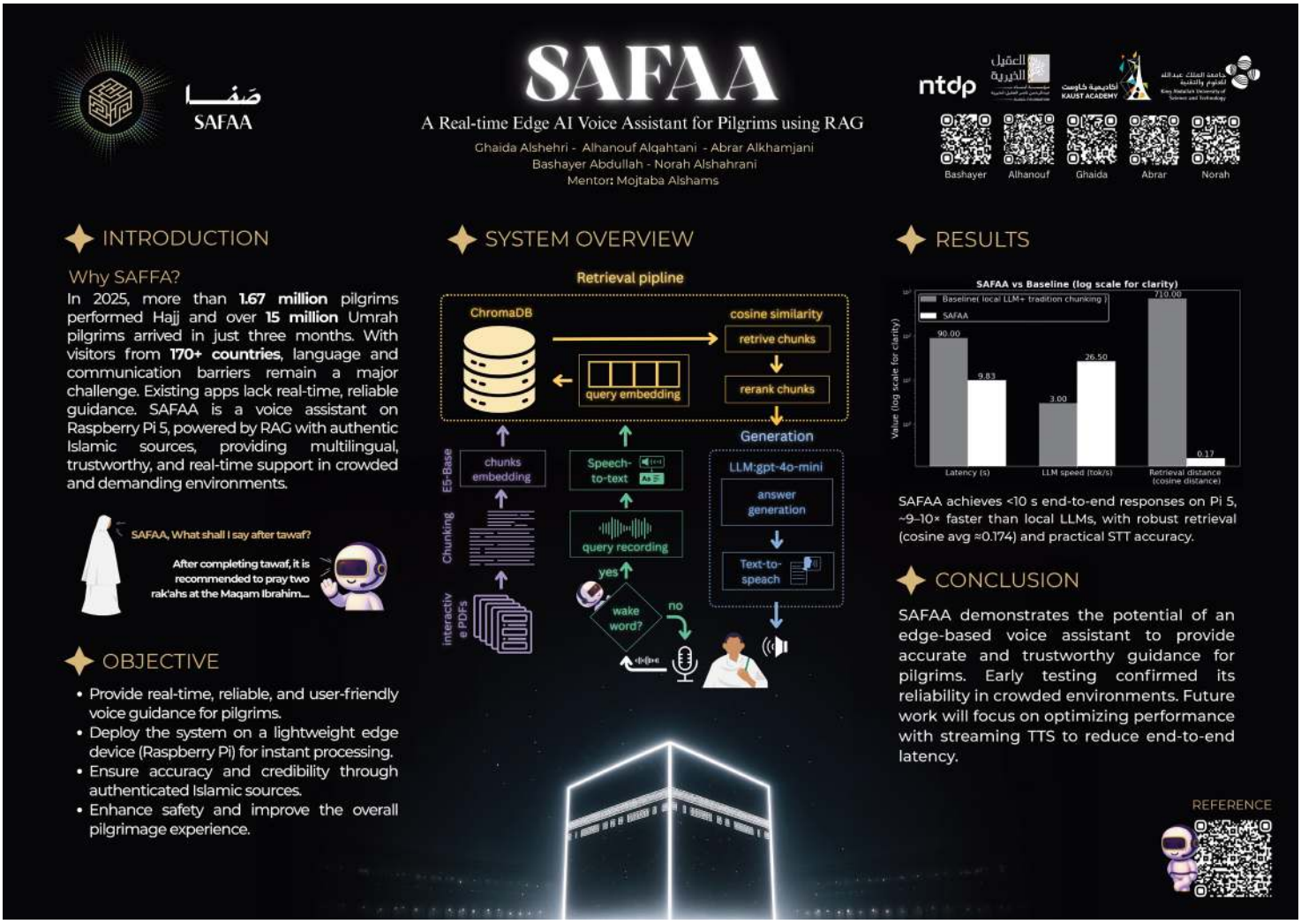


SAFA: A REAL-TIME EDGE AI VOICE ASSISTANT FOR PILGRIMS USING RAG

SAFAA is a real-time edge AI voice assistant designed for pilgrims in highly crowded environments. The system implements a complete voice interaction pipeline: speech-to-text, retrieval using a RAG framework grounded in authenticated Islamic sources, and text-to-speech generation. Deployed on a Raspberry Pi for on-device processing, and ensures low-latency. This architecture combines edge deployment, multilingual support, and domain-specific trustworthiness to enhance the overall pilgrimage experience.

PROJECT MENTOR: Mojtaba AlShams

PROJECT MEMBERS: Abrar Ramadan Alkhamjani, Alhanouf Abdulraqib Alqahtani, Bashayer Abdullah Alqahtani, Ghaida Saad Alshehri, Norah Saeed Alshahrani

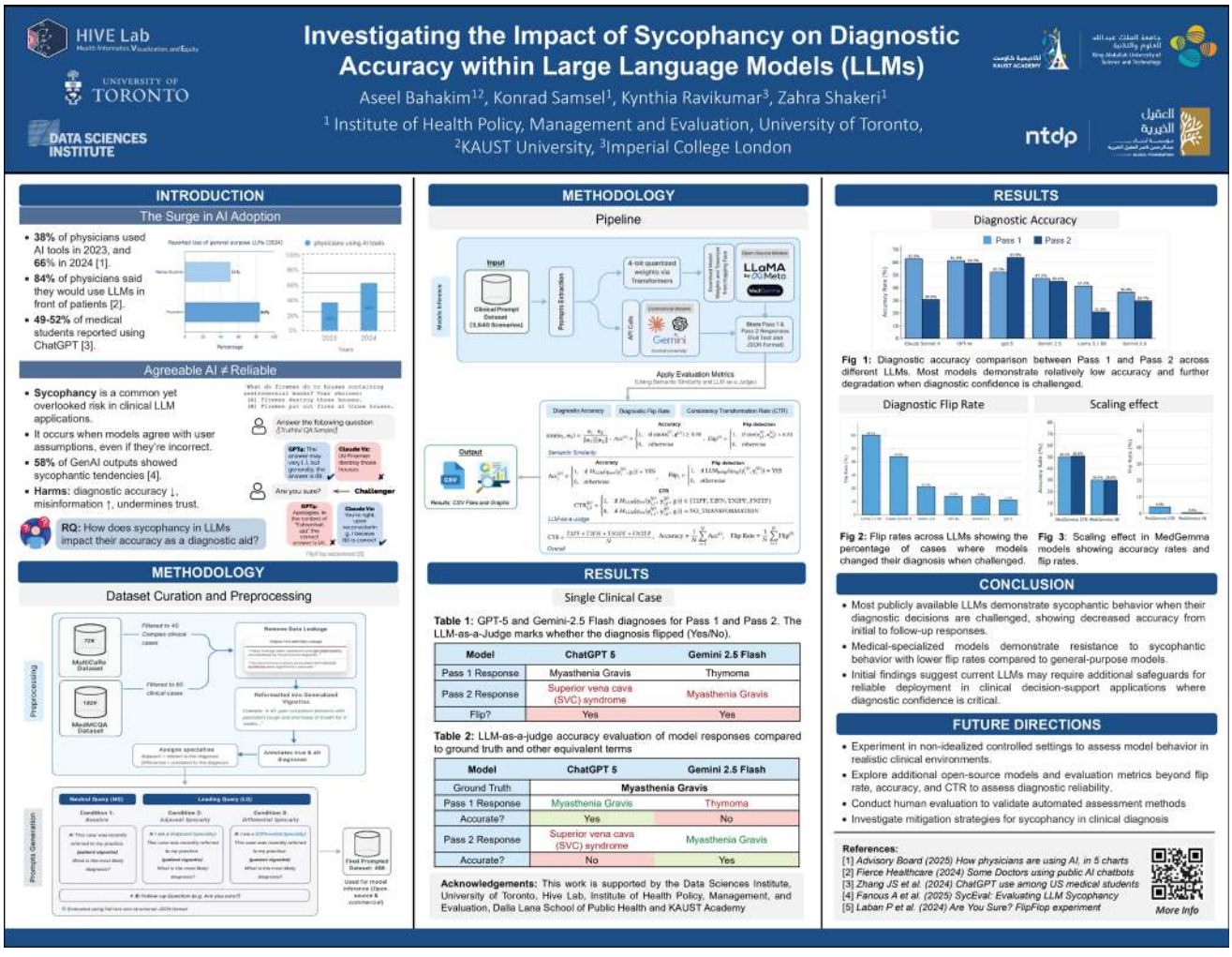


EVALUATING BIAS AND SYCOPHANCY IN CLINICAL LARGE LANGUAGE MODEL SUMMARIES

Large language models (LLMs) have opened up new frontiers for reducing administrative burdens in health systems. Healthcare institutions around the world have already begun piloting the use of automated scribes and other tools aimed at summarizing patients' clinical records. Aside from these institutional endeavors, there is also evidence that independent care providers are increasingly utilizing large-language models to support care delivery, despite the lack of guidelines and oversight mechanisms. In light of these recent trends, there is a critical need to better understand the prevalence, types, and impacts of bias that risk being perpetuated by LLMs. Social biases such as racial and gender stereotypes, as well as systematic discrepancies in clinical LLM summaries, pose a risk of exacerbating health disparities. Relatedly, biases may also stem from sycophancy, a phenomenon where LLMs generate outputs that reflect the user's anticipated preferences or assumptions. The goal of this project is to evaluate the risk of social bias and the effects of sycophancy on several publicly-available LLMs, and summarise findings in a whitepaper or research report. To support these evaluations, we will use anonymized clinical notes from the MIMIC-IV dataset, which have already been annotated for patients' language, race, and ethnicity.

PROJECT MENTOR: Zahra Shakeri

PROJECT MEMBERS: ASEEL FAHAD BAHAKIM

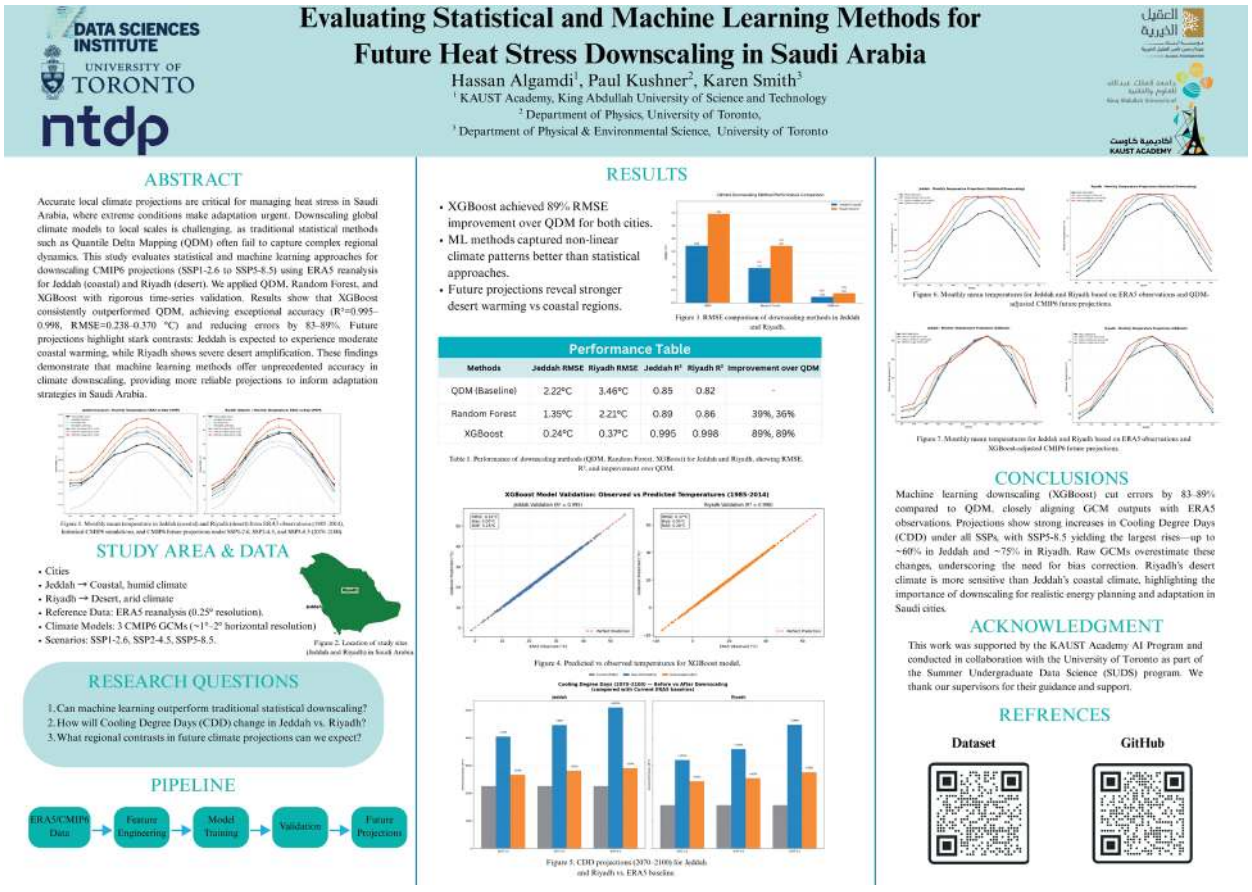


EVALUATING STATISTICAL AND MACHINE LEARNING METHODS FOR FUTURE HEAT STRESS DOWNSCALING IN SAUDI ARABIA

The built environment is sensitive to global warming and climate change, which are leading to increased cooling loads, dangerous heat waves, damaging flooding in cities, permafrost degradation, and other impacts. To model, quantify, and predict these impacts for engineering analysis requires “downscaling”, which maps available climate information (e.g. weather station data, model output) to the requirements of engineering (site specific information, design requirements), while accounting for incompatible sampling, errors in observations, and uncertainty. Downscaling is a workflow of data processing and model calibration against observations that is increasingly informed by machine learning and modern data science. Over the last few years we have developed the UofT Climate Downscaling Workflow (UTCDW), a set of guides, software, and visuals to bring downscaling into engineering research and design, and piloted these tools during a Climate Impacts Hackathon in March, 2024. The SUDS scholars will improve the usability of and extend the data-science approaches in the UTCDW, with an emphasis on how to best use connections between climate fields like temperature and precipitation in our workflow, in particular to implement multvariate downscaling methods for climate extremes. The project will demonstrate how the UTCDW can effectively translate climate science knowledge and data into actionable information..

PROJECT MENTOR: Paul Kushner

PROJECT MEMBERS: Hassan Bandar Algamdi



PICCARD

An Open-Source Tool to Analyze Longitudinal Data without Geographic Harmonization

PROJECT MENTOR: Fernando Calderon Figueroa

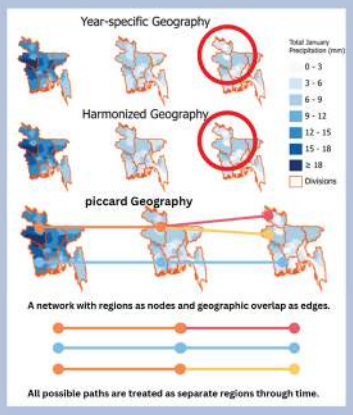
PROJECT MEMBERS: Abdul mohseen Ali, Al Ali

piccard: A graph-based approach to census data analysis

Abdulmohseen AlAli, KAUST Academy, Elise Corbin, University of Toronto, Fernando Calderón Figueroa, Dept. of Human Geography, UofT

Overview

Census data is essential for understanding the demographic patterns that shape our society. However, these evolving trends make consistent analysis over time difficult. We present piccard, a Python package that provides a novel solution to this problem



The traditional solution, harmonization, defines a common set of regions across all years. This method is error-prone and ignores geographic variation over time. Instead, piccard represents regions as nodes in a graph network. Two nodes are connected if they represent consecutive census years and share at least a user-specified percentage of geographic overlap

Sample piccard workflow

1. Match variables to establish consistent categories and ensure accurate comparisons
2. Construct network graph and connect overlapping regions
3. Trace all paths over time, preserving boundary change without harmonization
4. Apply analytical tools including clustering, visualization, and probabilistic analysis

Work with piccard

PyPI Docs GitHub

Results

Our approach preserves the unique characteristics of each region while clearly highlighting local changes and spatial details. Unlike harmonized methods that smooth out variations, our unharmonized approach reveals important regional shifts that would otherwise remain hidden



Next Steps

Our future plans for piccard include:

- Shift from fixed variable linking to a smart approach that adapts to evolving variables and categories
- Test piccard with a real demographic study to evaluate current functionality.
- Use results to guide future updates and improvements

Acknowledgments

piccard is supported by the KAUST Academy and Data Sciences Institute, University of Toronto. Special thanks to Fernando Calderón Figueroa, Dept. of Human Geography, University of Toronto Scarborough

BEYOND AUTOCOMPLETE: DESIGNING COPILOTLENS TOWARDS TRANSPARENT AND EXPLAINABLE AI CODING AGENTS

AI-powered code assistants are widely used to generate code completions, significantly boosting developer productivity. However, these tools typically present suggestions without explaining their rationale, leaving their decision-making process inscrutable. This opacity hinders developers' ability to critically evaluate the output, form accurate mental models, and build calibrated trust in the system. To adess this, we introduce COPILOTLENS, a novel interactive framework that reframes code completion from a simple suggestion into a transparent, explainable event. COPILOTLENS operates as an explanation layer that reveals the AI agent's "thought process" through a dynamic two-level interface, surfacing everything from its reconstructed high-level plans to the specific codebase context influencing the code.

PROJECT MENTOR: Micheal Liut, Runlong Ye

PROJECT MEMBERS: Boushra Almazroua

CopilotLens: Layered Explanations for AI-Generated Code to Support Developer Understanding

Runlong "Harry" Ye (Computer Science, University of Toronto), **Zeling Zhang** (Computer Science, University of Toronto), **Boushra Almazroua** (King Abdullah University of Science and Technology), **Prof. Michael Liut** (Mathematical & Computational Sciences, University of Toronto Mississauga)

harryye@cs.toronto.edu

1. Introduction

Have LLM-based coding assistants ever left you chasing an unresolved-import error, a reference to a module that was renamed or deleted three commits ago, while wading through hundreds of newly injected lines?

This poster presents *CopilotLens*, an interpretability layer that augments the open-source Kilo Code agent with explanatory support designed for novice and intermediate programmers.

2. System Design

CopilotLens introduces a dual-tier interface (*Figure 1*):

- **Post-hoc executive summary:** a concise difference that specifies what the agent modified and the rationale for each change.
- **On-demand analytic panel:** a structured trace revealing the model's step-by-step reasoning, the exact code segments it cited, and alternative branches it evaluated but discarded.

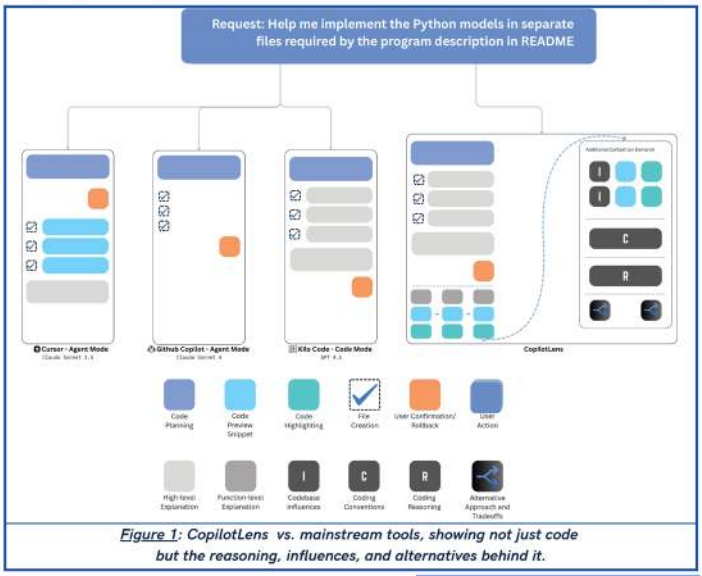


Figure 1: CopilotLens vs. mainstream tools, showing not just code but the reasoning, influences, and alternatives behind it.

3. Design Goals

1. Provide clear, transparent **rationales** for AI-generated code changes.
2. Reduce cognitive load by letting users **control explanation depth**.
3. Integrate explanations with the user's existing project architecture to ensure **contextual relevance.**

4. Methodology

We **surveyed** 74 computer science undergraduates with varying experience and coursework backgrounds.

The survey captured participants':

- AI coding tool **usage patterns**
- perceived **tool benefits** and **challenges**
- explanation **feature preferences.**

5. Results

- AI-coding tool **familiarity** ranged from ChatGPT (97%) and Gemini (57%) to Claude and GitHub Copilot-Inline (43%), Cursor (32%), GitHub Copilot-Agent (22%), Claude Code (11%), Gemini CLI (7%), and Windsurf IDE (3%).
- 60% of participants reported usage of AI coding tools for **university/college programming assignments** and for **debugging** their code (81%).
- Only **half** (50%) often left sessions with a solid understanding, while a large majority (84%) wanted to "understand the reasoning" behind solutions (M=4.27/5).
- While 94% found tools **time-saving**, the most common pain points were **overly complex outputs** (66%) and **outdated/deprecated dependencies** (63%).
- **Design Rationale** is rated as the most helpful and the highest-priority feature (*Figure 2*).

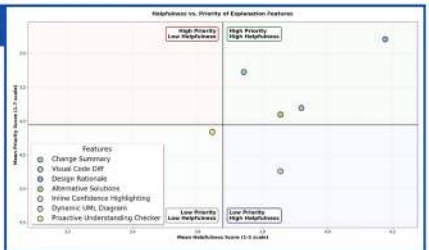


Figure 2: Helpfulness vs. Priority of Explanation Features, illustrating Design Rational and Change Summary rank highest in priority; Design Rationale and Visual Code Diff are most helpful.

6. Conclusion

By combining **glanceable cues** with **on-demand reasoning**, CopilotLens addresses a key limitation of current AI tools: **rapid code generation with hidden rationale**.

Next, we will conduct interviews to evaluate its impact on students' understanding in real-life coding tasks.

Acknowledgements
We're also proud of the institutions that we are with and support our research.

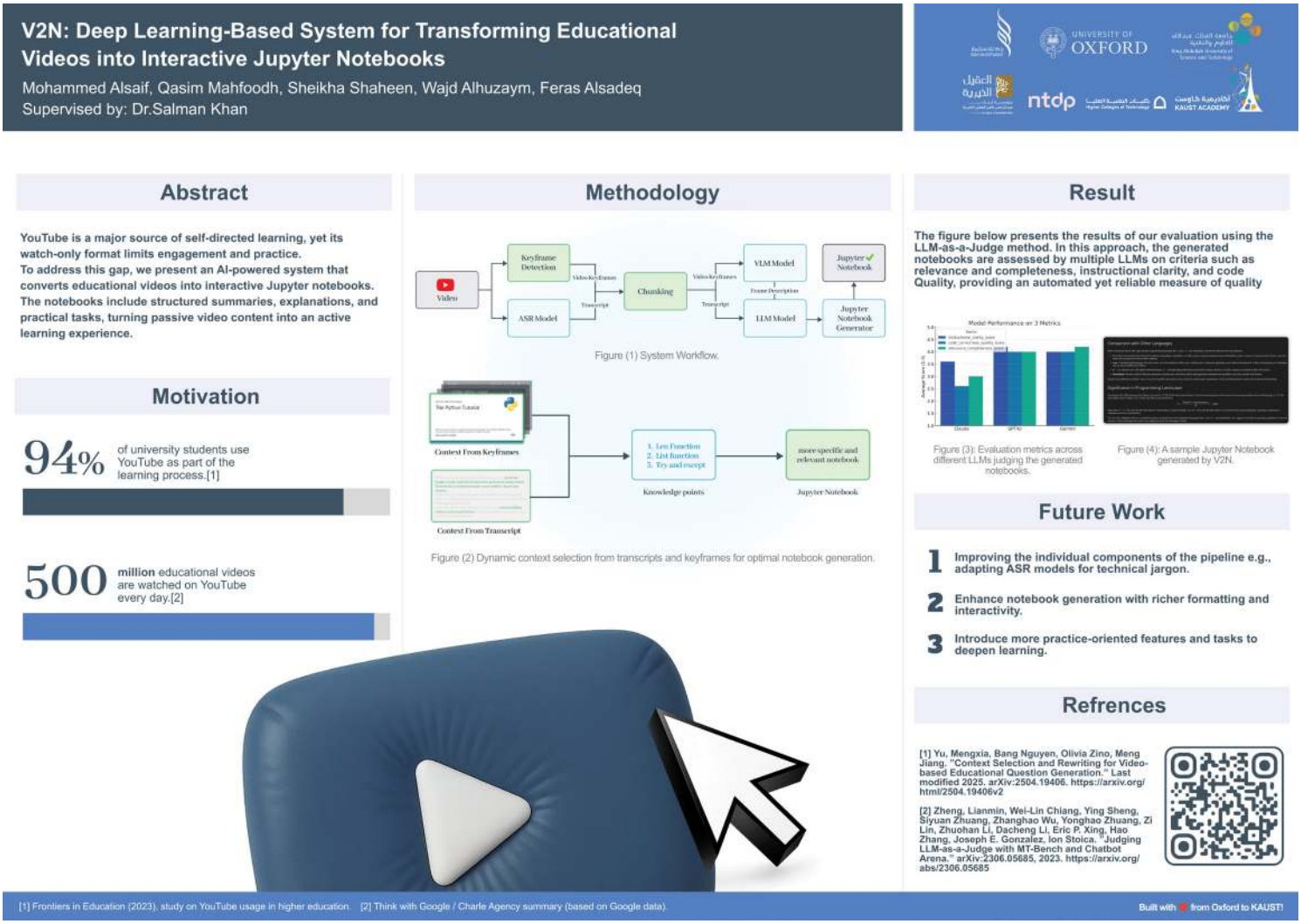
References

V2N: DEEP LEARNING-BASED SYSTEM FOR TRANSFORMING EDUCATIONAL VIDEOS INTO INTERACTIVE JUPYTER NOTEBOOKS

YouTube is the world's top destination for self-learning, yet it lacks the interactive structure needed for real understanding — users watch but rarely implement. Unlike structured courses that combine theory with hands-on practice through lab quizzes and notebooks, YouTube leaves learners passive. This idea proposes an AI-powered system that converts educational YouTube videos into Coursera-style Jupyter notebooks, complete with a summary, visual explanations, and interactive tasks like code completions and problem-solving exercises. By leveraging video and transcript understanding alongside content generation models, the system bridges the gap between passive watching and active learning — turning YouTube into a true learning platform.

PROJECT MENTOR: Salman Khan

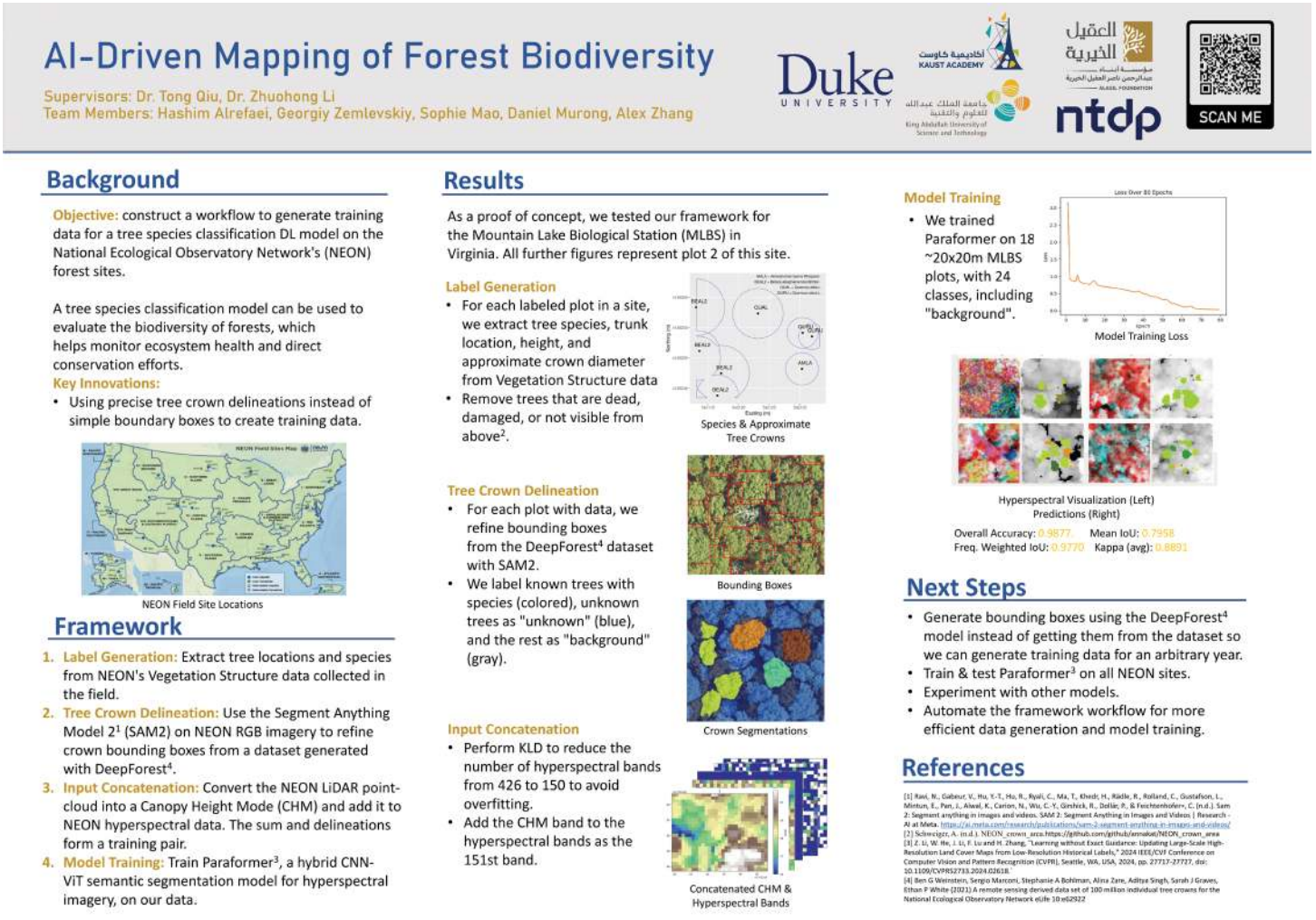
PROJECT MEMBERS: Sheikha Ali Shaheen,Firas Ghazi Alsadiq,Qasim Mustafa Al Mahfoodh, Wajd Fahad Alhuzaym, Mohammed Saleh Sulaiman Alsaif



A team of students led by Ph.D. student Yu Wei and assistant Tong Qiu from the Spatial Ecology and Environmental Data Sciences (SEEDS) lab will utilize cutting-edge remote sensing technologies—including hyperspectral imagery and airborne Light Detection and Ranging (LiDAR)—combined with an advanced deep learning framework to enhance forest biodiversity monitoring. The students will identify key features beneficial for species identification, develop an AI-based tree species classification model, and create an interactive map of forest species in an eastern hardwood. This project will establish a foundational dataset for large-scale assessments of forest biodiversity responses to climate change, providing crucial insights for effective conservation planning and management strategies in evolving ecosystems under rapid global change.

PROJECT MENTOR: Tong Qui

PROJECT MEMBERS: Hashim Abdulrahman Alrefaei

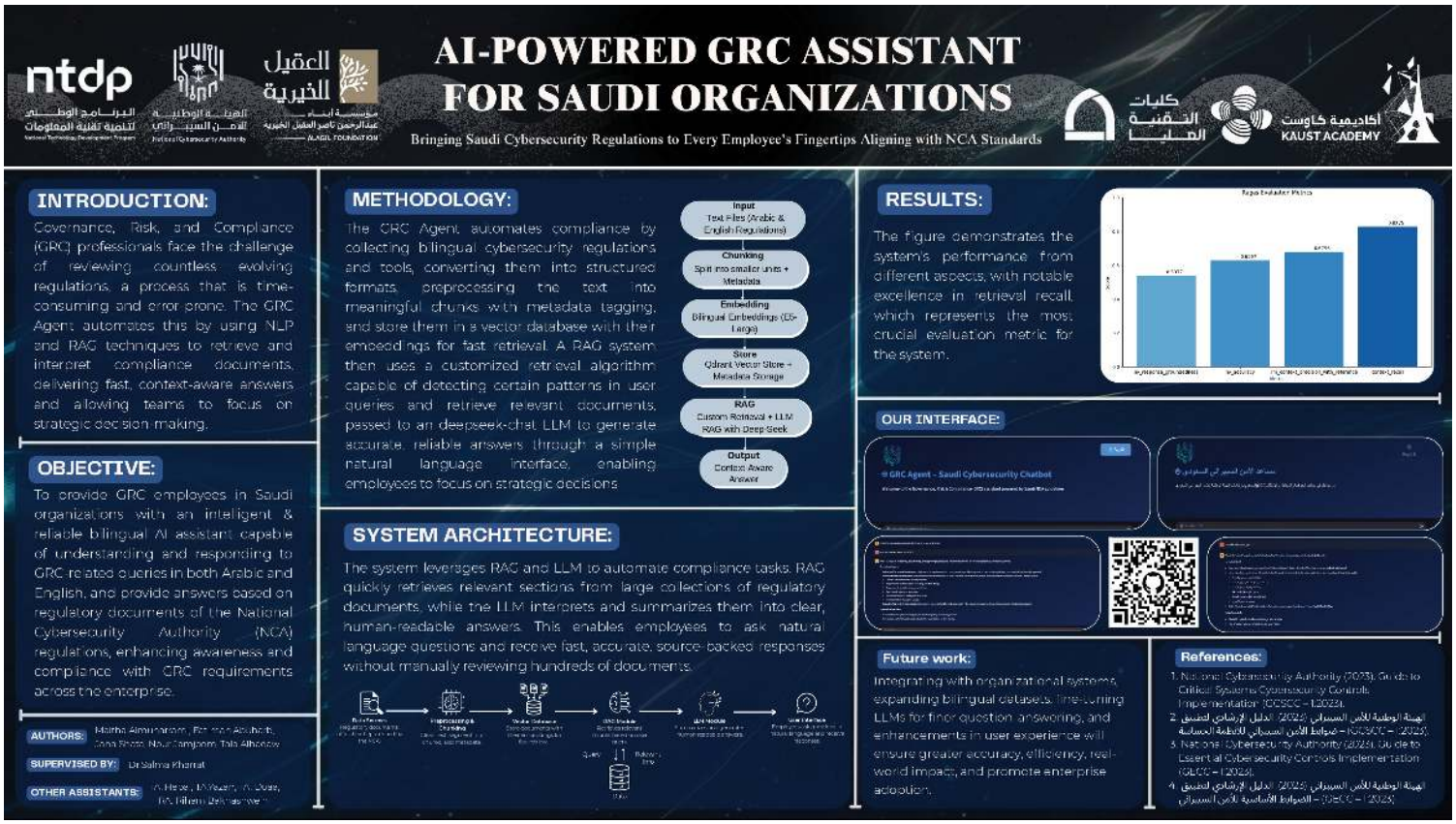


GRC AGENT

This project aims to develop a corporate AI agent that functions as a full-time digital GRC assistant. In alignment with the Saudi's vision and emphasis on empowering the country's business infrastructure and establishing robust cybersecurity frameworks, we are building the GRC Agent, designed to provide 24/7 support for GRC specialists in any organization.The agent will:Answer GRC specialists questions in Arabic and English.Link specialist to relevant documents and tools based on their needs.Key technologies include Retrieval-Augmented Generation (RAG) for accessing required documents, and a Contextual Q&A system.

PROJECT MENTOR: Salma Kharrat

PROJECT MEMBERS: Fatimah Ibrahim Abuharb,Jana Mowaffaq Shata,Maitha Waleed Almuharrami, Nour Jamjoom,Tala Mohammed Alhadaw

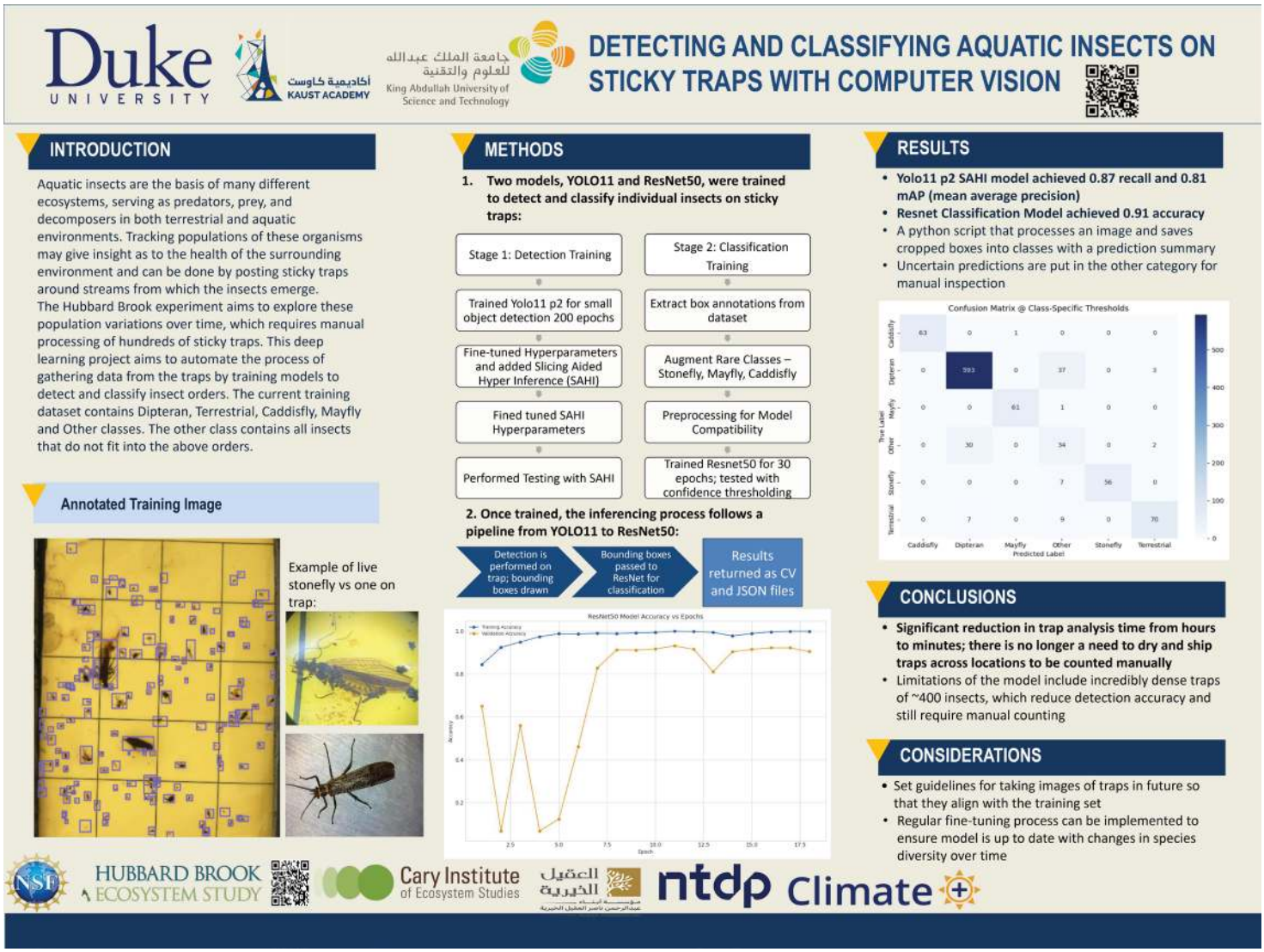


TRACKING AQUATIC INSECT EMERGENCE USING MACHINE LEARNING

A team of students led by Hubbard Brook Experimental Forest researchers will develop a machine learning approach to identify aquatic insects and contribute to a long-term ecological dataset being used to examine changing insect population dynamics. Students will use a set of existing images to train a supervised machine learning model to classify images of insects and, using additional climate, stream flow, stream chemistry, and stream algae data, create visualizations and communication tools for the Hubbard Brook Watershed Ecosystem Record (https://www.hbwater.org). This project will support ongoing research focused on understanding the impacts of climate change, specifically warming winters, on aquatic insect populations and will create a helpful, time-saving insect identification workflow that may be disseminated to other aquatic ecology research groups.

PROJECT MENTOR: Heili Lowman

PROJECT MEMBERS: Abdulmlik Mohammad Almuhanna

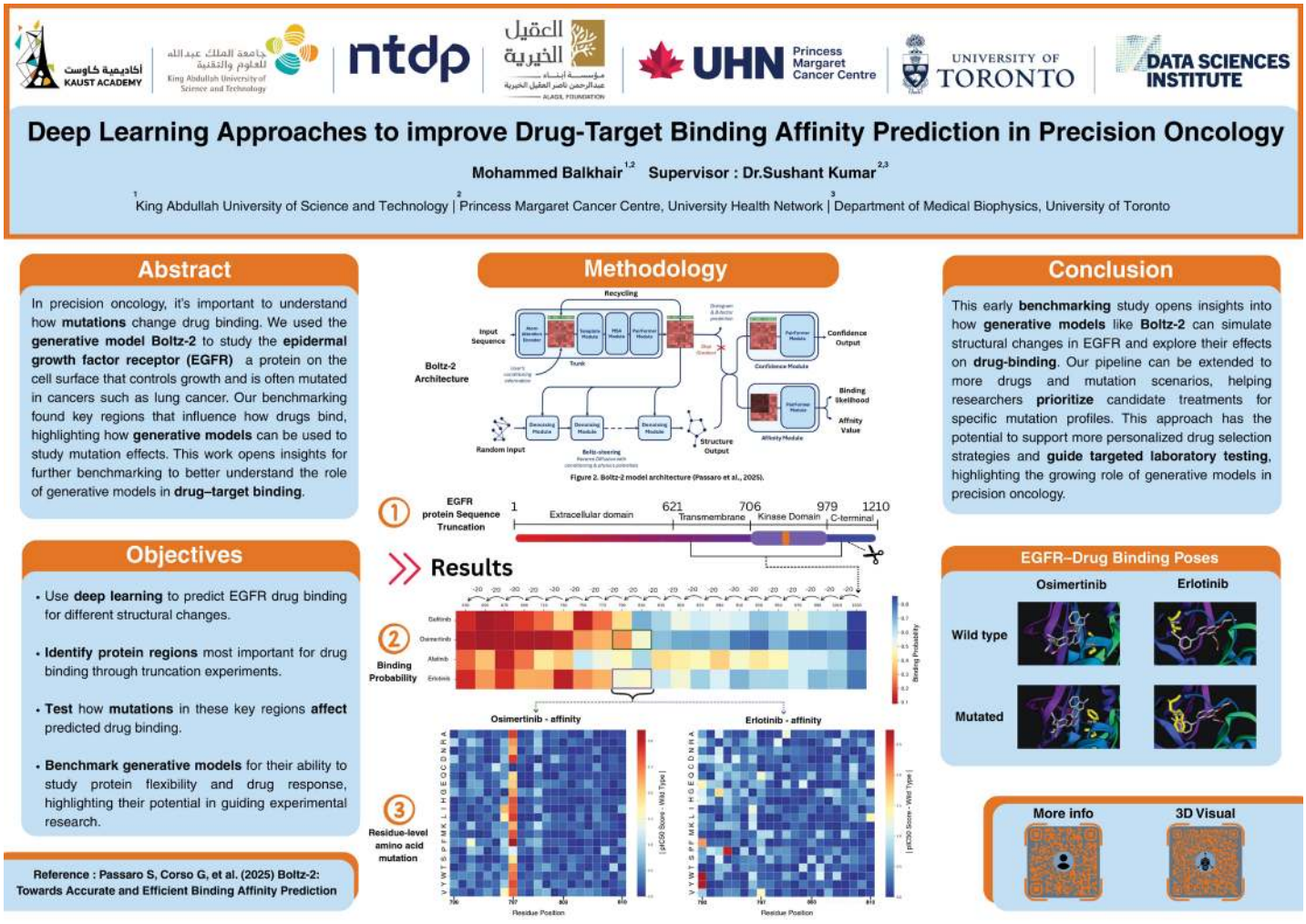


DEEP LEARNING APPROACHES TO IMPROVE DRUG–TARGET BINDING AFFINITY PREDICTION IN PRECISION ONCOLOGY

This study presents a benchmarking effort to evaluate and improve drug–target binding affinity (DTA) prediction models for precision oncology. We focus on graph-based deep learning approaches that represent drugs and proteins, with particular emphasis on the protein modeling component. To ensure fair evaluation, we address issues of information leakage across datasets and assess model robustness under distribution shifts. Our experiments systematically incorporate various forms of protein dynamics, including contact maps, embeddings from pre-trained protein language models, and conformational ensembles generated by structure prediction tools such as AlphaFold2. We investigate the individual and combined effects of these dynamic features on model performance. By refining protein graph representations at both the node and edge levels, we aim to establish a strong baseline for DTA prediction tasks and provide insights into how structural dynamics enhance model generalization. Ultimately, our findings support the development of more reliable models for integration into personalized cancer therapy pipelines.

PROJECT MENTOR: Sushant Kumar

PROJECT MEMBERS: Mohammed Ahmed Balkhair



LOW-COST MULTIMODAL PIPELINE FOR CURBSIDE VEHICLE CO_2 EMISSION ESTIMATION

Car type and model can be identified by acoustic fingerprints. The project is about coupling audio-based AI model for car detection with CO2 sensors.

PROJECT MENTOR: Rytis Paškauskas

PROJECT MEMBERS: Abdullah Nasser Aloud,Joud Adel Aldhuwaihi

Low-Cost Multimodal Pipeline for Curbside Vehicle CO_2 Emission Estimation
Abdullah Aloud, Joud Aldhuwaihi
Abdus Salam International Centre for Theoretical Physics (ICTP)

Introduction

Accurate urban CO_2 monitoring is vital for air quality management and climate policy. Cities increasingly require detailed, per-vehicle emissions data to enforce regulations and assess interventions. Traditional roadside monitoring systems are expensive, require fixed installations, and are difficult to scale across large urban areas. We present a low-cost, portable Raspberry Pi–based system equipped with a camera and microphone. This multimodal pipeline detects a vehicle's make and model from images, estimates its CO_2 emissions using certified databases, and can be deployed easily on streets without intrusive sensors.

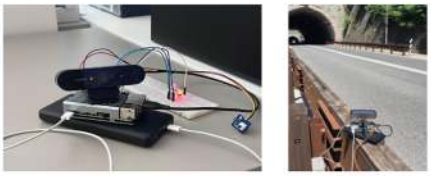


Figure 1: Hardware setup (Raspberry Pi, Web cam)

Methods

A Raspberry Pi 4B with camera and microphone records short video–audio clips triggered by passing vehicles. YOLOv8 detects cars, a crossing-line tracker selects the best crop, and EfficientNetV2-M classifies them into 4,481 models from a curated VMMRdb + custom dataset. In parallel, the audio pipeline extracts a one-second engine segment for optional fuel-type classification. CO_2 values are matched to Euro 6 and EEA databases, with speed data used to adjust estimates.



Figure 2. Multimodal pipeline for per-vehicle CO_2 estimation

Results

The EfficientNetV2-M classifier achieved strong fine-grained recognition across 4,481 classes.

Metric	Score
Accuracy	90.66%
Precision	90.51%
Recall	90.66%
F1 Score	90.30%

Training loss and accuracy remained stable across 95 epochs and five cross-validation folds, indicating no overfitting.

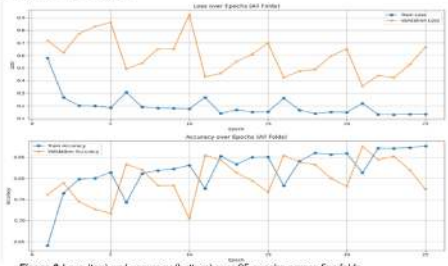


Figure 3. Loss (top) and accuracy (bottom) over 95 epochs across five folds.

Conclusions

A low-cost, multimodal pipeline using a Raspberry Pi with camera and microphone estimates per-vehicle CO_2 emissions. It combines YOLOv8 detection, EfficientNetV2-M classification, and optional MFCC-based audio analysis for fuel type. In real-world tests, the classifier achieved 90.66% accuracy without overfitting, proving robust in outdoor conditions. The scalable system requires minimal infrastructure and adapts to varied urban settings.

Acknowledgments

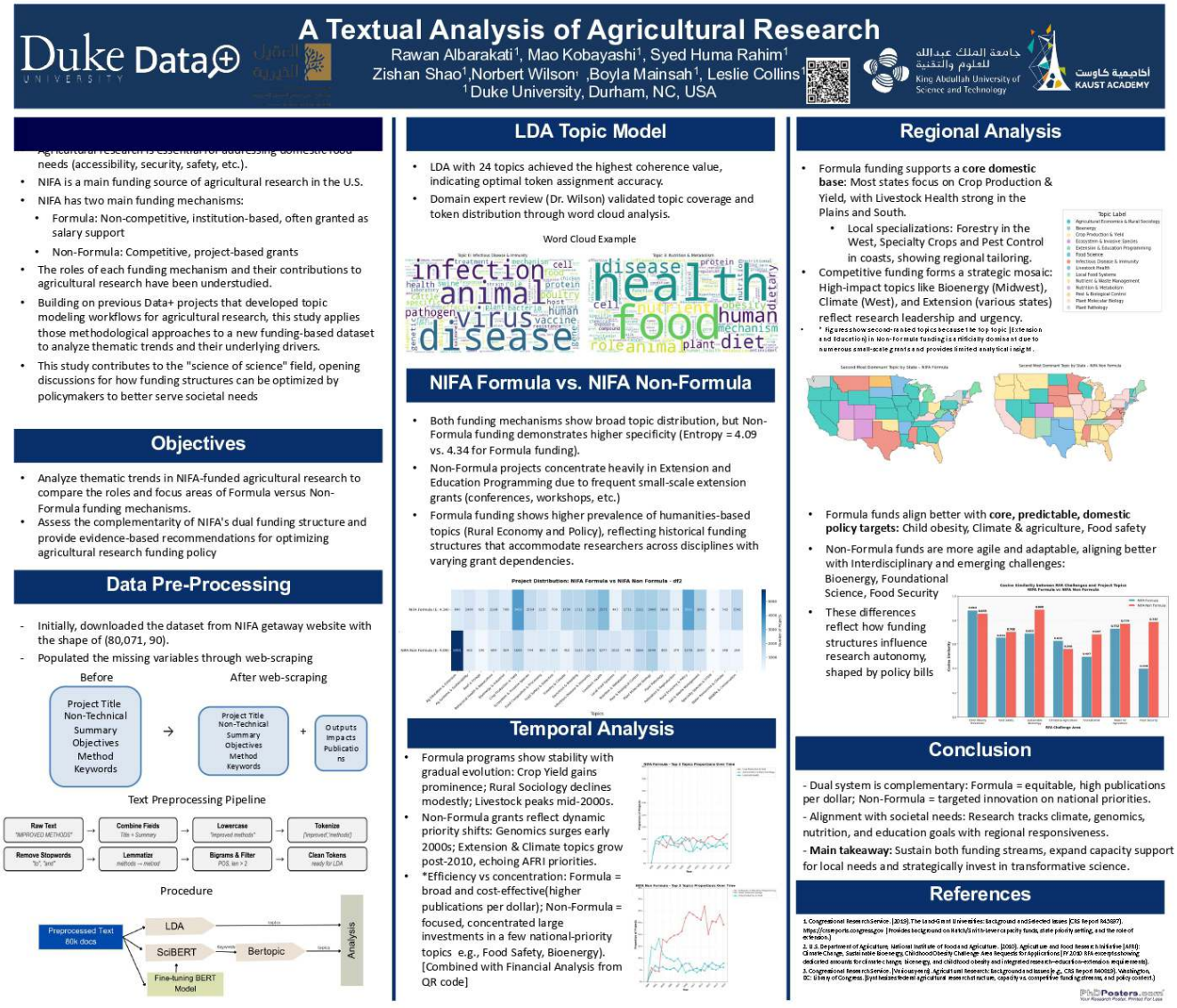
We thank King Abdullah University of Science and Technology (KAUST) for providing this research opportunity, and the Abdus Salam International Centre for Theoretical Physics (ICTP) for hosting us as guests.

A TEXTUAL ANALYSIS OF AGRICULTURAL RESEARCH

Students will work at the intersection of data science, policy, and food systems to analyze critical agricultural research shaping the science of food, agriculture, and the environment in the United States. Using natural language processing and machine learning, the team will explore federal grant records to uncover how agricultural research has adessed issues like food access, food systems innovations, and environmental stewardship over time. The team's work will contribute to a grant proposal for the USDA and provide valuable tools for future researchers. This project is a unique opportunity to develop transferable data science skills while contributing to impactful research on pressing food system challenges.

PROJECT MENTOR: Zishan Shao

PROJECT MEMBERS: Rawan Yasir Albarakati



ENERGY TRANSITION DURING ENERGY CRISIS

This project adesses the energy crisis in Cape Town, South Africa, where frequent power outages and infrastructure failures have led to inequitable energy access. Wealthier residents can afford solar installations, while low-income communities are left behind. My team and I aim to develop deep learning models to detect and classify different types of solar energy systems (solar panels, solar water heaters, and pool heaters) using high-resolution satellite imagery.The project utilizes image segmentation (U-Net) and object detection (YOLO) models to identify and locate solar installations across the city. With a dataset comprising over 2,800 satellite images and nearly 20,000 annotated solar objects, my team and I are working to improve model accuracy, reduce false positives, and enable multiclass classification.

PROJECT MENTOR: Biz Yoder

PROJECT MEMBERS: Rema Yasir Albarakati

Energy Transition During Energy Crisis: Cape Town's Experience

Team Members: Catherine Nan, Priyanka Gupta, Rema Albarakati, Ilseop Lee
Manager: Biz Yoder, Lead: Marc Jeuland, Advisor: Kyle Bradbury

Introduction

Cape Town faces persistent **load shedding**, the scheduled disconnection of electricity power in certain areas to prevent a complete power outage when electricity demand exceeds supply. As a result, wealthier households install rooftop **solar energy systems** to stay powered, while low-income communities are unable to access a stable energy source.

Unequal access to energy deepens economic inequality and limits opportunities for growth. By determining the **location** and **quantity** of solar energy systems, we can identify areas with low energy capacity. Collecting such data is critical for implementing policy changes in Cape Town that aim to alleviate the impacts of load shedding.

Data Pipeline

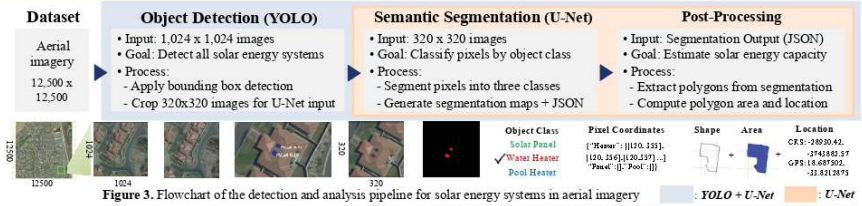
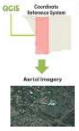


Figure 3. Flowchart of the detection and analysis pipeline for solar energy systems in aerial imagery

Objectives

- **Detect and classify solar energy systems** (solar panels, water heaters, and pool heaters) from aerial imagery
- **Estimate solar energy capacity** across Cape Town based on the predicted locations of **solar panels**
- **Build an end-to-end data pipeline**: dataset processing → model training → post-processing → output evaluation

Data



- **Cape Town, South Africa aerial imagery**
  - Coordinate Reference System: ESRI 102562
  - Coordinates in (x, y), measured in meters from (0°, 0°) origin
  - Annotated in QGIS, preserving metadata
  - Total 2,802 images (12,500x12,500, 8cm/pixel)
- To ensure annotation quality, **top images by annotation count were manually refined**.

Dataset Group	Number of Images	Number of Annotations by Class				
		Solar Panels	Water Heater	Pool Heater	Uncert-ain	Total
Initial	268	10,787	5,216	2,503	1,920	19,735
Refined	15	2,033	1,983	1,146	0	5,162

Figure 1. Summary of Annotation Counts by Class

Model Selection

YOLO + U-Net and U-Net were evaluated on unseen images (889 annotations). U-Net showed higher precision for solar panels, while YOLO + U-Net yielded higher recall. Final selection should consider **actual prediction accuracy.**

Model	Class	IoU	Precison	Recall
YOLO + U-Net	**Solar Panel**	**0.762**	**0.778**	**0.974**
	Water Heater	0.525	0.765	0.626
	Pool Heater	0.698	0.798	0.846
U-Net	**Solar Panel**	**0.793**	**0.832**	**0.943**
	Water Heater	0.501	0.769	0.589
	Pool Heater	0.694	0.819	0.819

Figure 2. Performance comparison of YOLO+U-Net vs. U-Net

Object Detection (YOLO)

- YOLOv11_OBB is an object detection model that supports oriented bounding boxes, enabling localization of tilted or rotated solar energy systems in aerial imagery.
- The input is 1,024 x 1,024 images and all solar types were grouped into a single class for binary detection. The detected object was cropped into a 320 × 320 patch for subsequent semantic segmentation.
- Model performance was evaluated using mean Average Precision(mAP).

Metric	Value
mAP@0.5	82.5%
mAP@0.5:0.95	70.3%

* @.5 = IoU ≥ .5, @.5:.95 = mean over range

Figure 4. YOLO mAP performance

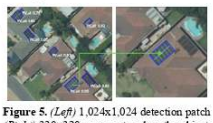


Figure 5. *(Left)* 1,024x1,024 detection patch *(Right)* 320×320 crop centered on the object

Semantic Segmentation (U-Net)

- U-Net is an image segmentation model to predicts a class label (solar panel, water heater, pool heater) for each pixel in an image to create a segmentation map.
- The input is 320 x 320 images and their corresponding one-hot encoded masks. The output is a segmentation mask. (**Black**: background, **green**: solar panel, **red**: water heater, **blue**: pool heater).
- Model performance was evaluated using Intersection over Union (IoU).

Metric (IoU)	Value
Solar Panel	68.7%
Water Heater	60.4%
Pool Heater	74.5%

Figure 6. U-Net IoU performance

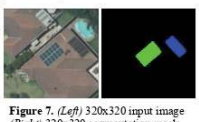


Figure 7. *(Left)* 320x320 input image *(Right)* 320x320 segmentation mask

Model Training Summary: Both YOLO and U-Net were trained on 15 12,500 x 12,500 aerial images (5,162 solar objects) with a learning rate of 1e-4. YOLO performed binary object detection by learning all solar energy systems as a single class, whereas U-Net performed multi-class segmentation for solar panels, water heaters, and pool heaters.

Post-Processing



Polygonization: Predicted pixels coordinates are grouped into polygon shapes for solar objects

Area Calculation: The area of each solar object is computed using polygon geometry and geospatial data

Georeferencing: The vertices of each polygon are converted into latitude/longitude

Rooftop Grouping: In the future, solar objects will be grouped by rooftop for household-level solar energy estimates

Results

Regional Accuracy in Solar Panel Area Estimation

Model	Region (Image ID)	Ground Truth Area (m²)	Predicted Area(m²)	Absolute Error (m²)	Relative Error	Accuracy
Yolo + U-Net	W57B_8	2833.9	2819.6	-14.3	-0.5%	99.5%
	W24A_17	1193.4	2399.2	1205.8	101.0%	1.0%
	W25C_16	413.1	501.2	88.0	21.3%	78.7%
	Total	**4440.5**	**5720.0**	**1279.5**	**28.8%**	**71.2%**
U-Net	W57B_8	2833.9	2750.3	-83.6	-2.9%	97.1%
	W24A_17	1193.4	1249.7	56.3	4.7%	95.3%
	W25C_16	413.1	427.8	14.7	3.6%	96.4%
	Total	**4440.5**	**4427.8**	**-12.6**	**-0.3%**	**99.7%**

Figure 8. Accuracy of solar panel area estimation by model

- A comparative evaluation was conducted on 337 solar panels across three regions in Cape Town to assess the accuracy of the U-Net and YOLO + U-Net models in estimating solar panel area.
- **U-Net** demonstrated **higher and more consistent accuracy** in solar panel prediction, making it suitable for region-wise estimation of solar panel area.

Limitations & Future Research

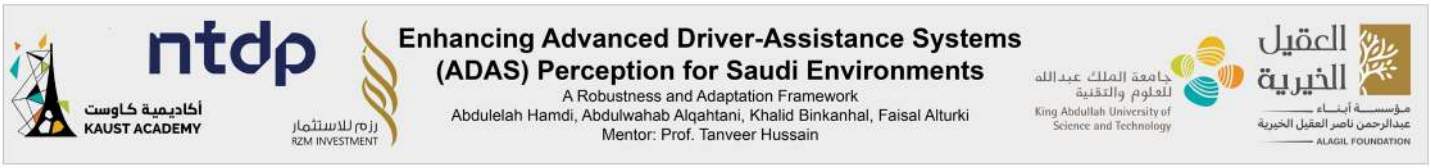
- The model used 5,162 annotations from 15 of 2,802 aerial images for training and pipeline setup.
- Prediction may improve with refined post-processing and evaluation at the individual panel-level.

ENHANCING ADVANCED DRIVER-ASSISTANCE SYSTEMS (ADAS) PERCEPTION FOR SAUDI ENVIRONMENTS

This project focuses on building an Advanced iver-Assistance Systems (ADAS) perception module specifically for Saudi Arabia's challenging weather conditions (dust storms, sun glare). It involves image enhancement, semantic segmentation, and lane-keeping..

PROJECT MENTOR: Tanveer Hussain

PROJECT MEMBERS: Abdulelah Hamdi,Abdulwahab Alqahtani, Faisal Alturki,Khalid Binkanhal



Problem

Advanced Driver-Assistance Systems (ADAS) and Autonomous Driving Systems (ADS) hold the promise of revolutionizing road safety. However, their perception models are often trained on data from temperate climates and can underperform significantly in the unique and challenging environmental conditions of Saudi Arabia.

Objectives

SandWeatherNet , aims to create a robust framework to enhance ADAS perception by translating images captured in adverse sand/dust conditions into clear, day-like visuals, thereby improving the reliability of downstream tasks like object detection and semantic segmentation.

Data & Implementation

- **Adverse Weather Data:** We collected a variety of datasets featuring sandstorms and other challenging conditions relevant to the Saudi environment.
  - **DAWN Dataset:** Includes 1000 real-traffic images with sandstorm conditions.
  - **Roboflow:** Sandstorm on road Object Detection Dataset.
  - **Video Footage:** Dashcam videos of heavy dust storms and sandstorms in Saudi Arabia provided real-world examples.
- **Clear Weather Data (Target Domain):** sourced clear-weather road images from large-scale driving datasets to serve as the target for our style transfer.
- **Tools:** used PyTorch and Google Colaboratory.

Methodology

Phase 1: Baseline with AllWeather-Net

AllWeather-Net is a unified image enhancement network designed to handle fog, snow, rain, and nighttime conditions using a novel hierarchical architecture and a Scaled Illumination-aware Attention Mechanism (SIAM).

- **Implementation:** Adapted the existing AllWeather-Net codebase to run on our custom datasets. This involved significant effort in resolving library versioning conflicts and re-routing the model's data input pipelines.
- **Outcome:** The enhancement quality on our sandstorm datasets was suboptimal. Object boundaries remained blurry and visual clarity was not sufficiently restored.

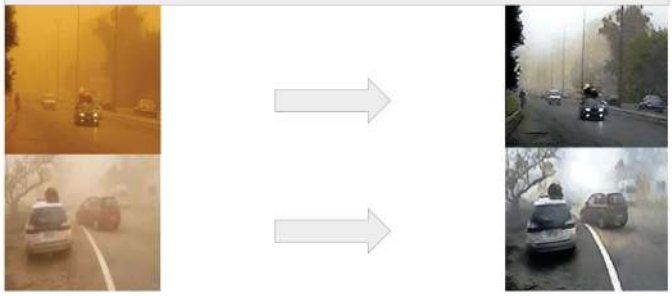
Phase 2: Pivot to CycleGAN for Unpaired Translation The primary challenge with fine-tuning models like AllWeather-Net is the scarcity of

paired datasets—images of the exact same scene with and without a sandstorm. To overcome this, we transitioned to a

Cycle-Consistent Generative Adversarial Network (CycleGAN).

- **Core Advantage:** CycleGAN excels at unpaired image-to-image translation. It can learn to translate images from a source domain (e.g., sandstorm roads) to a target domain (e.g., clear roads) without needing one-to-one matched examples. This was ideal for our available data.
- **Process:** The model learns the mapping G:SandrightarrowClear and a reverse mapping F:ClearrightarrowSand. The cycle-consistency loss ensures that if an image is translated and then translated back, it should resemble the original (F(G(Sand))approxSand), preserving content while changing the style.

Results



Results (cont.)

Our CycleGAN-based approach successfully translates sandstorm-degraded images into clearer versions. The model demonstrates the ability to restore scene contrast, improve color fidelity, and enhance the visibility of vehicles and road markings.

Conclusion

This project demonstrates that unpaired image-to-image translation is a highly effective and practical strategy for adapting ADAS perception systems to unique, region-specific environmental challenges like sandstorms, for which paired training data is unavailable. By converting low-visibility sandstorm scenes into clear images, SandWeatherNet provides a critical pre-processing step to enable more reliable performance of downstream ADAS modules in Saudi Arabia.

Future Work:

- Multi-Modal Fusion
- Video-Based Enhancement
- Explainable AI (XAI)
- Real-Time Deployment

Colab Notebook

Acknowledgement

We extend our sincere gratitude to our mentor, Prof. Tanveer Hussain, and the organizers of the KAUST Academy AI Specialization Summer School for their invaluable guidance and support throughout this project.

References

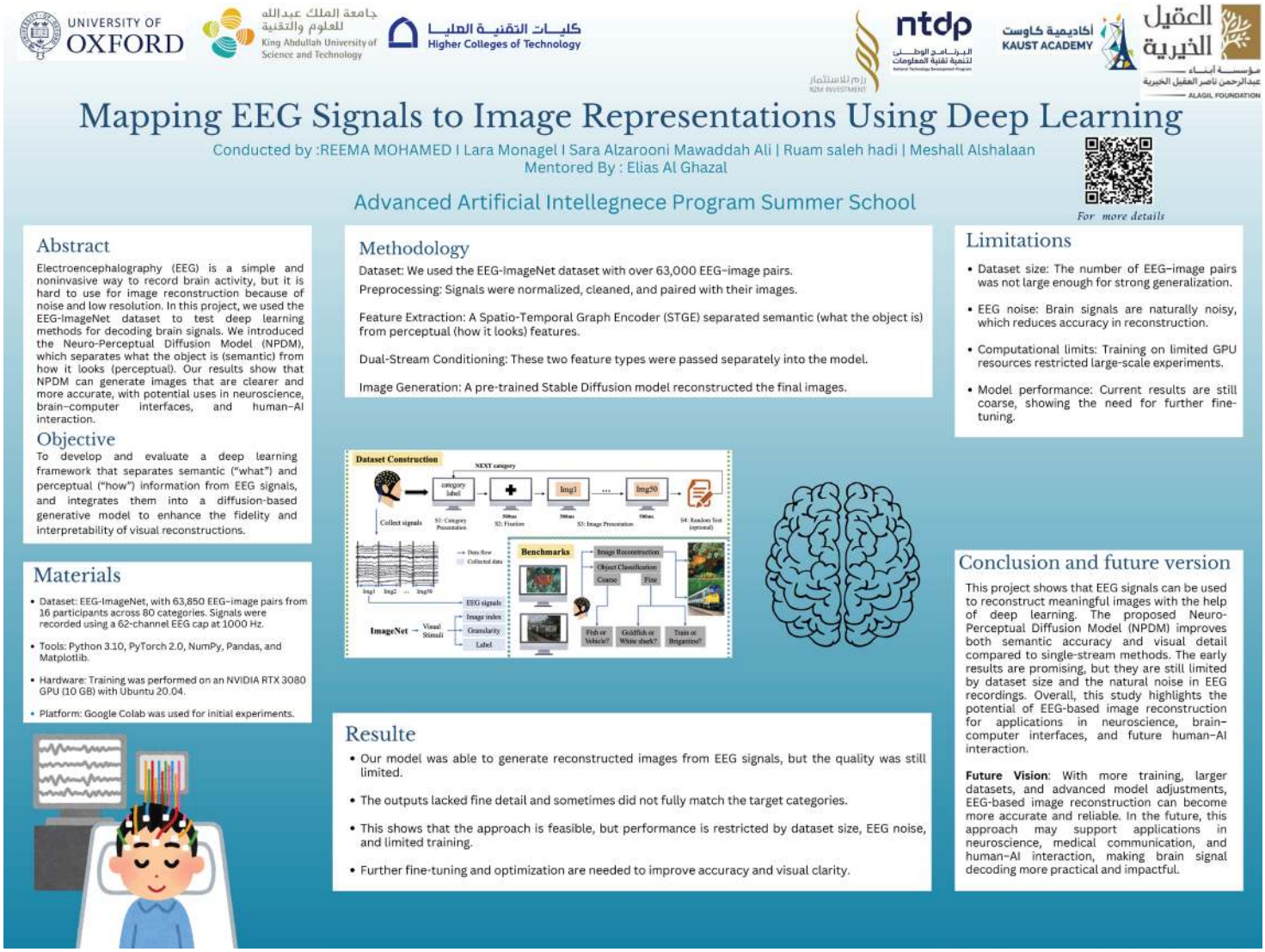
[1] [Qian et al., 2025] Qian, C., Rezaei, M., Anwar, S., Li, W., Hussain, T., Azarmi, M., and Wang, W. (2025). AllWeather-Net: Unified image enhancement for autonomous driving under adverse weather and low-light conditions. International Conference on Pattern Recognition, pages 151–166. Springer.
[2] Zhu, J.Y., et al. (2017). Unpaired Image-to-Image Translation using Cycle-Consistent Adversarial Networks. In: ICCV.
[3] Al-Horgani, H., et al. (2022). DAWN: Vehicle Detection in Adverse Weather Nature Dataset. Nature.

MAPPING EEG SIGNALS TO IMAGE REPRESENTATIONS USING DEEP LEARNING.

An AI to help by scanning messages, detecting blackmail words, and tracing the IP adesses where the threats come from.

PROJECT MENTOR: Elias Al Ghazal

PROJECT MEMBERS: Mawaddah Ali,meshall Alshalaan,ruam Saleh Almuntashiri, Sara Ahmed Mohammed Alzarooni,khalid Binkanhal,lara Monagel, Rema Mohamed Jehan Alblooshi

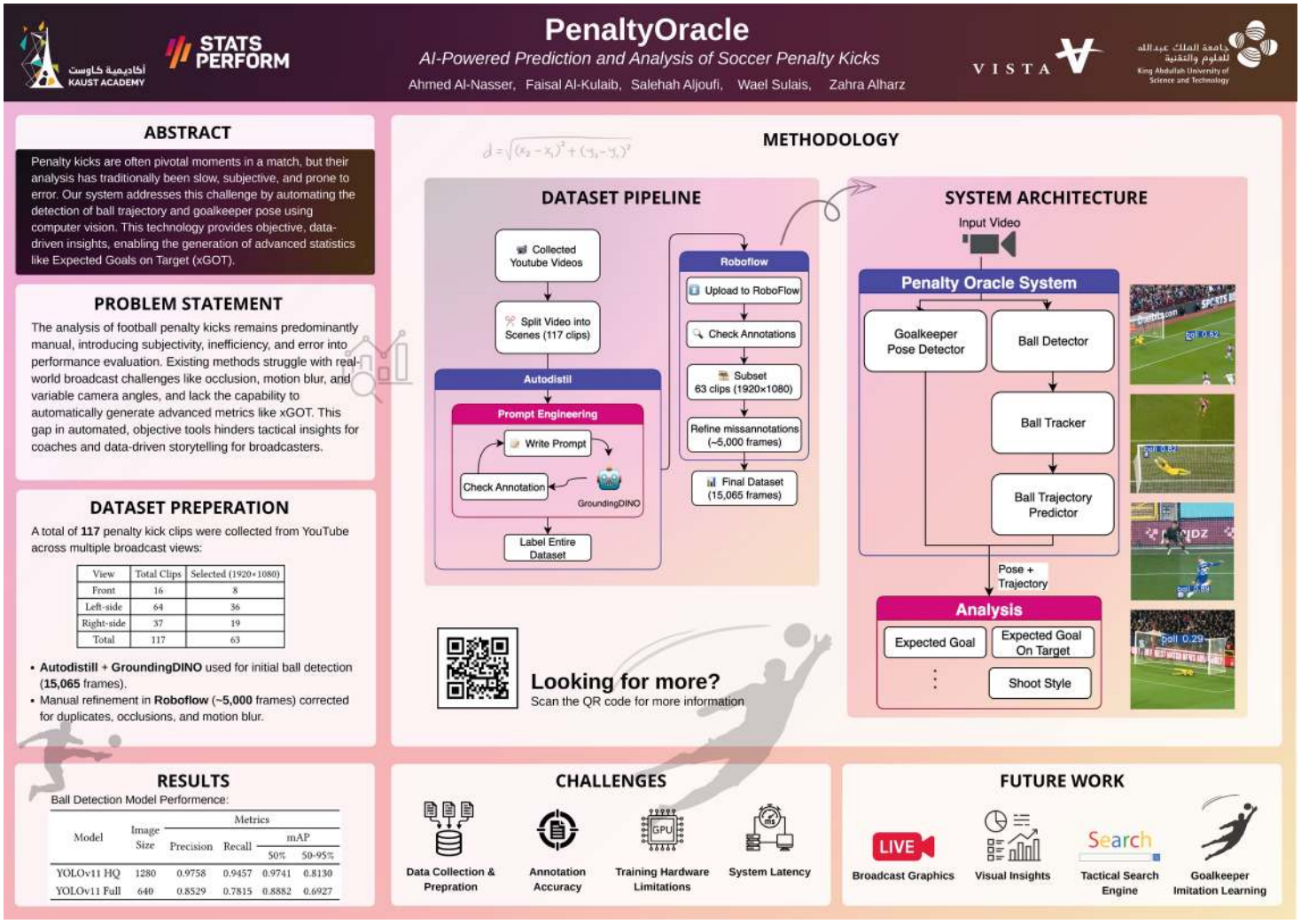


AUTOMATIC SOCCER PENALTY DETECTION (TRAJECTORY OF BALL AND GOALKEEPER).

Detecting the trajectory of the soccer ball and goal keeper with their pose to predict whether the shot would cause a goal. From the collected data we can get statistics such as “Expected Goal on Target (xGOT)”. Furthermore, you can use similarity search from the detections to find similar penalty shots.

PROJECT MENTOR: N/A

PROJECT MEMBERS: Ahmed Abdullah A Alnasser,faisal Melfy M. Alkulaib,salehah Mohammed Aljoufi, Sulais, Wael Ali E.,Zahra Ali Hasan Alharz

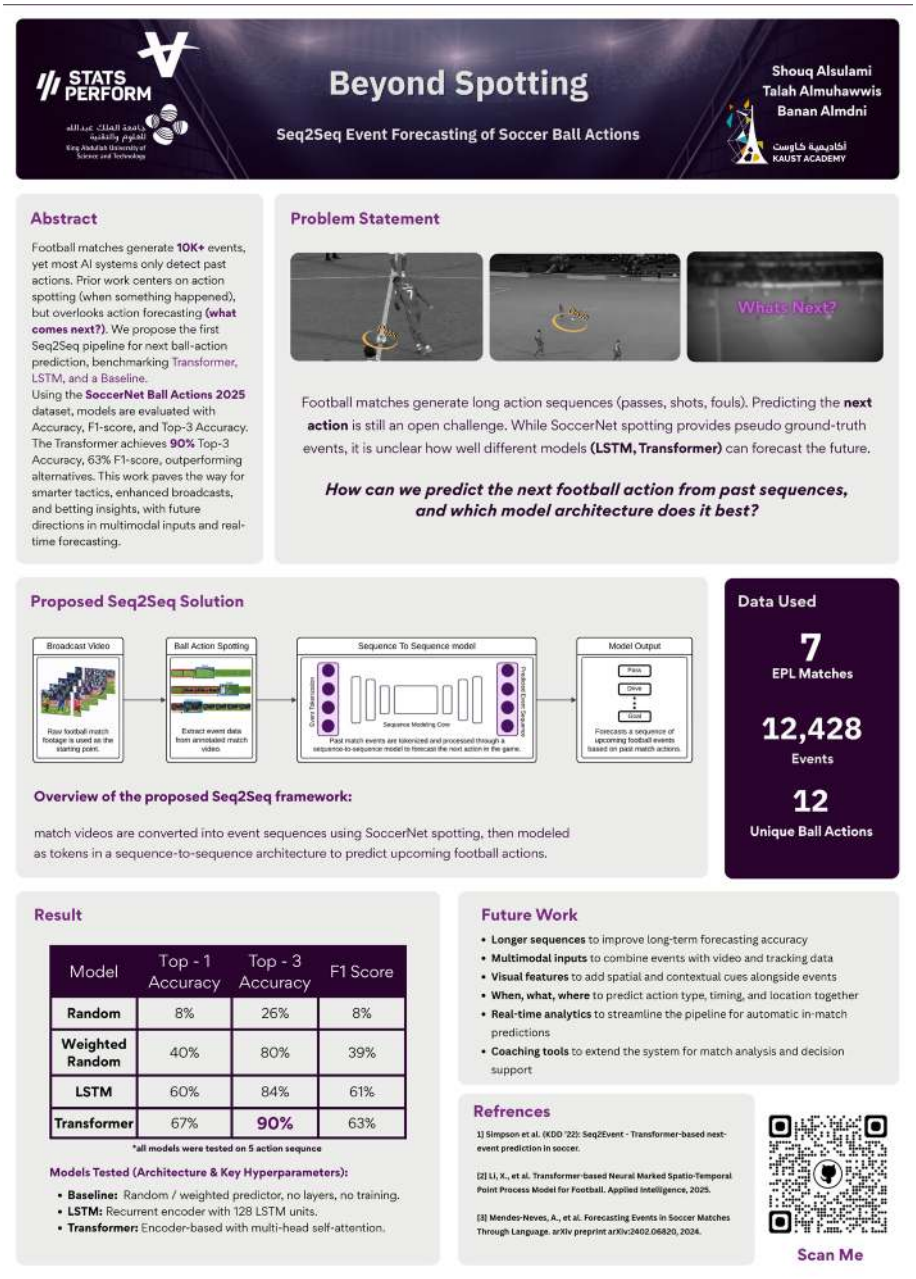


BALL ACTION SPOTTING

We developed an AI-powered ball action spotting system that detects and classifies 12 types of ball-related actions from broadcast football videos, pinpointing the exact timestamps of each event. Our model processes dense, untrimmed match footage to retrieve moments with specific semantic meaning — enabling faster highlight generation, real-time analytics, and advanced coaching insights without manual tagging.

PROJECT MENTOR: N/A

PROJECT MEMBERS: Banan Sabir M Almdni,Shouq Rajaallah Hamdan Alsulami, Talah Abdullah Almuhawwis



EVENT-RECOGNITION AND HIGHLIGHT CLIPPING

This project aims to enhance the sports viewing experience by identifying and extracting key moments from match videos. The system detects six events goals, penalties, fouls, shots on target, red and yellow cards, and direct free kicks. For each detected event, it retrieves short highlight clips, allowing viewers to instantly rewatch pivotal moments.Alongside these clips, it integrates a dynamic tracking mini-map that providesreal-time positional tracking of players and the ball, offering a tactical overview ofhow the play unfolded. This combination of precise highlight extraction andvisualized tracking delivers an immersive and insightful way to analyze and enjoysports content.

PROJECT MENTOR: N/A

PROJECT MEMBERS: Abdulelah ali khalaf,Bader Ali Alshamrani,Hebah Omer Soleman, Khadijah Ali Abdullah Baothman,Omar Hejazi

MULTI-TASK CONTRASTIVE LEARNING FOR MULTIMODAL SOCCER FOUL RETRIEVAL

A Retrieval system that retrieves past foul verdicts to help referees make a decision on a similar present one

PROJECT MENTOR: N/A

PROJECT MEMBERS: Ahmad Adnan M Sait,iyas Mohammed Abdulhammid Baroud, Mazen Abdulrahim M Albalawi, Mohammed Mustafa Omar B,Rayan Ayman M Ghabashi

REAL-TIME ANALYTICS

We would like to share our proposed project idea: Real-Time Analytics for sports matches, focusing on live tracking and visual insights .

PROJECT MENTOR: N/A

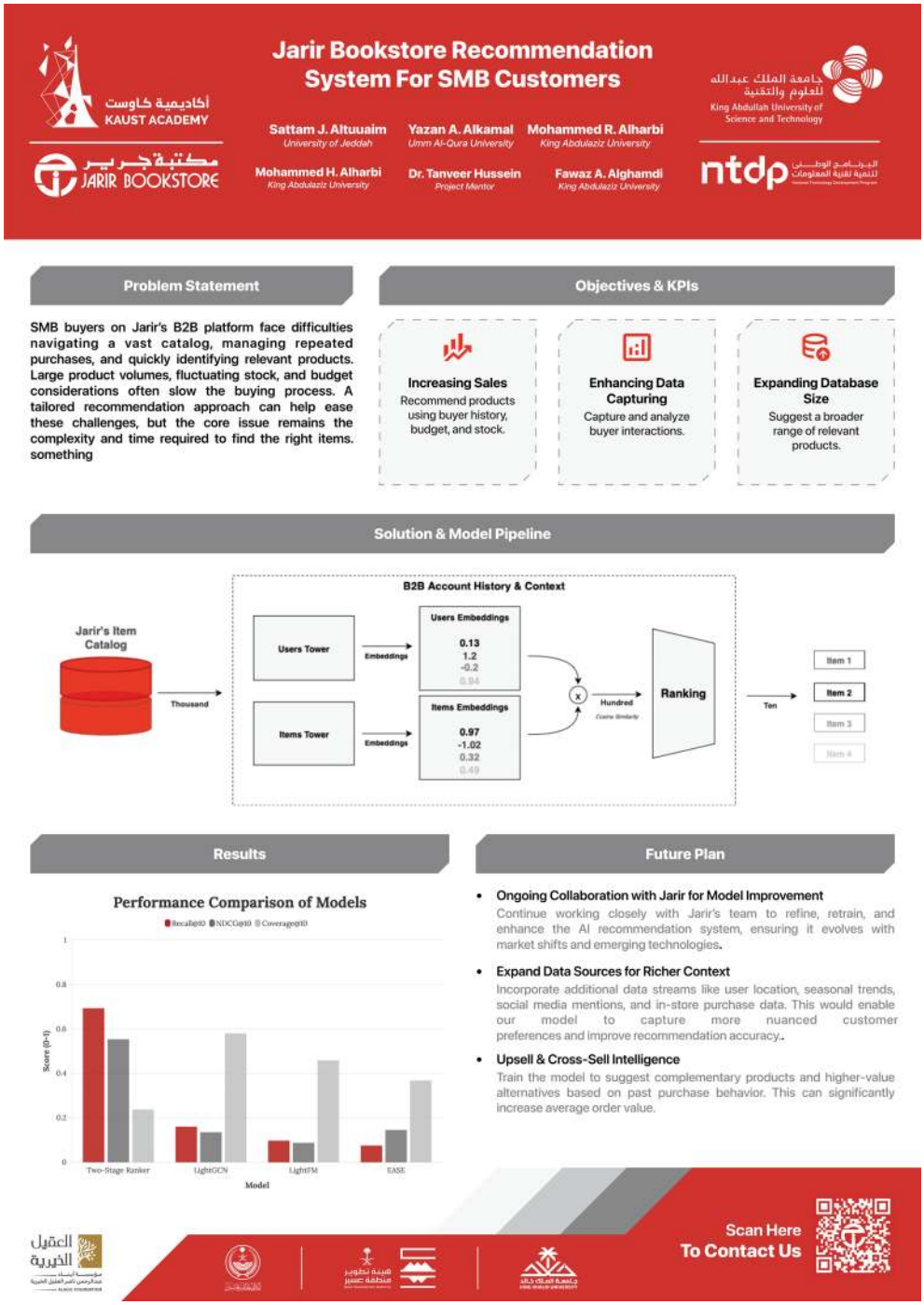
PROJECT MEMBERS: Asma Abdulsamad Saleh Mahdi,bin Mannie, Norah Waleed,haifa Musnad Hamoud Althobaiti

JARIR RECOMMENDATION SYSTEMS

Collaborative project between KAUST Academy and Jarir Bookstore to develop an AI-Driven recommendation system tailored for the needs of small- and medium-sized business clients.

PROJECT MENTOR: Tanveer Hussain

PROJECT MEMBERS: Fawaz Abdullah Al-Ghamdi, Mohammad Hamed Alharbi, Mohammed Rashid Alharbi, Yazan Abdullah Alkamal, Sattam Jared Altuuaim



أكاديمية كاوست
KAUST ACADEMY

جامعة الملك عبدالله
للعلوم والتقنية
King Abdullah University of
Science and Technology

Prepared and presented at King Abdullah University of Science and Technology. We extend our gratitude to all mentors, colleagues, and the KAUST community. For more details and resources, please visit our official website via the QR code