Workshop Introduction

Prof. Venki Muthukumar

About Me ...

- Name:
  - Prof Venkatesan Muthukumar (Venki)
- Qualifications:
  - BE (Electronics & Communication Engineering)
    - Anna University – College of Engineering, INDIA
  - MS (Computer Science)
    - Monash University, School of Computing, Australia
    - Research: Digital Design for FPGAs
  - PhD (Computer Science)
    - Monash University, School of Computing, Australia
    - Research: Digital Design for FPGAs

About Me …

- Teaching Experience
  - University of Nevada Las Vegas (UNLV)
  - 25+ Years of teaching in Electrical and Computer Engg.
  - Course Taught
    - Undergraduate Courses:
      - Digital Logic Design (I&II) [I& Yr], Embedded Systems[3 Yr], Advanced Embedded Systems [4 Yr], VLSI Physical Design [4 yr], Mobile Robotics [4 Yr], UAV Simulation & Testing [4 Yr], etc.
    - Graduate Courses:
      - Advanced Embedded Systems [1 Yr], VLSI Physical Design [1 yr], Mobile Robotics [1 Yr], UAV Simulation & Testing [1 Yr], Optimization of Digital Systems [PhD], Advanced Logic Design [PhD]
- Industrial Experience
  - Project Engineer, KONE Elevators (1 yr)
  - Consultant for Gaming Companies (Summers)

Research …

- Transportation
- UAV applications in wildfire, and 3D mapping
- Medical/Healthcare Systems
- Control Engineering
- Robotics
- Internet of Things (IoT)
- Emergency Response Systems
- Solar Forecasting for PV Systems

About of Graduate Students

- MD Shariful

About of Graduate Students

- Mugundan Prakash

About of Graduate Students

- Swarna Latha Boya

About ECE @ UNLV …

- The Department of Electrical and Computer Engineering has 18 faculty members covering a wide range of modern engineering fields including wireless communication, system on chip, nanotechnology, renewable energy and sensor networks.
- The Department offers B.S. in Electrical Engineering, B.S. in Computer Engineering, M.S. in Electrical Engineering and Ph.D. in Electrical Engineering.
- Undergraduate Students (600+) and Graduate Students (60+)
- Accreditation:
  - ABET & NWCCU
- Faculties:
  - 3 Research Centers, 5 Research Laboratories, and 5 Teaching Laboratories.

What is this Workshop/Course?

Embedded AI and Machine Learning refers to the *integration of artificial intelligence and machine learning techniques into embedded systems*. Embedded AI to *explore understanding and generating models on small and resource-constrained devices*, such as microcontrollers and sensors, which typically have limited memory, processing power, and energy resources. This course enables students the broad *knowledge to develop intelligent, efficient, and cost effective intelligent IOT devices*. It also provides the students with opportunities for innovation, and fosters interdisciplinary skills and knowledge.

Software

- Platforms
  - Windows
  - MAC
- Programming Language
  - Python
  - Object Oriented C
- Programming Frameworks
  - Anaconda
  - venv
  - PyCharm

Hardware

- **Hardware Kit (Per Student or Team)**
- M5Stack Core2 (ESP32, touchscreen, mic, IMU, Wi-Fi/BLE)
- Raspberry Pi Zero 2 W (with case, power supply, 32GB microSD)
- Raspberry Pi Camera Module v2 (for vision projects)
- USB-C, Micro-USB cables & SD Cards
- Various Senor Modules

Component List Overview

- The kit includes the following major components
- Vilros RPI Zero 2 W Kit
- M5Stack Core 2
- ArduCam
- AHT20, GY521 (MPU 6050), INMP441, VL53L0X, BMI 160, APDS-9960
- 64GB and 32GB MicroSD Cards
- Jumper wires and prototyping board

Raspberry Pi Zero 2 W Kit

- A Raspberry Pi Zero 2 W with power supply, case and some other components.

Fig: Velros RPi Zero 2 W starter kit

M5Stack Core 2

- An ESP32 based development board with various integrated sensors, microphone, speaker and display
- Wi-Fi and BLE connectivity

Fig: M5Stack Core 2

ArduCam

- 5MP OV5647 Camera module for Raspberry Pi

Fig: ArduCam

AHT20 (Temperature & Humidity Sensor)

- Digital temperature and humidity sensor
- Communication Interface: I2C
- Power Supply: 2.3V to 5V
- Accuracy:
  - Temperature: ±0.3°C
  - Humidity: ±3% RH

Fig: AHT20

MPU6050 (3-axis accelerometer and 3-axis gyroscope)

- 6-axis motion sensor
- Sensor Range:
  - Accelerometer: ±2g, ±4g, ±8g, ±16g
  - Gyroscope: ±125°/s, ±250°/s, ±500°/s, ±1000°/s, ±2000°/s
- Communication Interface: I2C
- Operating Voltage: 2.375V to 3.46V

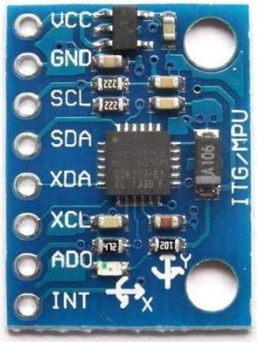

Fig: BMI 160

INMP441 (MEMS Microphone)

- Omni directional digital microphone
- High signal-to-noise ratio (SNR) : > 65 dB
- Communication Interface: I2S (Inter-IC Sound)
- Power Supply: 1.8V to 3.6V

Fig: INMP441

VL53L0X (Time-of-Flight Distance Sensor)

- Accurate distance measurement using laser light
- Communication Interface: I2C
- Power Supply: 2.6V to 3.5V
- Measurement Range: 30 mm to 2 meters

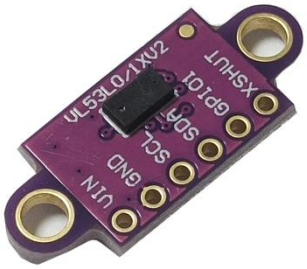

Fig: VL53L0X

BMI160 (3-axis accelerometer and 3-axis gyroscope)

- 6-axis motion sensor
- Sensor Range:
  - Accelerometer: ±2g, ±4g, ±8g, ±16g
  - Gyroscope: ±125°/s, ±250°/s, ±500°/s, ±1000°/s, ±2000°/s
- Communication Interface: I2C and SPI interface options
- Operating Voltage: 1.8V to 3.6V

Fig: BMI 160

APDS-9960 (Ambient Light, Proximity, RGB, and Gesture Sensor)

- Multi-function sensor (light, proximity, RGB, gesture)
- Integrated ambient light, proximity, and gesture detection
- Provides data for color, light intensity, and gestures
- Communication Interface: I2C
- Power Supply: 2.4V to 3.6V

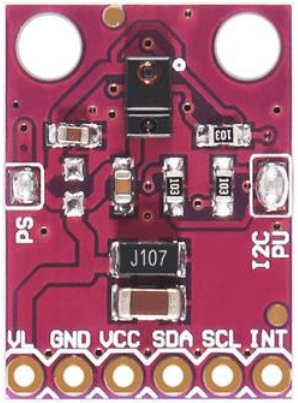

Fig: APDS-9960

Jumper Wires and Micro SD Cards

- Male to Male jumpers
- Male to Female jumpers
- Female to Female jumpers
- A 64GB SD card to be used with RPI Only
- A 32GB SD card to be used with M5Stack Only
- Do not swap the SD Cards once you have installed the RPI OS on the 64G SD Card.

Topics

Day	Lecture Topics	Lab Activity*	Tools	Hardware
1	Intro to Edge & Embedded ML — constraints & applications	Set up M5Core2 & Pi Zero 2, run “Hello World” on each	Arduino IDE (for M5), Raspberry Pi OS	M5Core2, Pi Zero 2
2	MCU vs SBC for Edge ML — architecture, trade-offs	Read IMU & mic data from M5Core2	Arduino IDE, M5Stack libraries	M5Core2
3	Sensor data acquisition & logging	Log M5Core2 sensor data to SD card & send to Pi over Wi-Fi	Arduino IDE, MQTT, Python	M5Core2, Pi Zero 2
4	Data preprocessing & feature extraction	Extract IMU features on M5Core2, compare with Pi preprocessing	Arduino IDE, Python	M5Core2, Pi Zero 2

Topics

Day	Lecture Topics	Lab Activity*	Tools	Hardware
5	ML fundamentals for embedded devices	Train MLP classifier on Pi using collected sensor data	scikit-learn, matplotlib	Pi Zero 2
6	Deploying models to microcontrollers	Convert model to TensorFlow Lite Micro & deploy to M5Core2	TFLite Micro, Arduino IDE	M5Core2
7	Model optimization: quantization, pruning	Quantize model on Pi, redeploy to M5Core2	TensorFlow Model Optimization Toolkit	Both
8	Audio keyword spotting	Capture audio on M5Core2, train on Pi, deploy back	Edge Impulse Studio, Arduino IDE	Both
9	Vision-based ML on Pi Zero 2	Attach Pi Camera, run MobileNet with TensorFlow Lite	TFLite, OpenCV	Pi Zero 2 + Camera

Day	Lecture Topics	Lab Activity*	Tools	Hardware
10	Wireless ML inference pipelines	Send M5Core2 inference results to Pi dashboard via MQTT	Arduino IDE, Python MQTT	Both
11	Edge-cloud collaboration	Split inference: preprocessing on M5Core2, inference on Pi	MQTT, TFLite	Both
12	Security in Edge ML	Secure OTA firmware updates for M5Core2	M5Burner, HTTPS update	M5Core2
13	Multi-device ML	Deploy same model to both devices, compare performance	TFLite, Arduino IDE	Both
14	Project development	Teams build end-to-end edge ML applications	All above	Both
15	Final project demos	Present and test applications	All above	Both

End of Workshop Final Projects

- **Example Final Projects**
- Gesture-controlled presentation pointer (M5 IMU + Pi presentation control)
- Voice-activated home automation node (M5Core2 audio + Pi MQTT broker)
- Low-power wildlife monitor (M5 wake-on-sound → Pi camera capture)
- Edge-based air quality anomaly detector (M5Core2 BME688 + Pi dashboard)
- Smart Anomaly-Detection Node (**M5Core2** as a vibration sensor + Pi **real-time anomaly scoring)**

Documentation & Report

- All teams publish:
- **GitHub Repository** (code, data, firmware)
- **GitHub Wiki** (project documentation)
- **Video Demonstration**
- **Final Project Report (PDF)** with metrics and visuals

Every-Day Workflow

- Morning Session (9:00 – 11:00 AM)
  - 9:00 – 10:00 AM – Theory
  - 10:00 – 11:00 AM – Introduction to Hands-on (afternoon session)

- Afternoon Session (2:00 – 4:00 PM)
  - 2:00 – 3:30 PM – Hands-on session
  - 3:30 – 4:00 PM – Documentation and Reporting