24AIM113-Introduction to NN, CNN, GNN
24AIM114-Analog System Design

Wrist Rehabilitation System for CTS patients

K. Nitya - CB.AI.U4AIM24123

B. Pavani Shreeya - CB.AI.U4AIM24106

Ardhra Vinod - CB.AI.U4AIM24105

Harikrishna Sivanand IYER - CB.AI.U4AIM24114

What is CTS ?

A disease that affects wrist movement in patients due to the compression in the median nerve within the carpel tunnel of the wrist.

SYMPTOMS:

- Pain in the hand
- Numbness in the hand or fingers
- Sensation of pins and needles in the fingers
- Weakness when gripping objects
- Using power tools that vibrate, such as drills or jackhammers
- Working with equipment that requires a lot of force

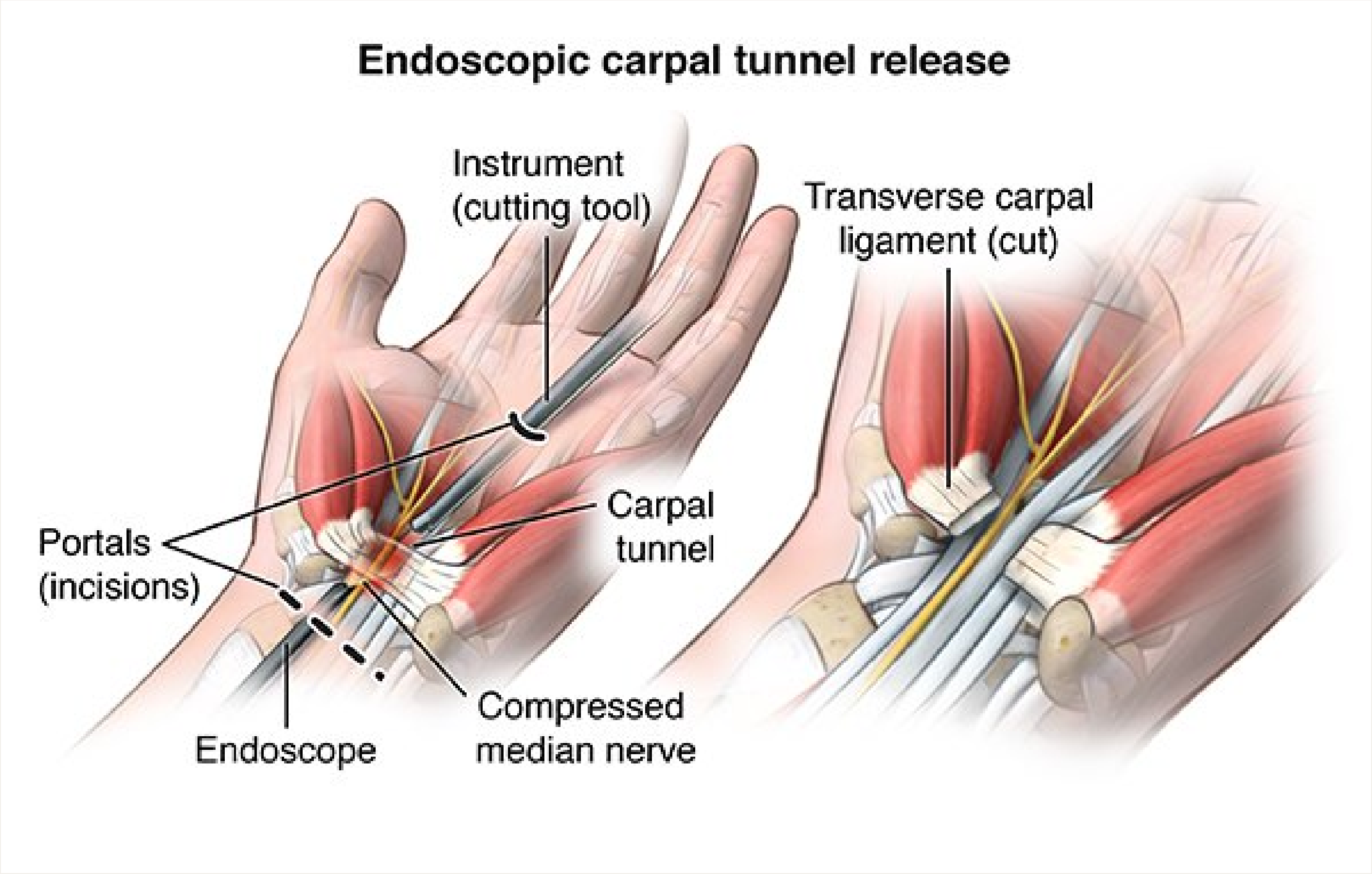
Existing Treatments:

Non-Invasive

wrist splinting, corticosteroid injections, activity modification, hand therapy, and anti-inflammatory medications

Invasive

- Open carpal tunnel release with a visible incision
- Endoscopic carpal tunnel release using an endoscope to guide the procedure[1] [3]



Literature Review

Sl no.	Title	Year	Methodology	Key contributions
1.	Deep Learning-Based Approaches for Enhanced Diagnosis and Comprehensive Understanding of Carpal Tunnel Syndrome	2023	Deep Learning (DL) models, Machine Learning (ML) models.	High accuracy was achieved (96.9%) in CTS diagnosis and evaluated disease progression using ML prediction.
2.	Diagnosis of Carpal Tunnel Syndrome from Thermal Images Using Artificial Neural Networks	2007	Thermography, Artificial Neural Networks (ANN)	Software-based intelligent system for CTS diagnosis using thermal imaging.
3.	Classification of the Angular Position During Wrist Flexion-Extension Based on EMG Signals	2021	Myoelectric pattern recognition using ANN, Time-domain features, AR model	ANN was used to classify wrist positions with up to 82% accuracy for rehabilitation applications.

4.	A New Approach to Applying Feedforward Neural Networks to the Prediction of Musculoskeletal Disorder Risk	2000	Feedforward neural networks (FNN), Error backpropagation.	FNN model for predicting musculoskeletal disorder risks was designed, achieving higher accuracy than traditional statistical methods.
5.	Comparative Study of Wearable Devices for Detection, Diagnosis and Rehabilitation of Carpal Tunnel Syndrome	2022	Review of wearable devices, biosensors, motion tracking systems	Examined the role of wearable technologies in detecting and monitoring CTS.
6.	A Wearable Sensor System for Monitoring Wrist Posture and Activity	2018	Wearable sensors, machine learning algorithms	Developed a system to monitor wrist posture and detect non-neutral positions in real-time.
7.	The Development of Wrist Joint Rehabilitation with Servo Motor Drive for Stroke Handed	2022	Servo motor-driven wrist rehabilitation device, Arduino-based automation	Automated wrist rehabilitation device using servo motors and IoT-based control was developed.

Research Gaps

- Small Data Sizes: Majority of the research studies reviewed used limited patient data, thus resulting in less generalizability.

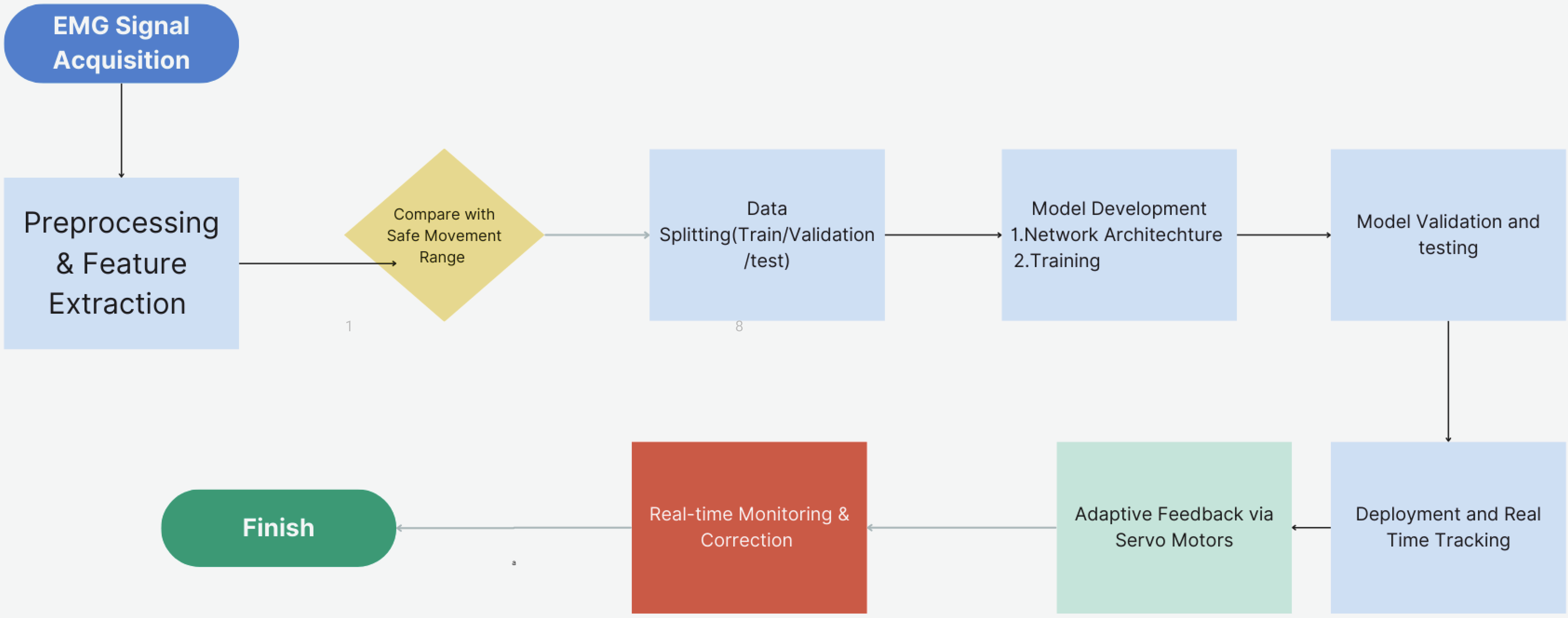
- Lack of adaptive feedback system: Personalized and adaptive feedback system like servo motor-driven rehabilitation is not used.

- Limited Sensor Integrations: Many of the developed frameworks have considered static features, no framework utilized dynamic muscular signals derived from EMG or motion sensors in real-time.

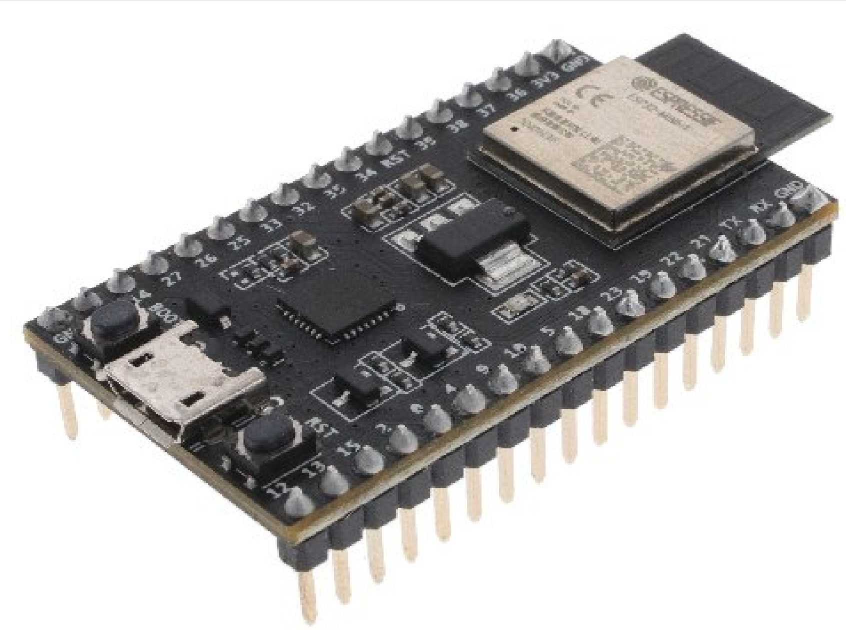
Problem Statement

CTS is caused by non-neutral wrist postures and abnormal muscle activity. Early detection of CTS is essential to prevent nerve damage. Thus, there is a need for non-invasive and cost-effective tool to provide therapy.

Workflow Diagram



Hardware Implementation



ESP32 (Microcontroller)

- RAM: 520 KB SRAM, 8 MB PSRAM (varies by model)
- Flash Memory: 4MB (varies by model)
- Wi-Fi & Bluetooth: 802.11 b/g/n, BLE 4.2
- Operating Voltage: 3.3V
- Application: acts as the hardware interface for connecting sensors with the software

MG995 (Servo Motor)

- Operating Voltage: 4.8V - 7.2V
- Torque: 9.4 kg.cm (4.8V), 11 kg.cm (6V)
- Rotation Angle: 0° - 180°
- Speed: 0.2 sec/60° (4.8V), 0.16 sec/60° (6V)
- Application: provide suitable rotation to wrist

EMG Sensor (Electromyography Sensor)

- Operating Voltage: 3.3V - 5V
- Output: Analog Signal
- Gain: Adjustable via onboard potentiometer
- Application: Muscle activity monitoring

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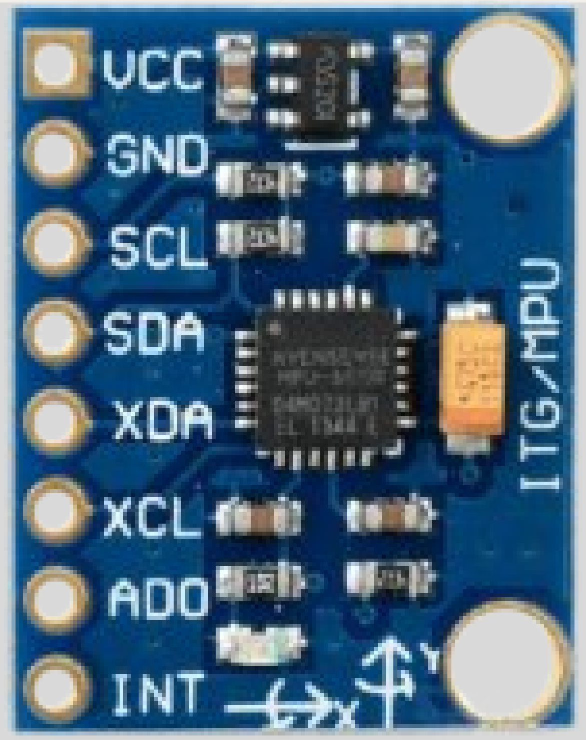
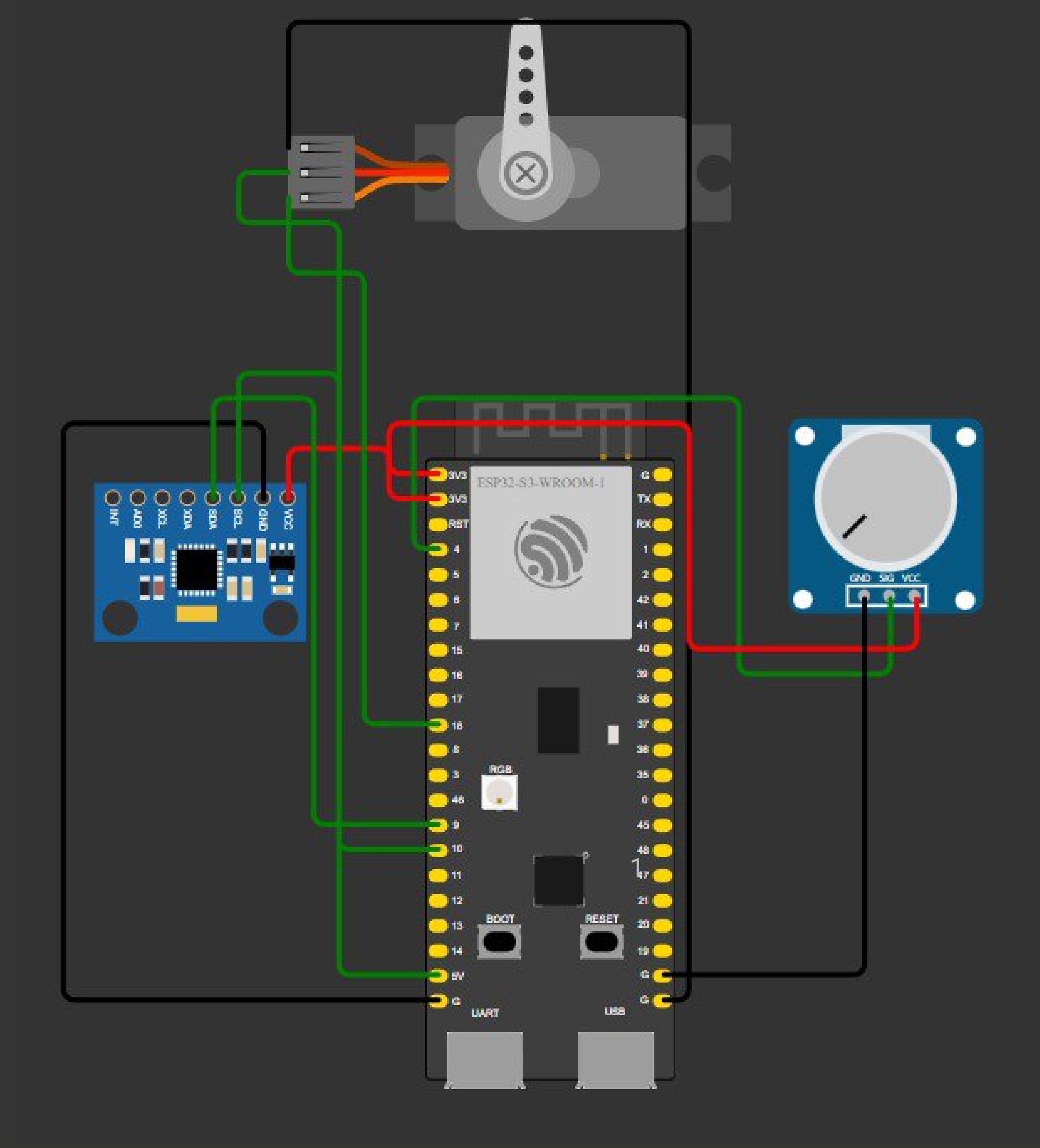


MPU6050 (IMU Sensor)

- Gyroscope Range: ±250, ±500, ±1000, ±2000 °/s
- Accelerometer Range: ±2g, ±4g, ±8g, ±16g
- Operating Voltage: 3.3V to 5V
- Power Consumption: ~3.9mA (active mode)
- Sampling Rate: Up to 1kHz

Circuit Diagram



https://wokwi.com/projects/421939157587167233

Working Principle

- EMG Sensor- Used to detect electrical activity of the muscle.
- Servo Motors- A servo motor is an electromechanical device that produces torque and velocity based on the supplied current and voltage
- MPU6050- The MPU-6050 combines 3-axis Gyroscope, 3-axis Accelerometer motion tracking devices. Changes in motion, acceleration and rotation can be detected.

Deep-learning

Relevant aspect in our project: Binary Classification

- Feedforward neural network (FNN) is used to classify EMG signals as 'No CTS' or 'CTS Detected'.

Choice of suitable NN:

- FNN is preferred over CNN and RNN because it has simpler architecture, easy to implement and effective for tasks like prediction whereas CNN and RNN are complex and these are computationally expensive.

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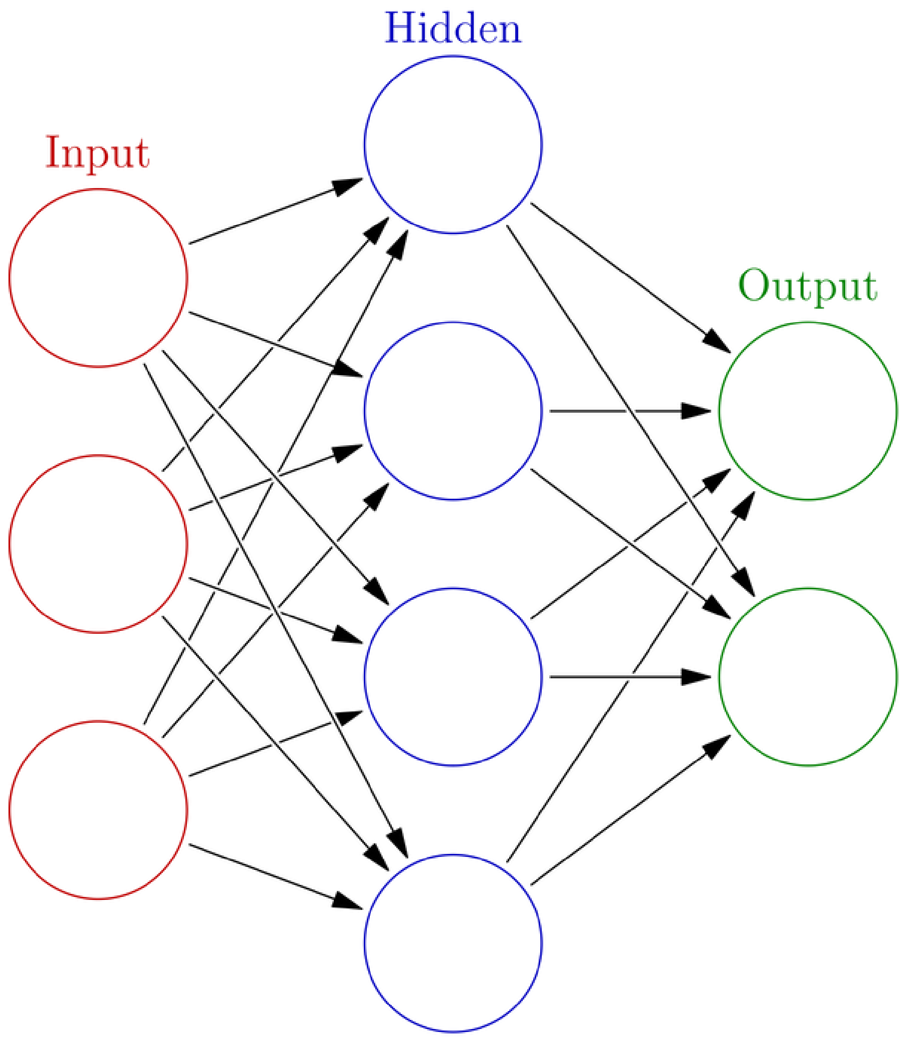
FNN Algorithm:

- FNN is a type of Artificial neural network (ANN) where information flows only in one direction from input layer to output layer through hidden layers. "Feedforward" refers to the connections between the units do not form a cycle, unlike in RNN.



Selection of dataset:

- Data is collected from EMG sensors through eight channels
- Class labels are

  1 - hand at rest,

  3 - wrist flexion,

  4 – wrist extension,

  5 – radial deviations,

  6 - ulnar deviations

Data Pre-processing:

- Handling missing values
- Feature extraction
- Normalization/ Standardization
- Assigning Target labels
- Data splitting into training, validation and testing

Timeline

Hardware Integration

Week 1-2

Hyperparameter tuning

Week 3-4

Model Testing and deployment

Week 4-6

References

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