# Low-cost smart footwear for remote gait monitoring of incomplete spinal cord injured patients

A project report submitted in partial fulfillment

of the requirements for the degree of

Bachelor of Technology

in

Electronics & Communication Engineering

by


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# Declaration

I hereby declare that the report titled ***Low-cost smart footwear for remote gait monitoring of incomplete spinal cord injured patients.*** submitted by me to the School of Electronics Engineering, Vellore Institute of Technology, Chennai in partial fulfillment of the requirements for the award of **Bachelor of Technology** in **Electronics and Communication Engineering** is a bonafide record of the work carried out by me under the supervision of ***Dr. Muthulakshmi S***.
I further declare that the work reported in this report has not been submitted and will not be submitted, either in part or in full, for the award of any other degree or diploma of this institute or of any other institute or University.

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## School of Electronics Engineering

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|---|---|---|---|
| Signature: | .................... | Signature: | .................... |
| Name: | .................... | Name: | .................... |
| Date: | | Date: | |

**Examiner**

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# *Abstract*

The present invention discloses a Smart Foot Wear to assess the rehabilitation progress of individuals suffering from spinal cord injuries (SCI). Body-mounted sensors, including Inertial Measurement Units (IMUs), offer a cost-effective means of measuring gait parameters, with the Foot Trajectory algorithm demonstrating efficacy in determining gait speed and stride length. Previous research highlights the promise of smart Footwear in quantifying gait characteristics and identifying subtle changes during rehabilitation. However, detecting initial and end contacts in gait monitoring, particularly in spinal cord-injured patients, remains crucial. To address this, a shank-mounted IMU system and a standalone IMU-based insole system have been developed, achieving accurate gait event detection of SCI patients.

Commercially available IMU sensors are susceptible to environmental noise, necessitating robust methods for event detection. The Smart Foot Wear features a sensor ensemble strategically integrated within the footwear's design enabling precise capture of foot-specific movement data, facilitating measurement of key gait parameters such as stride length, gait speed, and cadence with consistent data when walking in a straight path. Designed for ease of use in clinical and home-based settings, its cost-effective design offers a portable alternative to conventional gait analysis systems. Real-time data transfer to a cloud platform enables visualization and comparison of gait parameters over time, aiding therapists in monitoring patient progress.

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# Contents

# List of Figures

# Chapter 1

# Introduction

A Spinal Cord Injury can result in decreased strength and spasticity, depending on the level and type of lesion. It is known that individuals with an incomplete Spinal Cord Injury have more potential to regain ambulation in comparison to those with a complete Spinal Cord Injury, but gait training is often included in rehabilitation for all types of spinal cord injury. It becomes necessary to assess and document the patient's walking ability, function, ambulation speed, endurance, capacity and so on before beginning the training to compare from time to time so that his progression can be noted.

A potential application of these inertial sensors is to complement the aforementioned clinical gait tests by providing, in addition to the walking speed, information on the gait pattern and thus gait deficits of the patient. The benefit of using inertial sensors during the six-minute walking test has already been demonstrated for neurological diseases including multiple sclerosis, Parkinson's disease and stroke. Furthermore, wearable sensors carry the promise for long-term monitoring of gait speed and quality outside of laboratory settings, opening the potential to target remote interventions for individual patients.

# Chapter 2

# Literature Survey

## 2.1 Comparison of Different Algorithms for Calculating Velocity and Stride Length in Running Using Inertial Measurement Units

Body-mounted sensors, such as Inertial Measurement Units (IMUs), have emerged as a cost-effective means of measuring gait parameters in individuals. Among the plethora of algorithms developed, the Foot Trajectory algorithm has demonstrated remarkable efficacy in determining gait speed and stride length, leveraging an acceleration-based approach that minimizes energy consumption.

## 2.2 Complementing Clinical Gait Assessments of Spinal Cord Injured Individuals using Wearable Movement Sensors

The direct integration model for speed estimation offers flexibility, as it does not necessitate a training process or subject-specific calibration. Research indicates that IMU-based systems can yield results comparable to clinical tests like the 6-Minute Walk Test (6MWT).

Previous research has explored the potential of smart Foot Wears in analyzing gait parameters like stride length, foot angle, and pressure patterns in healthy individuals and those with neurological conditions. These studies demonstrate the promise of smart Foot Wears in quantifying gait characteristics and identifying subtle changes that may reflect progress or challenges during rehabilitation.

## 2.3 Gait analysis using wearable sensors

A standalone IMU-based insole system has been devised for monitoring gait parameters in patients undergoing physical therapy. This system optimizes computational resources for orientation estimation and acceleration de-drifting while employing dynamic thresholds for gait event detection

## 2.4 Enhancing Gimbal Stabilization Using DMP and Kalman Filter: A Low-Cost Approach with MPU6050 Sensor

By leveraging the DMP's capabilities, our study aims to enhance the accuracy and granularity of orientation data obtained from the MPU6050-equipped smart Foot Wears. This high-fidelity orientation information, combined with pressure sensor data, offers a comprehensive view of foot-specific movement patterns during gait. Moreover, the DMP's ability to reduce computational burden ensures real-time processing of orientation data, enabling continuous monitoring of gait dynamics without compromising performance.
They demonstrated the efficacy of DMP-enabled MPU6050 modules in various applications, including human movement analysis and attitude estimation in unmanned aerial vehicles (UAVs). By extending this technology to rehabilitation monitoring, we anticipate significant advancements in understanding gait recovery trajectories among incomplete spinal cord injury (SCI) patients.

## 2.5 A wireless sensor network for the biomechanical analysis of the gait

the work revolves around the development of a wireless sensor network for biomechanical gait analysis. Within their work, sensor nodes affixed to the limbs are utilized, with a significant focus on the MPU6050 module. This module integrates both a gyroscope and an accelerometer, essential for capturing motion data. Initial calibration is followed by data acquisition, with the MPU6050's outputs processed using rotational matrix methods and combined via a complementary filter to validate body motion. Test results underscore the MPU6050's effectiveness in capturing precise data, positioning it as a pivotal component in cost-effective alternatives to traditional opto-tracking cameras for gait analysis.

## 2.6 AN INTELLIGENT REMOTE MONITORING FOR LOWER LIMB REHABILITATION TREATMENT USING IoT

With a focus on reducing rehabilitation costs and improving patient care, wearable IoT devices play a crucial role. The author's work introduces the Lower Limb Rehabilitation Device (LLRD), featuring the MPU6050 sensor for precise movement data capture. Through gyroscope sensors and a 3-axis accelerometer, the LLRD efficiently records lower limb movements, facilitating categorization, monitoring, and estimation of patient status with minimal intervention. Transitioning from non-dependent accelerometers to the MPU6050 underscores its enhanced performance, offering comprehensive measurement capabilities across three axes. Integration with the MPU6050 enables smoother transitions during activities like standing and walking, ensuring seamless data access within the connected health environment and advancing rehabilitation technology.

## 2.7 A wearable comprehensive data sampling system for gait analysis

They addressed the need for robust biomechanical data sampling equipment for gait analysis and rehabilitation research, proposing a compact-embedded system capable of acquiring four types of lower limb biomechanical signals. This system, powered by a lithium battery, synchronizes signals through an embedded clock and stores them for offline analysis, offering portability and versatility for experiments in various terrains. However, a key challenge highlighted is the translation of acquired data into meaningful 3D positional data, particularly regarding joint angles of the lower limbs during gait. Various methods for drift compensation are discussed, with a focus on utilizing the MPU6050 sensor and Kalman filtering for enhanced accuracy.

## 2.8 Real-time Detection System of Gait Event for Disabled People

The author presents a portable gait detection system for lower limb amputees, crucial for objective gait analysis. Central to this system is the integration of the MPU6050, an innovative 6-axis motion processing component from InvenSense, featuring a 3-axis gyroscope and accelerometer, along with an expandable Digital Motion Processor (DMP).

This integration offers enhanced accuracy and efficiency in capturing gait data, reducing mounting space and simplifying hardware design. Coupled with the STM32F103C8T6 microcontroller for processing, the system demonstrates the author's comprehensive understanding of motion sensor technology, particularly the MPU6050's role in advancing gait analysis for lower limb amputees.

## 2.9 Development of Low-cost Wearable Walking Pattern Recognition System using Inertial Sensors

The author's research is focuses on developing a low-cost wearable walking pattern system using inertial sensors, particularly the MPU-6050 module, known for its versatility and reliability. The MPU-6050 meets specified requirements with configurable sampling rates and full-scale measurement ranges, enhanced by features like FIFO buffer and Digital Motion Processor (DMP). The DMP facilitates efficient sensor data processing, crucial for accurate motion detection and pattern recognition. The author demonstrates a comprehensive understanding of the MPU-6050's capabilities, showcasing its relevance in developing cost-effective motion sensing solutions for gait analysis and pattern recognition.

# Chapter 3

# Methodology

## 3.1 Gait Analysis

#### Definition

Gait analysis is the systematic study of animal locomotion, more specifically the study of human motion, using the eye and the brain of observers, augmented by instrumentation for measuring body movements, body mechanics, and the activity of the muscles.[1] Gait analysis is used to assess and treat individuals with conditions affecting their ability to walk. It is also commonly used in sports biomechanics to help athletes run more efficiently and to identify posture-related or movement-related problems in people with injuries.

### 3.1.1 Gait Parameters

Gait Parameters are the measures obtained from walk or run tests. Gait analyses are used for the identification of movement patterns, which are unique to everyone. Some major gait parameters are:

1. Stide Length
2. Stride Width
3. Cadence
4. Gait Speed

#### 3.1.1.1 Stride Length

Heel-to-heel distance of the same leg/foot in successive steps.

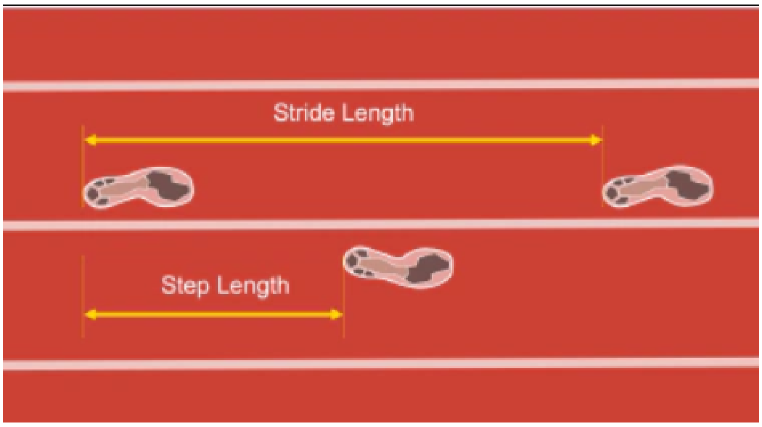


FIGURE 3.1: Stride Length for a person

When analyzing a patient's gait, it's crucial to acknowledge the inherent variation among individuals. Comparing standard values may not always provide an accurate assessment, as factors like training, habits, and individual bio mechanics significantly influence gait patterns.For instance, consider the case of a sprinter who has sustained a spinal cord injury (SCI). Despite the injury, this sprinter may exhibit faster movement compared to an untrained individual with no injury, due to their specialized training and unique gait adaptations.To address this variability, a more personalized approach can be adopted. By comparing an individual's gait analysis readings from their initial assessment to subsequent evaluations, we can track their progress over time. By observing changes in gait speed, stability, and other parameters relative to their baseline, we can assess improvements in their mobility and overall function.

#### 3.1.1.2 Stride Width

The distance between the heels of the two feet during a double stance

Stride width, also called base of support, is the distance between the heels of the two feet during a double stance. Stride width is measured either between the medial-most borders of the two heels or between lines through the mid-line of the two heels.

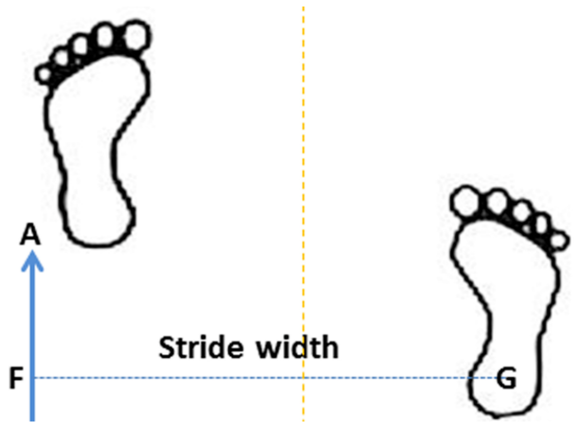


Figure 3.2: Stride Width for a person

#### 3.1.1.3 Cadence

Cadence in sports involving running is a measure of speed calculated as the total number of full cycles (of both a right and left foot strike) taken within a given period, often expressed in steps per minute or cycles per minute. It is used as a measure of athletic performance.

#### 3.1.1.4 Gait Speed

Gait speed is the time one takes to walk a specified distance on level surfaces over a short distance. This is not a measure of endurance. A distance of 3-10 meters is measured over a level surface with 2 meters for acceleration and 2 meters for deceleration.

## 3.2 Process Work Flow

### 3.2.1 Sensor Calibration and Data Collection

In the proposed methodology, three main sensors are utilized: gyroscope, accelerometer, and pressure/force sensors. These sensors play a crucial role in accurately capturing the movement and dynamics of the patient during gait analysis.

#### 3.2.1.1 Calibration

Calibration adjusts sensor readings to account for any biases or inconsistencies, thus providing more reliable measurements. Gyroscope and accelerometer offsets are calculated while keeping the sensor stable which are compensated in the future readings.

#### 3.2.1.2 Data Collection

Sensor data is collected in real-time from the gyroscope, accelerometer, and pressure/-force sensors. This real-time data collection ensures a continuous stream of information regarding the patient's movement. This collected data is processed and monitored using the Thingspeak cloud platform and visualized using PowerBi.

### 3.2.2 Orientation Estimation

Accurate orientation estimation is essential for understanding the spatial positioning of the patient during the gait cycle. By integrating the data of both the accelerometer and the gyroscope, the orientation of the sensor is obtained.

#### 3.2.2.1 Sensor Fusion Techniques

Utilize DMP for orientation estimation as it integrates data from the gyroscope and accelerometer to estimate orientation accurately. Compared to more computationally intensive filters like the Kalman filter, the digital motion processor inside mpu6050 can offload the work making it more efficient.

### 3.2.3 Acceleration Projection into Global Frame

Transforming accelerometer data into a global frame of reference is necessary to analyze the patient's linear acceleration.

#### 3.2.3.1 Gravity Removal

The readings provided by the accelerometer comprise of both the force exerted by external factors and the unchanging gravitational force.To isolate the true acceleration caused by motion, the gravitational component must be removed.. This can be achieved by leveraging the sensor's orientation data. By calculating The gravity vector, which is measured in sensor's reference frame (the sensor frame), one can subtract it from the overall acceleration measurement. This process effectively removes the influence of gravity, leaving behind the desired data representing the sensor's true acceleration. The accelerometer readings free from gravity are projected into the global frame based on its orientation.

### 3.2.4 Event Detection

Detection of gait events, such as foot lift off and landing, is a crucial factor in analyzing the gait cycle and identifying Gait phase transitions.

#### 3.2.4.1 Pressure Sensor Utilization

Pressure sensor detect heel strikes indicating foot landing or zero velocity phase within the gait cycle, facilitating the analysis of valid steps.

### 3.2.5 Zero Velocity Update (ZUPT) and De-drifting

To address integration drift in accelerometer readings, one can implement zero velocity update (ZUPT) techniques coupled with de-drifting procedures.

#### 3.2.5.1 ZUPT Implementation

ZUPT assumes zero velocity and displacement during the mid-stance phases of the gait cycle. By integrating accelerometer data piece wise within each gait cycle, DE-drifting integration over time.

### 3.2.6 Integration

The single and double integral of linear acceleration is estimated using the Trapezoidal rule to obtain the velocity and displacement during each stride. These integral values are used to calculate the temporal gait parameters to monitor in cloud platform Thingspeak and visualized in PowerBi.

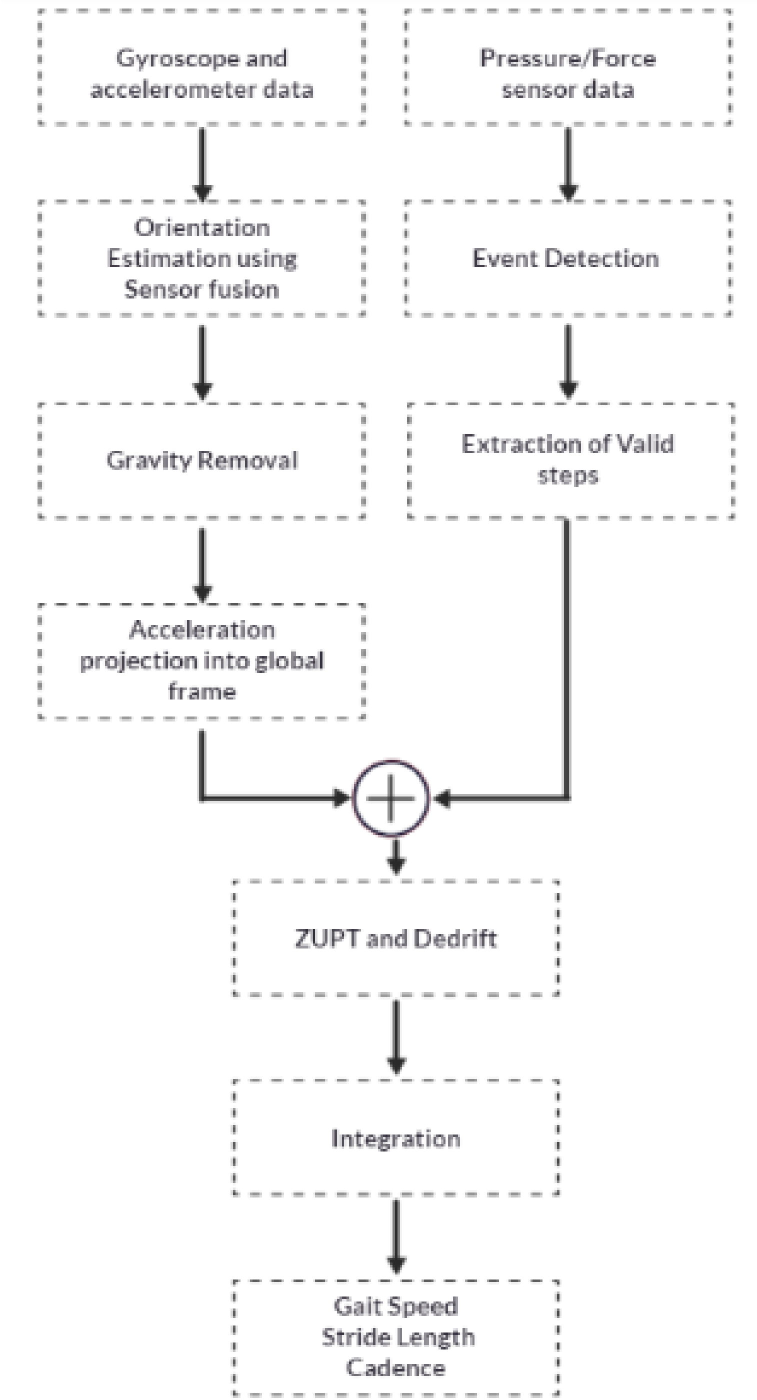


FIGURE 3.3: Process Flow

# Chapter 4

# Cost distribution

This study explores the cost-effectiveness of the gait analysis model designed for spinal cord injury (SCI) rehabilitation patients. The model leverages affordable sensor technology and a cloud-based platform for data visualization, aiming to provide a cost-efficient alternative to existing gait analysis solutions.

## 4.1 Cost Breakdown of the Proposed Gait Analysis Model

### 4.1.1 Hardware Components

Two MPU6050 Inertial Measurement Units (IMUs): (Rs150-Rs220 each)
Two ESP8266 Wi-Fi microcontrollers: (Rs350-Rs400 each)
Smart Foot Wear integration: (Rs600 each)
Pressure sensors: (Rs350-Rs500 each)

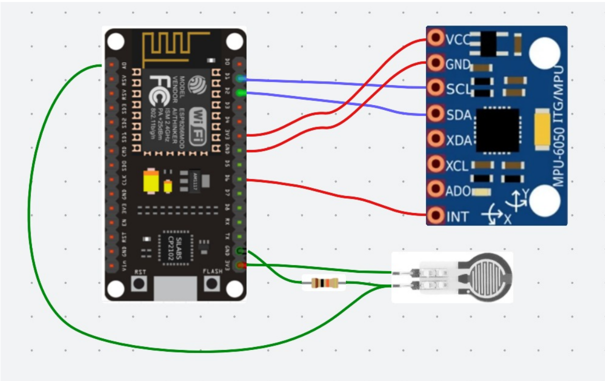


FIGURE 4.1: Block Diagram of our system.

### 4.1.2 Software Development

#### 4.1.2.1 Data collection and processing software

This study utilizes the ThingSpeak platform, a free, cloud-based Internet of Things (IoT) analytics platform, minimizing software development costs.

#### 4.1.2.2 Cloud Storage(ThinkSpeak)

ThingSpeak is a platform by MathWorks for collecting, storing, and analyzing data from IoT devices in real-time. It's commonly used for projects involving home automation, environmental monitoring, and IoT applications. ThingSpeak offers a free tier with sufficient storage capacity for basic gait analysis data collection.

### 4.1.3 Deployment Costs

Manufacturing cost per unit on the Basis of component estimates approximately Rs3500.

FIGURE 4.2: Footwear after incorporation of our system into it.

### 4.1.4 Cost Comparison with Existing Gait Analysis Products

#### 4.1.4.1 Overground Gait Labs

These high-end systems, typically used in clinical settings, employ advanced technologies like cameras and force plates. Their cost ranges from tens of thousands to hundreds of thousands of dollars.

#### 4.1.4.2 Wearable Sensor Systems

Offering a balance between cost and portability, these systems can include IMUs embedded in socks, Foot Wears, or ankle braces. Their cost varies from a few hundred dollars to several thousand dollars.

#### 4.1.4.3 Smartphone-based Systems

The most affordable option, these systems utilize smartphone sensors and potentially connect to wearable sensors for data collection. Their cost is generally less than a hundred dollars.

### 4.1.5 Cost Advantage of the Proposed Model

The proposed model offers a significant cost advantage compared to traditional overground gait labs. When compared to wearable sensor systems, the model's cost can be competitive, especially if those systems offer more advanced features. While potentially more expensive than basic smartphone-based systems, the proposed model offers the potential for richer data collection through the inclusion of pressure sensors, providing a more comprehensive gait analysis.
This study presents a sensor-based gait analysis model for SCI patients undergoing rehabilitation. By utilizing cost-effective hardware components, leveraging a free cloud-based platform for data visualization, and minimizing software development efforts, the proposed model offers a cost-efficient solution compared to existing gait analysis products. This cost advantage makes the model a potentially attractive option for promoting gait analysis in home-based rehabilitation settings, improving accessibility and affordability for SCI patients.

# Chapter 5

# Results and Discussions

## Objective

The Primary objective of our Footwear is to collect and analyze the Gait Parameters of an SCI(Spinal Cord Injured) patient. The analysis needs consistent and reliable data on the patient's Gait. This collected Data of the patient is further used by doctors to decide further treatment that will be given to the patient.

This data is visualized and compared with the person's data after a certain period. The results shown here are a simple comparison of the Data collected from three people of age groups between 15-25 and of different heights. This data is collected in real-time walking as on the road on a straight path, which is not the case in other work that has been done till now.

So, these data comparison is based on real-time situations. To make the comparison easy every subject tried to walk at the same pace as the subject-2. That is because the data collected can be validated whether the data is consistent and reliable.

## 5.1 Results and Comparison

The following results are a comparison of three individuals:

1. Subject-1
    - Height - 160cm
    - Weight - 50Kg
2. Subject-2
    - Height - 172cm
    - Weight - 65Kg
3. Subject-3
    - Height - 178cm
    - Weight - 70Kg

The data collected here includes gait parameters for the following gait parameters of the left and right foot are measured during walking: stride length, stride width, cadence, and walking speed. study subjects as outlined in Chapter 2.
After each data collecting session, the patient downloads the data and clears the cloud data. The doctor then receives the data for comparison in Power-Bi.

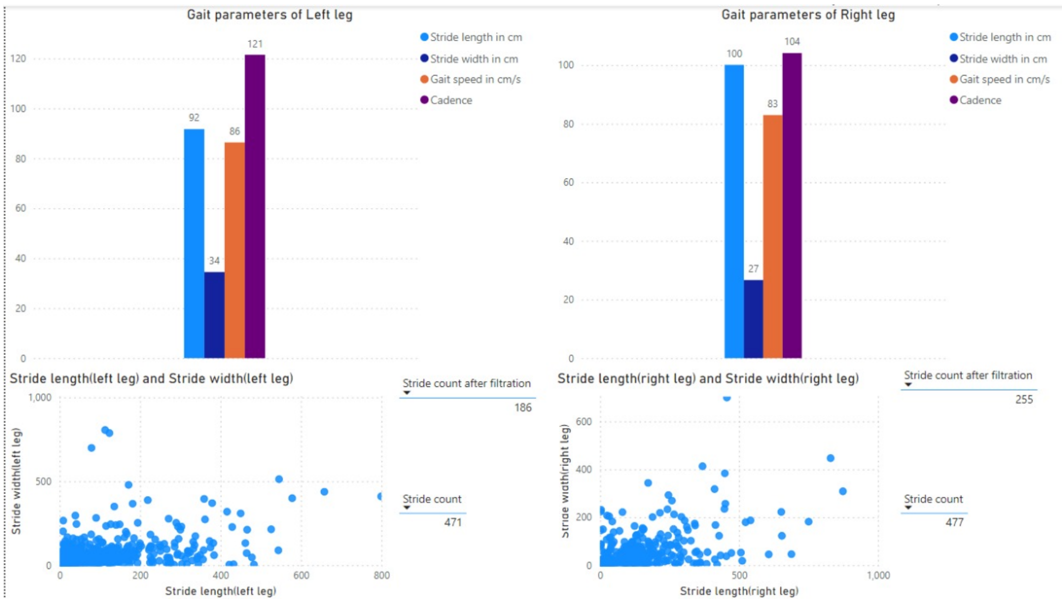


FIGURE 5.1: Data Visualisation of the Subject-1

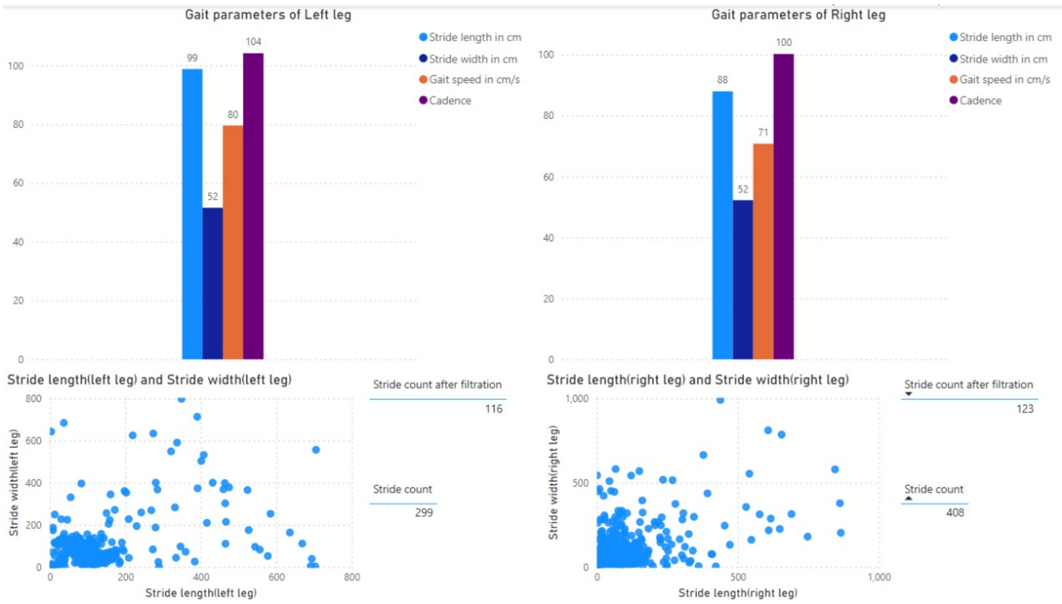


FIGURE 5.2: Data Visualisation of the Subject-2

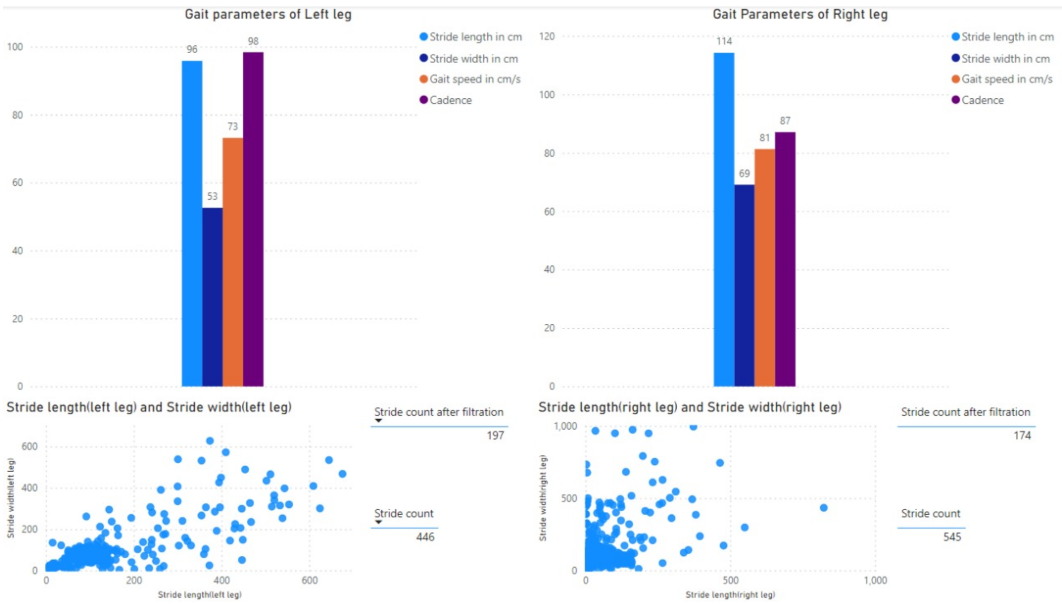


FIGURE 5.3: Data Visualisation of the Subject-3

| Parameter | Subject 1 | Subject 2 | Subject 3 |
|---|---|---|---|
| Stride length (Left Leg) | 91.71±34.04 | 95.82±26.79 | 98.77±32.04 |
| Stride Width (Left Leg) | 34.49±18.49 | 52.55±14.38 | 51.56±23.67 |
| Gait speed (Left Leg) | 86.38±35.33 | 73.15±20.79 | 79.53±23.32 |
| Cadence (Left Leg) | 121.49±45.31 | 98.36±36.98 | 104.14±38.92 |
| Stride length (Right Leg) | 100.08±29.69 | 114.23±28.32 | 87.98±30.79 |
| Stride Width (Right Leg) | 26.65±16.65 | 69.07±15.96 | 52.24±22.21 |
| Gait speed (Right Leg) | 82.96±33.14 | 81.27±22.45 | 70.80±24.34 |
| Cadence (Right Leg) | 104.09±44.01 | 87.06±20.85 | 100.26±30.73 |

FIGURE 5.4: Table containing data of all the subject's Gait parameters

In the data for Subject-1, who is the shortest among the group, we can observe that their stride length and width are smaller, while their gait speed and cadence are higher compared to the other two subjects. This is because due to their shorter limbs, Subject-1's stride length and width are naturally smaller than the others. However, to maintain the same pace as Subject-2, Subject-1 increase gait speed because they need to cover the same distance with a smaller stride length. We can see the details of this in Figure 5.4. In contrast, the data for the other two subjects is similar or close to each other.

Based on the data projections, we have observed some errors and deviations as anticipated. Despite this, we can confidently conclude that our system is dependable for providing accurate and cost-effective data to assist doctors and patients in their treatment plans. Our system proves to be a viable alternative to the existing systems available in the market.

# Chapter 6

# Conclusion and Future Scope

In Conclusion, the development of Smart Foot Wear represents a significant step forward in evaluating the rehabilitation progress of patients with spinal cord injuries (SCI). The utilization of body-mounted sensors, specifically Inertial Measurement Units (IMUs), made this innovation cost-effective for measuring essential gait parameters. The Foot Trajectory algorithm's incorporation enhanced the accuracy of determining gait speed and stride length, critical metrics in rehabilitation monitoring.

Furthermore, Smart Foot Wear's design prioritizes resilience against environmental noise for precise data collection. Its integration within footwear provides a practical solution for measuring foot-specific movement data enabling consistent measurement of key gait parameters such as stride length, Stride width, gait speed, and cadence, especially during straight-path walking.

The user-friendly design of the Smart Foot Wear makes it suitable for clinical and home settings, offering a portable alternative to conventional gait analysis systems. Real-time data transfer to a cloud platform enhances its utility, enabling visualization and differentiation of gait parameters over time. Ultimately, this assists therapists in closely monitoring patient progress and adjusting rehabilitation strategies as required.

Furthermore, work needs to be done taking data from more people and patients. A fully dedicated PCB can be built for developing a more compact system. By fabricating a PCB external noise or issues caused due to wiring also be Deducted. This makes the commercialization of our system.

A dedicated app for collecting and visualizing the data can be created rather than inserting data into a Power BI and comparing it with each session. This ensures smooth and hassle-free sessions during doctor appointments for the patient and the doctor.

# Appendix

*Appendix*

Code:

Code link

```
#define ESP8266BOARD

#include <PubSubClient.h>
  #include <ESP8266WiFi.h>

#ifdef USESECUREMQTT
  #include <WiFiClientSecure.h>
  #define mqttPort 8883
  WiFiClientSecure client;
#else
  #define mqttPort 1883
  WiFiClient client;
#endif


#include "I2Cdev.h"
#include "MPU6050_6Axis_MotionApps20.h"

#if I2CDEV_IMPLEMENTATION == I2CDEV_ARDUINO_WIRE
#include "Wire.h"
#endif

const char* server = "mqtt3.thingspeak.com";
int status = WL_IDLE_STATUS;
long lastPublishMillis = 0;
int connectionDelay = 1;
int updateInterval = 2;
```

FIGURE 6.1: code for loading all required libraries.

*Bibliography*

```
VectorInt16 aa;
VectorInt16 aaReal;
VectorInt16 aaWorld;
VectorFloat gravity;

#define INTERRUPT_PIN 15 // use pin 15 on ESP8266

int pin=A0;
int sensor;
bool collectData = false;
bool datatransfer=false;

volatile bool mpuInterrupt = false;

float velocityX = 0.0;
float velocityY = 0.0;
float velocityZ = 0.0;
float displacementX = 0.0;
float displacementY = 0.0;
float displacementZ = 0.0;
float previousAccelerationX = 0.0;
float previousAccelerationY = 0.0;
float previousAccelerationZ = 0.0;

float gaitspeed=0.0;
float stridelength=0.0;
float cadence=0.0;
float samplecount=0.0;
```

FIGURE 6.2: Code for initializing the parameters.

```
void mpu_loop() {
    static unsigned long prevTime = 0;

    if (!dmpReady) return;

    if (!mpuInterrupt && fifoCount < packetSize) return;

    mpuInterrupt = false;
    mpuIntStatus = mpu.getIntStatus();
    fifoCount = mpu.getFIFOCount();

    if ((mpuIntStatus & 0x10) || fifoCount == 1024) {
        mpu.resetFIFO();
        Serial.println(F("FIFO overflow!"));
    } else if (mpuIntStatus & 0x02) {
        while (fifoCount < packetSize) fifoCount = mpu.getFIFOCount();
        mpu.getFIFOBytes(fifoBuffer, packetSize);
        fifoCount -= packetSize;

        mpu.dmpGetQuaternion(&q, fifoBuffer);//orientation of the sensor
        mpu.dmpGetAccel(&aa, fifoBuffer);//accelerometer data is from th
        mpu.dmpGetGravity(&gravity, &q);//gravity component in different
        mpu.dmpGetLinearAccel(&aaReal, &aa, &gravity);//gravity componen
        mpu.dmpConvertToWorldFrame(&aaWorld, &aaReal, &q);//acceleration

         unsigned long currentTime = micros();
           unsigned long timeInterval = currentTime - prevTime;
```

FIGURE 6.3: Code for MPU6050 Loop.

```
void mqttPublish(long pubChannelID, String message) {
  String topicString ="channels/" + String( pubChannelID ) + "/publish";
  mqttClient.publish( topicString.c_str(), message.c_str() );
}

// Connect to WiFi.
void connectWifi()
{
  Serial.print( "Connecting to Wi-Fi..." );
  // Loop until WiFi connection is successful
  #ifdef ESP8266BOARD
    while ( WiFi.waitForConnectResult() != WL_CONNECTED ) {
  #else
    while ( WiFi.status() != WL_CONNECTED ) {
  #endif
    WiFi.begin( ssid, pass );
    delay( connectionDelay*1000 );
    Serial.print( WiFi.status() );
  }
  Serial.println( "Connected to Wi-Fi." );
}
```

FIGURE 6.4: Code for MQTT callback.

```
void setup() {
  Serial.begin( 115200 );
  // Delay to allow serial monitor to come up.
  delay(3000);
  // Connect to Wi-Fi network.
  connectWifi();
  // Configure the MQTT client
  mqttClient.setServer( server, mqttPort );
  // Set the MQTT message handler function.
  mqttClient.setCallback( mqttSubscriptionCallback );
  // Set the buffer to handle the returned JSON. NOTE: A buf
  mqttClient.setBufferSize( 2048 );

    mpu_setup();
}
```

FIGURE 6.5: Code for setup.

```
void loop(void) {
sensor=analogRead(pin);

    if (sensor<5) {
        collectData = true;

    }
if (sensor>5 && datatransfer==false) {
        collectData = false;
        datatransfer = true;
    }

    if (!collectData&&datatransfer) {
     stridelength=displacementY*100;
  stridewidth=displacementX*100;
      gaitspeed=gaitspeed*100/samplecount;
      cadence=60*2*gaitspeed/displacementY;

      if (WiFi.status() != WL_CONNECTED) {
      connectWifi();
      }
      // Connect if MQTT client is not connected and resubscr
      if (!mqttClient.connected()) {
        mqttConnect();
      }
      mqttSubscribe( channelID );

      // Call the loop to maintain connection to the server
```

FIGURE 6.6: Code for loop.

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