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Rehabilitation Monitoring System with IoT Application

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Abstract: The rehabilitation process is one of the crucial elements to a quicker recovery, particularly for stroke and sports injury patients who require ongoing rehabilitation. This study proposes a web-based, multimodal leg rehabilitation monitoring system for use in the home. While there have been many studies conducted on leg performance and home-based rehabilitation techniques, there are still limitations in the field of leg rehabilitation. One of these limitations is the complexity and cost of current rehabilitation equipment, which require supervision by trained therapists. Additionally, it takes a long time for doctors to receive data from these devices for monitoring purposes. In order to address these issues, it is important for leg rehabilitation exercises to be continually assessed by professionals with the knowledge to identify leg dysfunction and conditions such as stroke early on. This system is designed to aid in the rehabilitation of stroke and sport injury patients by tracking leg movement and pressure during therapy. This study presents a three-stage data acquisition, processing, and logging system for leg rehabilitation that uses flex sensors, force-sensitive resistors, and an accelerometer. The system employs an Arduino Mega Controller and ESP Wi-Fi shield to establish an IoT system named ThingSpeak, allowing doctors to remotely monitor and diagnose patient recovery progress. Data were collected for five subjects, as each subject performed six exercises. The graph showed the difference between the different subjects, as the readings were close to the same patient diagnosis. The system is portable, user-friendly, and has low power consumption, providing an efficient and cost-effective solution for leg rehabilitation.

Keywords: Leg Rehabilitation Monitoring System, Iot.

1. Introduction

Rehabilitation is a concept that is highly debated across the world. Rehabilitation is the process of physical therapy and exercises that help people regain physical function after an accident, stroke, or surgery [1]. It highlights that over a billion people worldwide live with a handicap, and 2.41 billion

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people live with illnesses that could benefit from rehabilitation services [2]. Studies show that rigorous rehabilitation reduces recovery time and improves outcomes. However, the continuous observation and correction by physical therapists during long-term treatment can be costly for patients and demanding for healthcare professionals [3]. To tackle these issues, new solutions, such as using Internet of Things (IoT) technology in rehabilitation supervision systems that are cost-effective and easy to use in both ambulatory and home settings, are being developed. The project outlined involves using IoT and sensors to monitor leg movement remotely. The data is analysed via a microcontroller and sent to the IoT network via Wi-Fi. Stroke sufferers can use these low-cost devices at home with minimal help from healthcare professionals.

The Internet of Things, which was originally a broad notion, has progressively become a part of life thanks to the rapid growth of the Internet and embedded sensor technologies. The use of the Internet of Things in the field of rehabilitation, in particular, is extremely beneficial to patients who must undergo rehabilitation therapy both in the hospital and at home [4]. The project aims to create a leg rehabilitation monitoring gadget that can provide continuous rehabilitation support and send data online to help stroke victims. It uses various sensors, such as flex sensors, force-sensitive resistors, and an accelerometer, with an Arduino to log and send data to a computer for analysis. The device is designed to collect data from multiple sensors during human movement actions and uses software development, signal processing, device specifications, and physiology knowledge to create suitable and affordable equipment.

2. Materials and Methods

The project aims to design and construct a device that can monitor the performance of leg rehabilitation. This device is designed to track the progress of patients with a stroke or other leg injury. The device has multiple benefits in this study, including low cost and network-based, which can store the data online for monitoring. The concept has been divided into two sections: hardware design and software design.

Figure 1 illustrates the project's concept, which is divided into three sections. The initial stage, the sensors unit, consists of a force sensor, flex sensor, and accelerometer sensor to detect pressure, flexibility, and direction of the leg. The microcontroller, equipped with a Wi-Fi shield, controls the sensors and records and transfers data via the Internet of Things for analysis and storage.

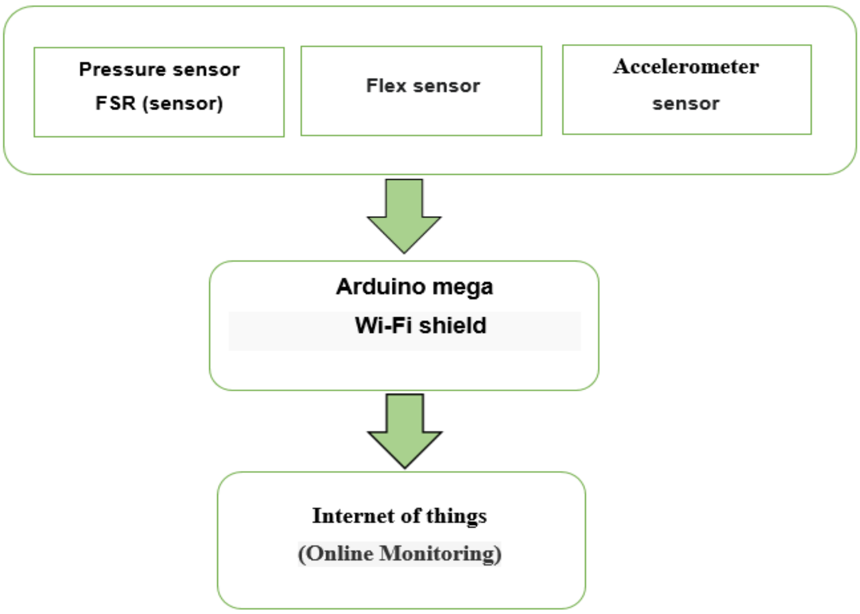

Figure 1: Block diagram for the main concept of the project.

2.1 Materials

The present project utilized several hardware and software components to fulfill the requirements outlined in the system diagram effectively. The hardware components employed included a sensor unit and a controller unit. The sensor unit consisted of a Force Sensitive Resistor (FSR) sensor, a Flex sensor, and an ADXL335 accelerometer. On the other hand, the controller unit was composed of an Analog Digital Converter (Arduino Mega), an ESP8266 Wi-Fi shield, and an I2C LCD. The FSR sensor was utilized to measure force or pressure applied to a surface, while the Flex sensor was employed to detect the bending or movement of a device. Additionally, the ADXL335 Accelerometer was utilized to measure acceleration in three dimensions. The Arduino Mega served as an analog-to-digital converter to convert the analog signals received from the sensors to digital signals for processing. Furthermore, the ESP8266 Wi-Fi shield was used to establish a wireless connection to the Internet, while the I2C LCD display was employed to display the measured data in real time.

Apart from the hardware components, the project also utilized two software components: the Arduino Integrated Development Environment (IDE) software and ThingSpeak. The Arduino IDE software was employed to program the Arduino Mega and to control the sensor readings and calculations. On the other hand, ThingSpeak was utilized to collect, store, and analyse the sensor data obtained from the system.

2.2 Methods

Three types of sensors were selected, which will read different types of readings. The first type of sensor is the force sensor, which will determine the force applied to the foot when moving. Three sensors were placed under the foot and inserted into the sock in 3 different positions: the front foot, the middle foot, and the heel. The second type of sensor is the flex sensor. There are three flex sensors. One flex sensor was placed in the ankle to determine the ankle's flexibility by assessing the angle of the ankle. The sensor was inserted into the sock. The two other flex sensors in the knee were inserted into the knee guard, one in the front of the knee and the other in the back of the knee, which will determine the angle bending of the knee. The last type of sensor is the Accelerometer, which is placed at the front of the leg. This sensor will read the direction of the leg when it is moved in the X, Y, and Z axis.

After identifying the pins and connecting them to the controller, the sensors read the leg movement and send it from the controller to the Wi-Fi via the Wi-Fi Shield. The data is sent to the Internet of Things system (ThingSpeak), which enables the specialist to analyse the patient's movement. Figure 2 shows the flowchart for the IoT system and data logging.

2.3 Device Development

The completed leg rehabilitation device, which consists of the main unit, sensory unit, Arduino shield, and ESP-Wi-Fi shield, is seen in Figure 3. The Accelerometer is on the leg, two of the flex sensors are stuck on the knee guard, one is jammed in the sock, and three force resistors are stuck on a sock. A crucial issue that warrants consideration is the pin connection between the ESP Wi-Fi shield and the Arduino. The most crucial component of this gadget is the Vero board, which provides perfect multi-connection to prevent short circuits caused by numerous wires and gives the project prototyping a good appearance and smaller size to apply to patients. Figure 4 shows the diagram of sensor connections to Arduino mega with Vero board.

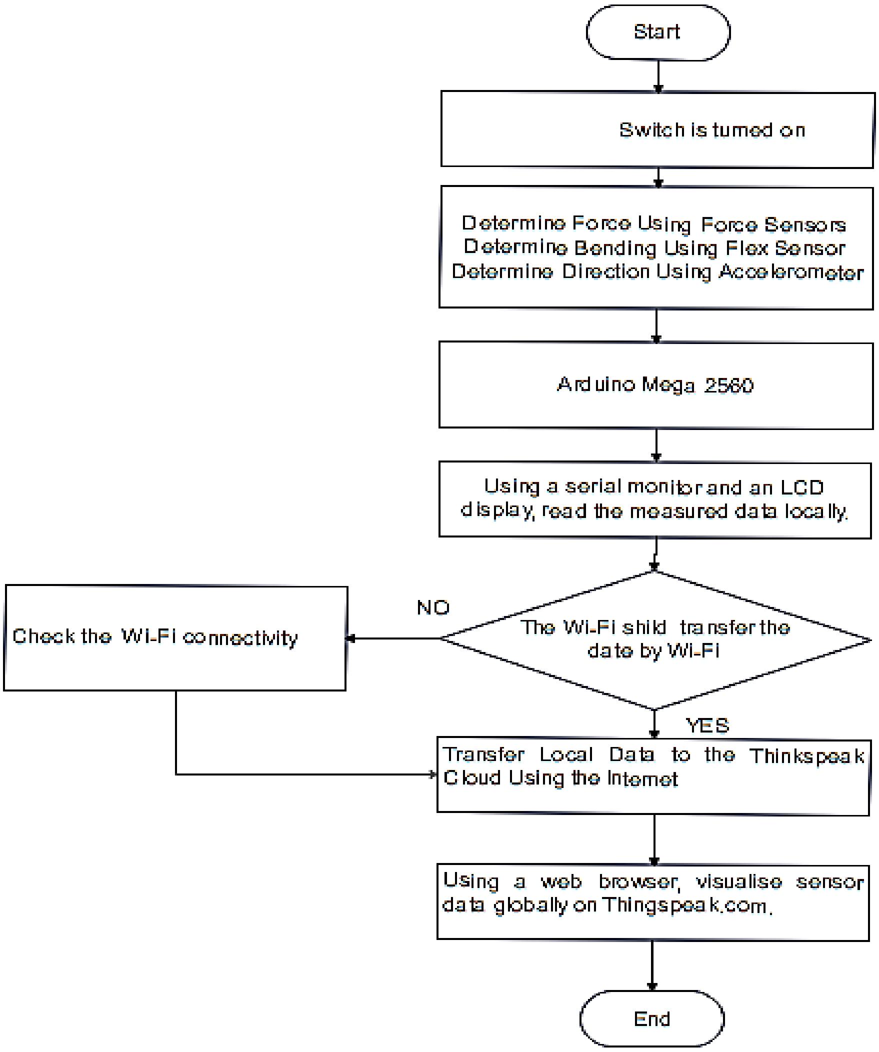

Figure 2: Flow chart for Internet of Things system and data logging

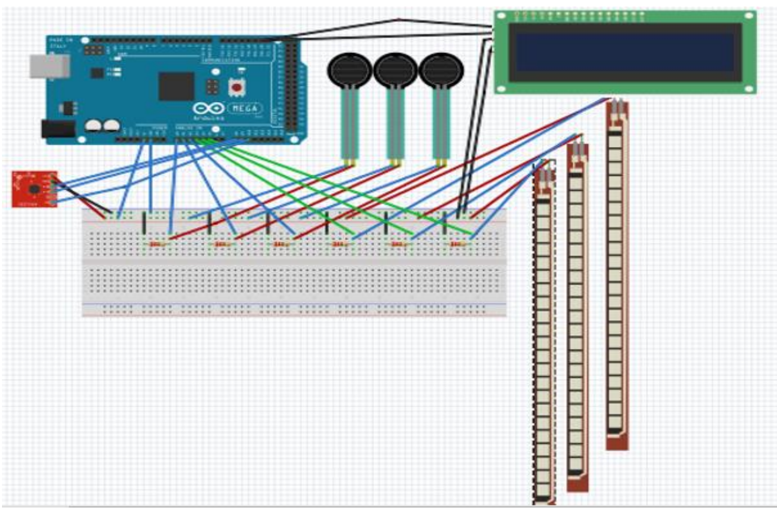

Figure 1: Diagram of sensor connections to Arduino mega

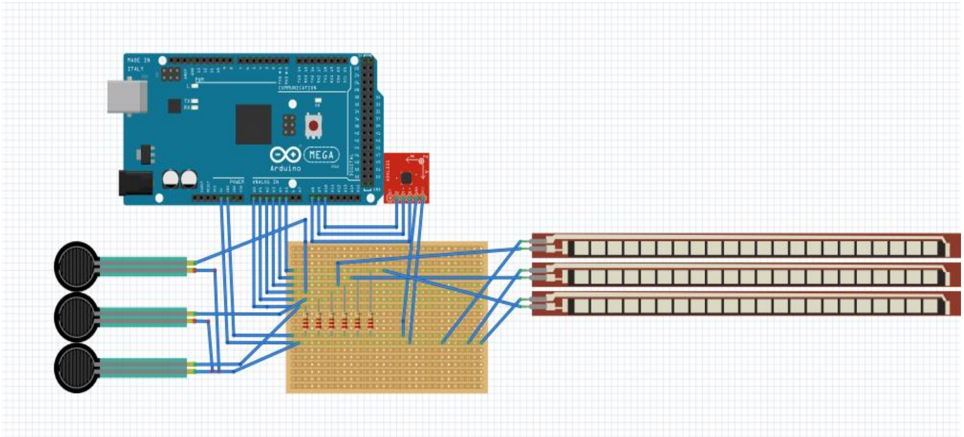

Figure 2: Diagram of sensor connections to Arduino mega with Vero board

Soldering the designed circuit into the Vero board was the focus of this project. The circuit was successfully soldered together, including the resistors required for each sensor. The overall configuration of the circuit is shown in Figure 5.

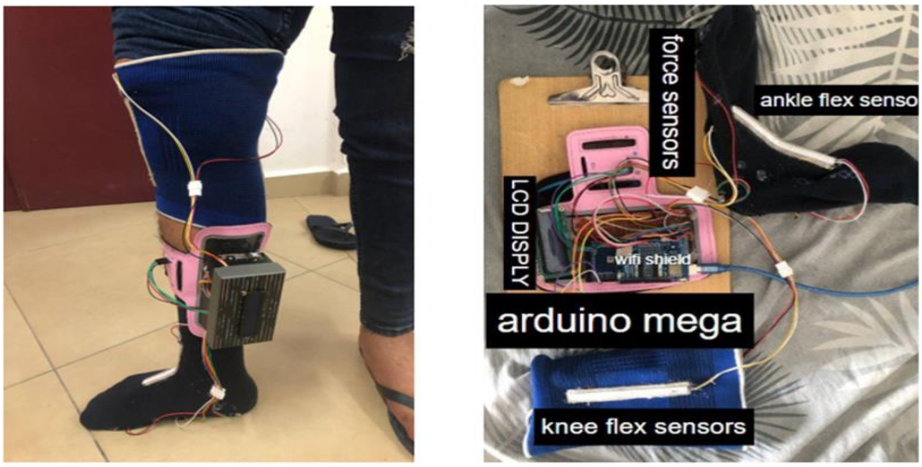

Figure 3: Device Development

2.4 Online Results

The data collected from the flex sensors, force resistor sensors, and Accelerometer was stored on the Thingspeak website and displayed the state of bending on an LCD screen to motivate the patient during exercise. And to access the data, a channel called "Leg Rehabilitation Monitoring System" was created on the ThingSpeak platform. It could be accessed by logging in with a registered email and password. The channel is displayed as shown in Figure 6.

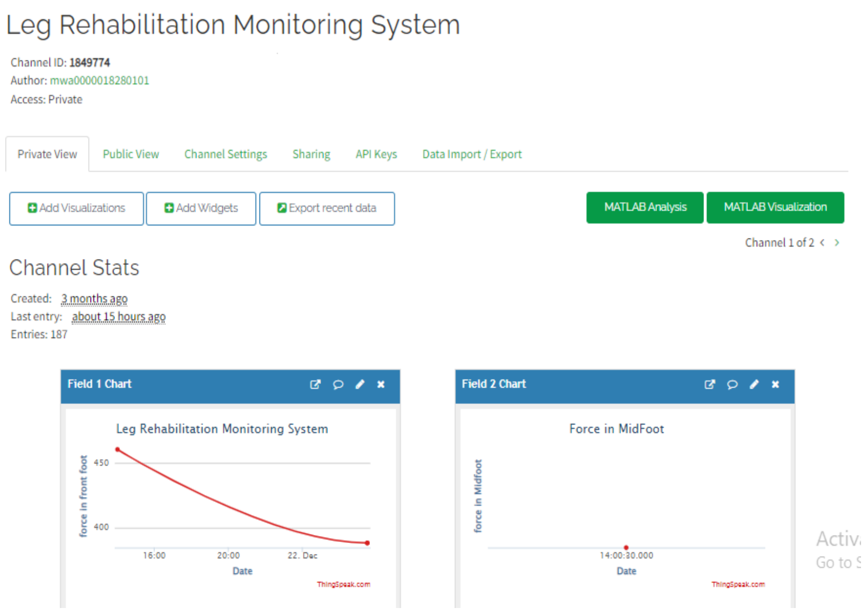

Figure 4: Channel interface in ThingSpeak

The data collected from the sensors were stored on the Thingspeak website, a platform for Internet of Things (IoT) applications. It allowed the researchers to access and analyse the data efficiently and to track the patient's progress over time. All data collected from the sensors were analysed and used to develop a system that could produce quantified results. This system was designed to help improve the accuracy and reliability of the rehabilitation device and to provide a more personalized and effective treatment for the patients.

3. Results and Discussion

The experiment will be based on the sensors. One force sensor, one Accelerometer, and two flex sensors. In this project, there are three main experiments for each type of sensor. This experiment was carried out on five subjects in order to measure the force in the foot, ankle flexibility, knee flexibility, and leg direction while performing activities. The subjects will be two stroke patients, two sport injury patients, and one normal person to validate the performance. The subject was asked to do serval exercises based on sensors functions.

3.1 Results

3.1.1 Force Sensitive Resistor Results Analysis

Experiment: The subject in this experiment was asked to Walk three steps forward slowly, then stand for 15 seconds, then walk three more steps. There are three sensors placed in three different positions on the bottom of the foot with socks to know the amount of pressure on the foot while walking as can be seen in Figure 7.

Based on the result in Figure 8, the heel is part of the foot that carries the force applied by the subject's body. When the subject was standing on one foot alone, the most pressure was on the heel, then the front of the foot, and then the middle foot.

Figure 7: Subject While Walking Exercise

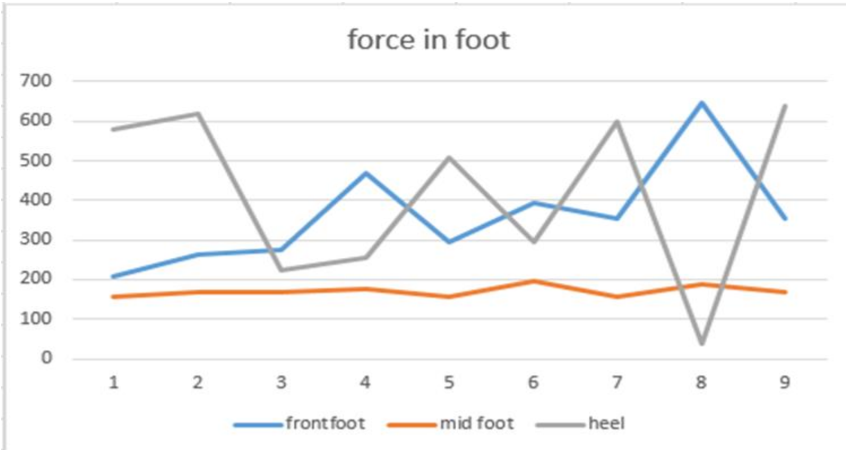

Figure 8: Provide excel graphs for all force finding for subject1 (healthy)

The body weight force undergoes constant changes as a person walks, owing to the alternating support of each foot. This force is transmitted through the leg bones and tissues to the supporting foot, which then applies a reaction force to the ground, propelling the body forward. The magnitude and direction of the force are determined by various factors, including the body's position, speed, and direction of motion. The gait cycle, which comprises the stance and swing phases, is a repeating pattern of movement that depends on the body weight force for balance and stability. During the swing phase, the body weight force shifts from the supporting foot to the swinging foot.

The gait cycle refers to the repetitive sequence of movements that occur during walking or running. The relationship between body weight and the gait cycle is important because it affects the mechanics of human movement, which in turn affects the way people walk or run. A person's body weight influences the amount of force that is applied to the ground during each step, which affects the timing and duration of different phases of the gait cycle.

The graph in Figure 9 shows that body weight changes during exercise can vary based on individual factors, such as medical conditions or injuries. The healthy subject's body weight increases, indicating hydration, whereas the stroke patients and sport injury patients exhibit varying body weight trends. The results of the experiment suggest the importance of considering individual factors when evaluating body weight changes during exercise.

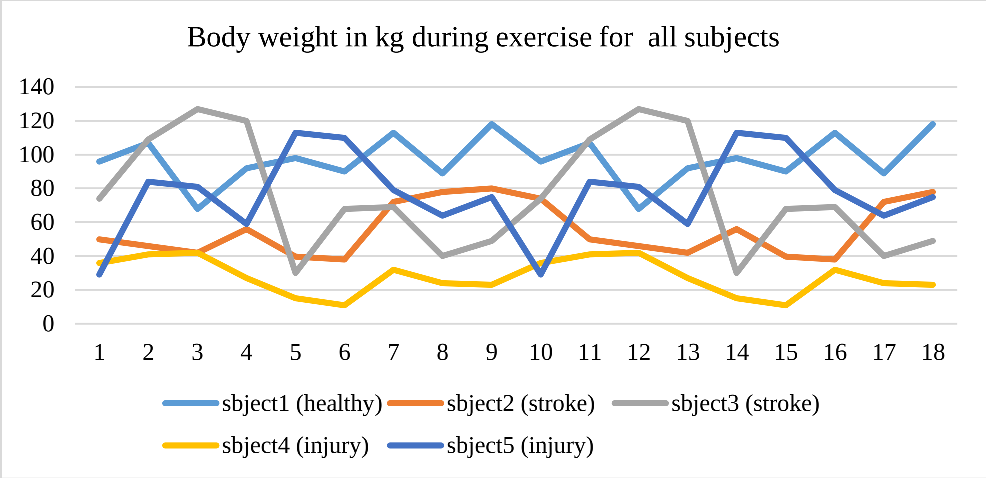

Figure 9: Provide Excel graphs for body weight in kg during exercise for all subjects

3.1.2 Flex Sensor Results Analysis

3.1.2.1 Flex Sensor Results Analysis for Ankle

Experiment: The subject in this experiment was asked to Point the toes upward as if attempting to touch the toes to the front of the shin as in Figure 10. Figure 11 depicts five graphs for five subjects performing the same exercise at the same time. Because of the excellent accuracy of the flex sensor, the results of the three patients were nearly identical in these graphs.

Figure 10: Ankle Pump Up and Down Exercise

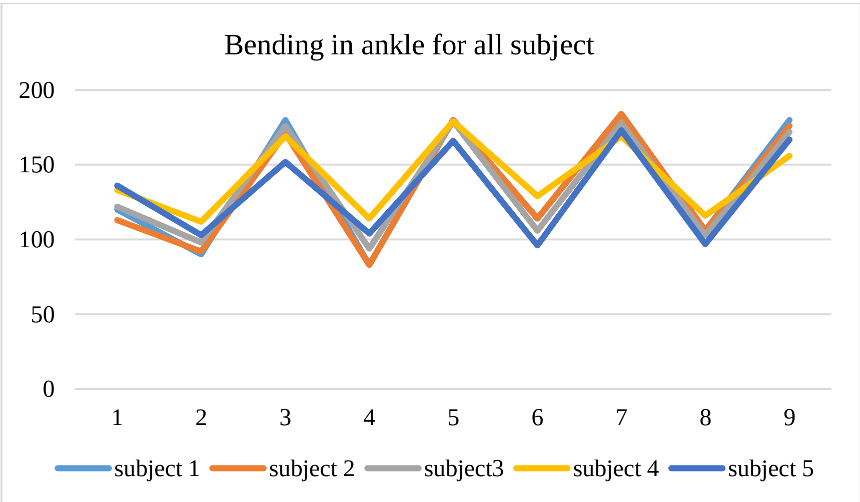

Figure 11: Ankle bending for all subjects

3.1.2.2 Flex Sensor Results Analysis of Knee

The subject in this experiment was asked to bend the knee to a 90-degree angle, holding briefly, and lower down to the ground, as shown in Figure 12. Repeat the exercise four times.

Figure 13 shows the result of knee bending. Based on the result, the angle of bending for the knee and the back knee is almost the same angle while doing the exercise.

Figure 12: Knee Flexion exercise

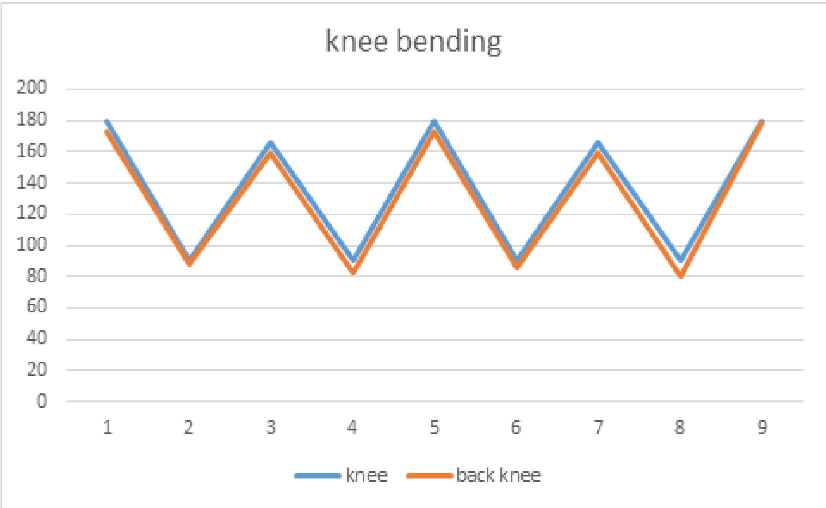

Figure 13: Knee bending for subject 1(healthy)

The angles plotted in the ThingSpeak field show the eight repeated measurements. Additionally, while the patient was bending their knee, an LCD was used to motivate them, as depicted in Figure 14.

Figure 14: LCD displays the status of knee bending

3.1.3 Accelerometer Results Analysis

In the last experiment, an accelerometer is attached to the front of the leg to track the inclination and force values of the lower limbs along the X, Y, and Z axes.

3.1.3.1 Accelerometer Results X

Figure 15 shows the lateral leg swing exercise while Figure 16 shows the result of the exercise. As a result, the angle of moving the leg right and left is almost the same angle while doing the exercise

Figure 15: Lateral Leg Swings Exercise

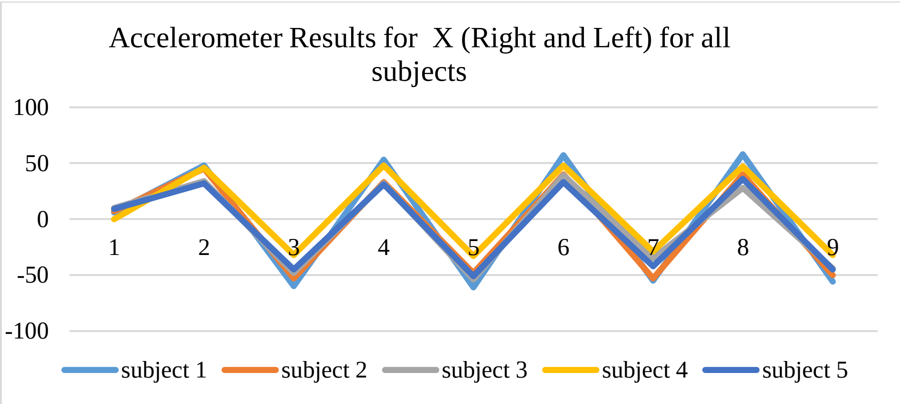

Figure 16: Accelerometer findings for X (Right and Left) for all subjects

3.1.3.2 Accelerometer Results Y

Figure 17 shows the standing quad stretch exercise while Figure 18 shows the result of the exercise. As a result, the angle of moving the leg up and down is almost the same angle while doing the exercise.

Figure 17: Standing Quad Stretch Exercise

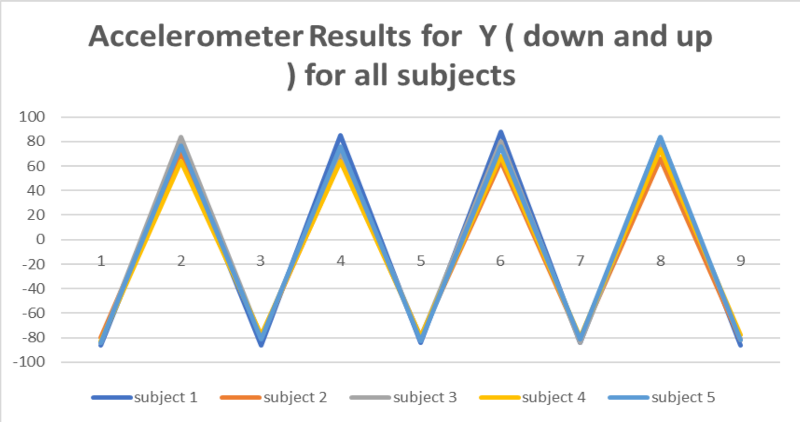

Figure 18: Accelerometer findings for Y (down and up) for all subjects

3.1.3.3 Accelerometer Results Z

Figure 19 shows the leg swing front and back exercise while Figure 20 shows the result of the exercise. As a result, the angle of moving the leg front and back is almost the same angle while doing the exercise.

Figure 19: Leg Swings Front and Back Exercise.

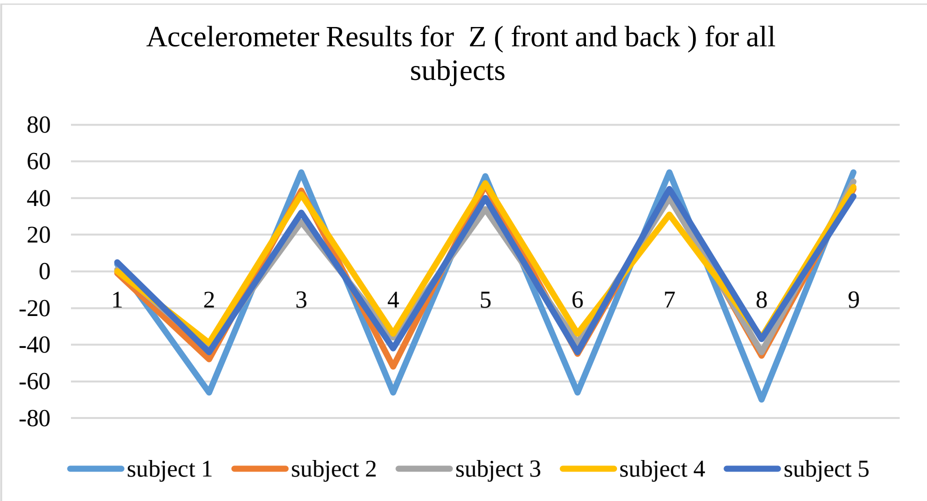

Figure 20: Accelerometer findings for Z (front and back) for all subjects

3.2 Discussions

A device for monitoring and analysing the movements of lower limbs in real time can provide valuable insights and information for rehabilitation purposes. The device consists of a sensory unit that activates when powered and transmits data such as bending of the ankle or knee, sudden acceleration of the leg, and changes in foot pressure to a microcontroller that processes the information before transmitting it wirelessly to a computer for online data tracking. The data is saved and displayed on a platform, allowing users to monitor and analyse the movements of their legs easily. The factors that can impact the results of a rehabilitation program for lower limb subjects include the severity of the injury or condition, the subject's age and overall health, and the type of rehabilitation program used. By monitoring and analysing the movements of healthy subjects, those who have had a stroke, and those who have had a sports injury, it is possible to compare and contrast their progress and determine the effectiveness of the rehabilitation program for each individual.

4. Conclusion

Rehabilitation Monitoring is one of the challenges for a doctor or specialist who is keeping an eye on a patient who has a serious injury or illness like a stroke. In this paper, the design and development of a wearable device for the rehabilitation of lower limb stroke and injuries have been demonstrated. A sock and knee guard with three different kinds of sensors, all of which are connected to Arduino. Force sensors are the first type of sensor. The sock has three force-sensitive resistors to track the forces the foot applies. Flex sensors built into the knee guard and sock track actions that result in leg bending. The accelerometer sensor recognises the x, y, and z directions while the leg is spinning. The Arduino microcontroller reads the analogue data from the sensors and converts it to digital values. These data are recorded in an IoT system that collects, stores, and makes data available online for clinicians to monitor. This project provides many advantages overall, including portable, low power usage, and low cost.

Acknowledgement

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