Design and Implementation of Remote Surface Electromyography Monitoring System for Patients with Muscle Disorders

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Abstract

Remote electromyography monitoring systems have emerged as a valuable tool in the field of healthcare. Wearable surface electromyography monitoring systems have the potential to provide continuous and objective monitoring of muscle activity in patients with muscle disorders. This paper presents a wearable surface electromyography monitoring system that consists of electromyography sensors, transmission unit and a processing unit which utilize Internet of Things. The system is capable of acquiring and processing surface electromyography signals from biceps muscles simultaneously and providing real-time feedback on muscle activity patterns allowing patients to carry out their daily activities without interference. The proposed system has the potential to improve the diagnosis of patients with muscle disorders.

Keywords - surface electromyography, muscles disorder, remote monitoring, real-time notifications, sensors, GPS/GSM communication

1. Introduction

For patients with muscular disorders such as muscular dystrophy, myasthenia gravis, or amyotrophic lateral sclerosis, surface electromyography monitoring systems can be particularly useful. These conditions are characterized by muscle weakness, wasting, and degeneration, which can lead to difficulties with mobility, breathing, and other activities of daily living. Surface electromyography monitoring systems can provide clinicians with an objective measure of muscle activity and function, which can be used to tailor treatment plans and monitor disease progression. In addition to clinical applications, remote surface electromyography monitoring systems also have the potential to improve patient self-management and quality of life.

By providing patients with access to real-time muscle activity data, these systems can help patients to better understand their condition, track their progress, and make informed decisions about their treatment and lifestyle choices. Furthermore, remote monitoring can reduce the need for in-person clinic visits, which can be particularly beneficial for patients who live in remote or underserved areas.

Wearable sensors have increasingly been incorporated and used in the rehabilitation of patients who suffer from diseases with associated movement restrictions. The advantage here is that wearable sensors provide real-world data on patients' movement performance. Wearable sensors are used in various contexts, both for monitoring purposes at home and in community settings. Applications focus on the assessment of treatment efficacy, early detection of disorders, prevention and home rehabilitation as well as the provision of an input variable for the control of prostheses and assistive systems such as robots and intelligent orthoses. Quantitative measures enable the assessment of treatment efficacy and are an important tool with which clinicians can tailor therapy to the individual needs of their patients as they provide information about the patients' performance between two therapeutic sessions. This not only allows remote monitoring by the therapist but can also give direct feedback to the patient.

2. Literature Review

A significant portion of the global population suffers from muscular diseases, which is a widespread health problem. These ailments frequently cause the muscles' capacity to contract and relax to be impaired, which lowers the patient's functional ability. An essential tool for identifying and tracking muscular illnesses is surface electromyography (surface electromyography), a non-invasive method that measures the electrical activity of muscles. Traditional surface electromyography monitoring methods, however, need that patients go to a clinic or hospital, which can be both expensive and difficult in remote areas. Additionally, because these devices only record the patient's muscle activity in a single moment, it is challenging to track improvements over time.

Smart sensors are typically used in wearable technology to identify different bodily factors and prompt the user or caregiver to take the proper action [1,2]. Wearable medical devices have emerged as a result of improvements in mobile technology and the growing demand from an older population for healthcare management [3,4,5]. These devices allow people to monitor their personal health information in real time. Because of the capability of constant monitoring, diseases can be prevented and urgent health problems can be avoided. Currently, a large number of wearable healthcare devices offer body bio-signals for diagnosis, including electroencephalograms, electrocardiograms (ECGs), blood glucose levels, body temperature, and electromyograms (EMGs) [6,7,8]. ECG and EMG measurements, which are brought on by changes in electrical signal during muscular activity, are significant and often utilized metrics for healthcare management.

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Electrocardiography involves applying electrodes to the skin to capture the electrical activities of the beating heart muscles over time [9]. The electro physiologic pattern-the heart muscle depolarizing and repolarizing during each heartbeat-produces the minor electrical change on the skin, which is produced and detected by an ECG signal detection device. The ECG signal detection system is being developed in the direction of miniaturization, family, and intelligence in response to the growing awareness of people's health and the ongoing advancement of science and technology. For precise ECG monitoring while exercising, Sun et al. inserted conductive fabric ECG electrodes into a health shirt [10].

Another electro diagnostic medical tool is electromyography, which measures and records the muscular electrical signal produced by skeletal muscle activities [11]. When muscle cells are stimulated by electricity or nerves, muscle potentials can result. As a result, it is possible to identify and assess human biomechanics, medical problems, or activation level [12]. EMG signal analysis has recently been used in medical and healthcare applications [14,15]. Benatti et al. suggested an adaptable integrated architecture for EMG acquisition for gesture recognition [15].

The current electromyography tests done in Kenyan Neurological hospitals are short-lasting and it is confined in a limited laboratory space since they are wired and non-remote. And these tests are done by few hospitals making it hard to access the service easily. Most use needle electrodes which are invasive, uncomfortable and intolerable to patients. Requires regular visits to neurologist and booking of appointments are required. All this makes the whole system expensive. For example, Nairobi Neurocare hospital charges Kshs. 20,000 to perform a single EMG test. The absence of efficient and trustworthy remote monitoring capabilities for surface electromyography systems, which restricts their usage for patients who require long-term monitoring or who live in rural or underserved locations, is thus the issue that the surface electromyography remote monitoring system attempts to address. The creation of a dependable and user-friendly remote monitoring system for surface electromyography has the potential to promote research into the health and function of muscles as well as patient care and outcomes for those with muscular illnesses. Consequently, take into account the shortcomings of the present system. In comparison to invasive EMG systems, remote EMG monitoring systems have a number of benefits, including improved convenience, mobility, cost-effectiveness, data quality, patient participation, and efficiency. They also address the problem of staff inadequacy in Kenya. To conclude, this project will be a great achievement in telemedicine field in Kenya particularly remote monitoring in remote areas. We have used the cheapest components.

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3. Methodology

Remote monitoring device will consist of both hardware and software components which will be integrated together to accomplish the task.

Hardware Components

NodeMCU -This is a powerful development board based on the ESP8266 chip, which allows for easy integration of Wi-Fi functionality into electronic projects. The board can be powered via micro USB or through an external power supply connected to the VIN pin. The NodeMCU can communicate the processed signals and output to other devices, such as my laptop, through various communication protocols such as USB or Wi-Fi. The NodeMCU will transmit Surface Electromyography (surface electromyography) data to ThingSpeak and via GSM module to a phone. I preferred NodeMCU board due to its built-in Wi-Fi capabilities, powerful microcontroller, high customizability, and affordability. Its ability to connect to the internet and transmit data wirelessly is essential for transmitting EMG data to the cloud-based IoT platform. Its powerful microcontroller and Lua programming language allow for efficient data processing, while its customizability enables developers to add custom functionalities and integrate various sensors and modules. Additionally, its affordability and availability make it accessible to a wide range of users, including healthcare professionals, researchers, and caregivers.

Power Supply- The proposed system will be supplied by two 9V batteries connected in series. The surface electromyography sensor will be directly connected to this power supply while the other components will be powered by 5V power supply from a buck converter. A Buck Converter can be used to power a NodeMCU (which operates at 5V) by converting a 18V to 5V required by the NodeMCU. The Buck Converter can regulate the voltage and ensure a stable and consistent power supply to the NodeMCU. The NodeMCU produces 3.3V by using its onboard voltage regulator. The voltage regulator is responsible for converting 5V to the required voltage for the NodeMCU and its peripheral devices. This 3.3V will power GSM and GPS module.

GSM Module -SIM800L is a quad-band GSM/GPRS module that operates on the frequencies of 850MHz, 900MHz, 1800MHz, and 1900MHz. It communicates with microcontrollers via serial communication and requires a minimum of four connections (V_{CC}, GND, RX, TX). The NodeMCU will send the processed surface electromyography data to a phone via a GSM module (SIM800L) by establishing a mobile connection and sending a text message. The NodeMCU will use an appropriate

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library or API to interface with the GSM module and send the data. If the internet connection fails, the 2G capabilities of GSM will still function to send the data.

EMG Sensors- A sensor is a transducer device to detect events or changes in its environment, and then provide a corresponding electrical output. The most important characteristics of a sensor are precision, resolution, linearity, and speed. Figure. 1 shows the Surface EMG v3 sensor is a type of electromyography (EMG) sensor that is used to measure the electrical activity of skeletal muscles.

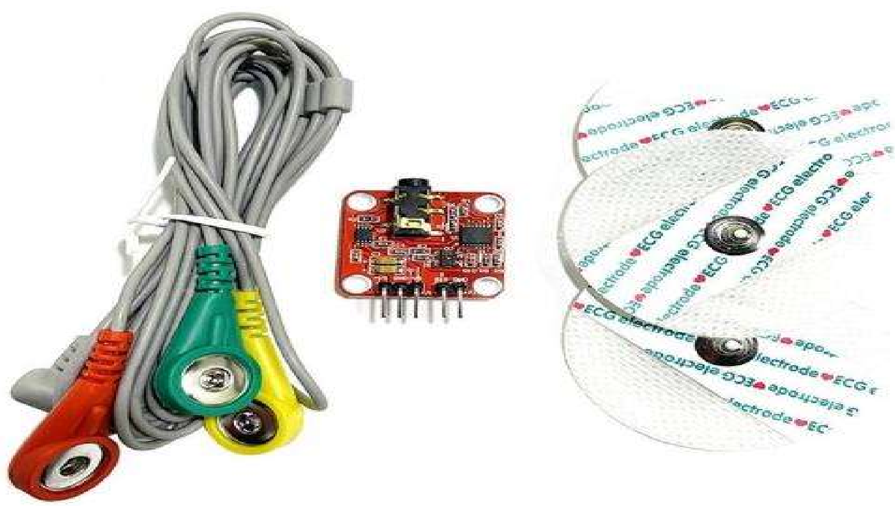

Figure 1: EMG V3 Sensor with Electrodes

The sensor works by detecting the electrical signals that are generated by muscle fibers when they contract. The Surface EMG v3 sensor consists of three electrodes that are placed on the skin surface above the muscle of interest. Two electrodes serve as the recording electrode, while the other electrode serves as the reference electrode. The recording electrodes detects the electrical signals generated by the muscle fibers, while the reference electrode provides a stable reference point for the measurement. The two electrodes on the belly of the biceps muscle serve as the recording electrodes and detect the electrical signals generated by the muscle fibers during contraction. The reference electrode provides a stable reference point against which the electrical activity of the biceps muscle can be measured. The output signals can then be processed and analysed by a NodeMCU microcontroller. Surface EMG electrodes provide a non-invasive technique for measurement and detection of EMG signal. These electrodes are simple and very easy to implement. Gelled electrodes are preferred over Dry electrodes due to its light weight reducing problems of electrode fixation Encountered when using dry electrodes.

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GPS Module - The NEO-6M GPS module is a compact, low-power GPS receiver with high accuracy and fast time-to-first-fix. It communicates with microcontrollers via serial communication and requires a minimum of four connections (V_{CC}, GND, RX, TX). It will provide precise locations as needed.

Software

Arduino IDE (Integrated Development Environment) is an open-source software development platform designed for programming Arduino boards. Arduino IDE is used to write, compile, and upload code to Arduino boards, which can be used for a wide range of applications such as robotics, home automation, Internet of Things (IoT), and many more. The IDE includes a code editor with features such as syntax highlighting, code completion, and error highlighting. It also includes a library manager with a wide range of pre-built libraries that can be easily added to the code. The serial monitor in the IDE allows for real-time monitoring of the input and output of the Arduino board. Arduino IDE will be used to write, compile, and upload code to the NodeMCU development board.

ThingSpeak : The NodeMCU will be programmed to send the processed surface electromyography data to ThingSpeak, an IoT platform, using the ThingSpeak API. The NodeMCU establishes a secure connection with ThingSpeak and sends the data in a specific format. In order for the results to be send and displayed on a web site, the system was linked to thingspeak.com web server, a site that supports Internet of Things (IoT) developers to post and manipulate their data for visualization. SYSTEM DESIGN

The software design for this project involves several components that need to be developed and integrated together to achieve the desired functionality. The main components include the NodeMCU firmware, EMG data processing algorithm, ThingSpeak integration, GSM module integration, GPS module integration, and threshold checking algorithm. Below is a block diagram of how the whole system will work. Figure 2 shows how EMG electrode sensors will detect muscle activities. They will continuously monitor muscle activities present as electric potential generated by muscle cells when they are electrically or neurologically activated.

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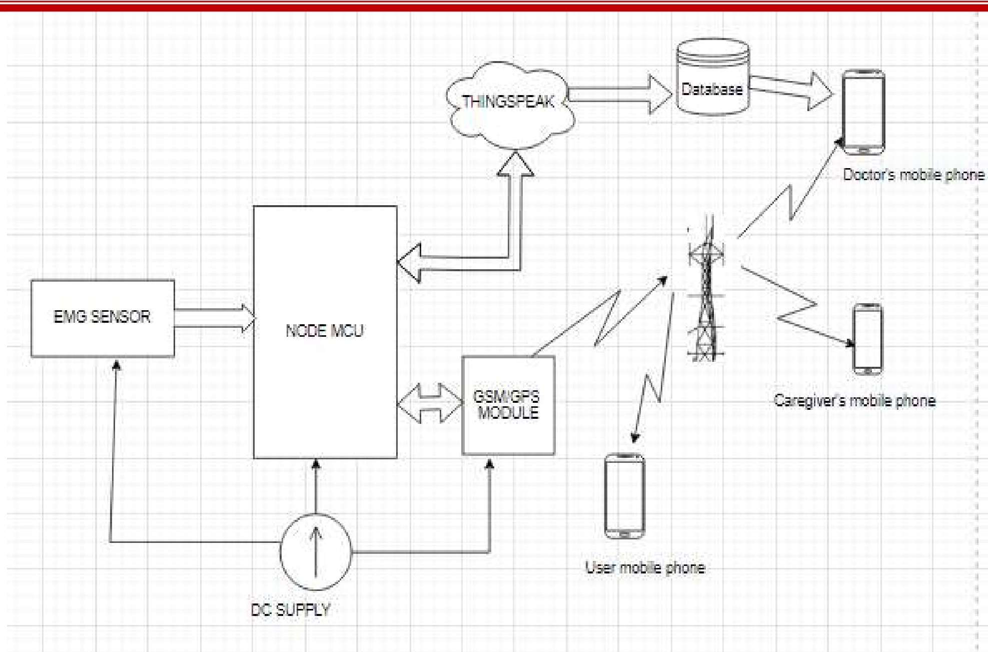

Figure 2: Block Diagram of Remote surface electromyography monitoring system

NodeMCU is responsible for reading data from the EMG v3 sensor, processing the data to obtain meaningful information, setting thresholds, and sending data to ThingSpeak and the GSM module. The data is then stored in ThingSpeak channels for further analysis and visualization by the doctor. The GPS coordinates are sent to GSM module when the muscle activity level exceeds the threshold.

The threshold checking algorithm was integrated into the EMG data processing algorithm and the NodeMCU firmware. The algorithm compares the RMS value of the EMG signal to a pre-defined threshold and determines if the muscle activity level is within a normal range or if it has exceeded the threshold. If the threshold is exceeded, the algorithm triggers the GSM module to send SMS messages containing the GPS coordinates. The circuit diagram as shown in Figure 3.

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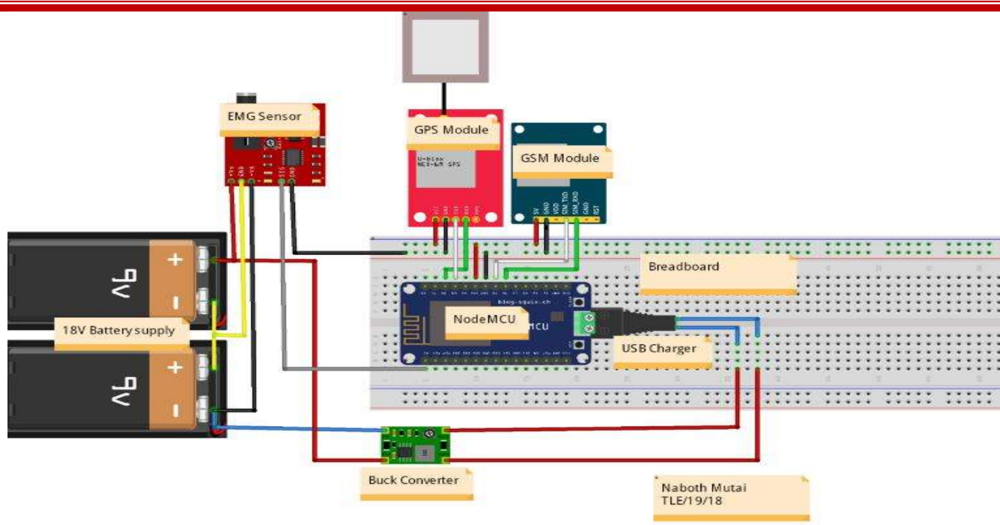

Figure 3: Circuit Diagram of Remote surface electromyography monitoring system

Figure 4 represents the flowchart of operations of the surface electromyography Remote monitoring, showing each step with various conditions. The process starts with collection of EMG data, processing them to be sent via WiFi and GSM module, it checks if there's WiFi connection, this process repeats until the connection is made, during the internet connection process, GSM will sent the readings to the phone.

After this threshold is checked, if exceeded GPS is activated to obtain its coordinates and alert messages with GPS coordinates are sent. The process is repeated sequentially.

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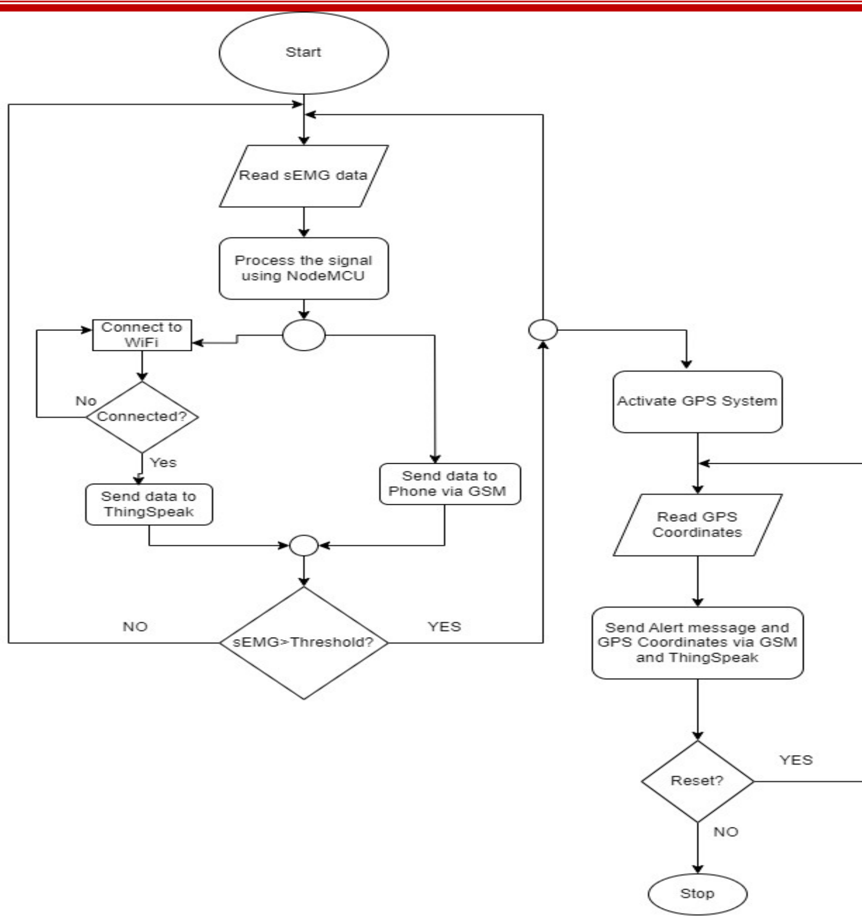

Figure 4: Flowchart of operations of the of surface electromyography Remote monitoring system

4. IMPLEMENTATION

The prototype or experimental setup is depicted in Figure 5. This system has been tested by placing the surface electrodes on a human body for reference, detection and ground junction.

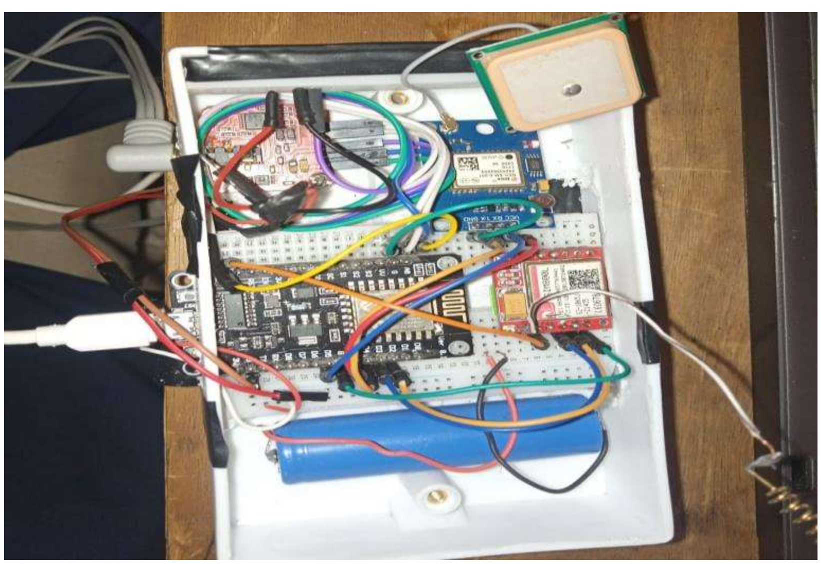

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Figure 5: Prototype of the surface electromyography monitoring system

Figure 6 shows the placement of electrodes on the biceps brachii muscles. These electrodes are connected to the EMG sensor module which is then powered up to start collected data. The procedure was conducted based on Weiss guide on Performing Nerve Conduction Studies and Electromyography [13].

Figure 6: Electrode placement during testing

When the EMG sensor is interfaced with the NodeMCU then after compiling and building the code which also configures the ThingSpeak server, real-time EMG readings can be monitored. This implementation thus utilizes the concept of IoT. The EMG monitoring signal is displayed on the Cloud as shown in Figure 7 depicts visual representation of EMG data that was collected and uploaded to ThingSpeak. This provides a valuable insights into the electrical activity of skeletal muscles that can be used by the doctor to analyse muscle activation patterns.

Figure 7: ThingSpeak EMG charts

The same data was sent via WiFi to the cloud was also sent to my phone using GSM module, sample EMG data was received as shown in Figure 8. In remote areas where internet connectivity is limited, GSM will still transmit the data from EMG sensor to the doctor's phone. This makes the system suitable for monitoring in remote locations.

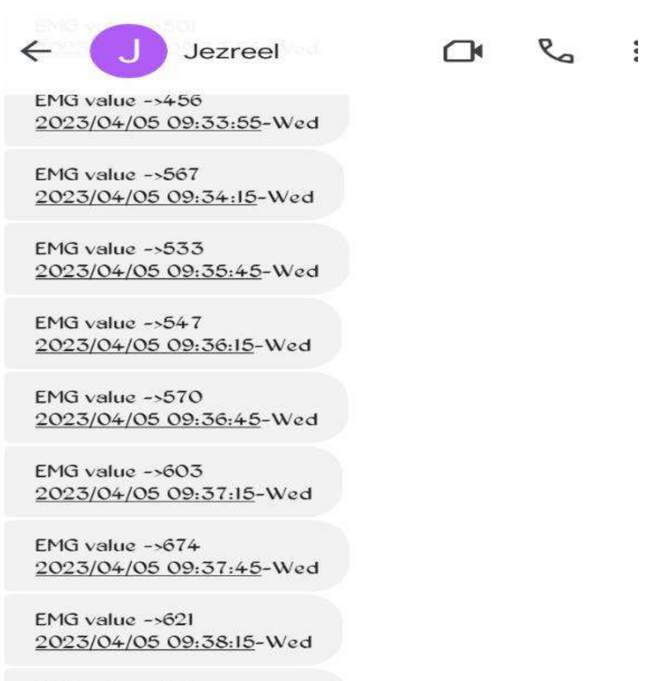

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Figure 8: Sample EMG data received from GSM module

After doing a vigorous muscle exercise, threshold was exceeded and alert messages with GPS locations were also sent to phone as SMS messages as shown in Figure 9.

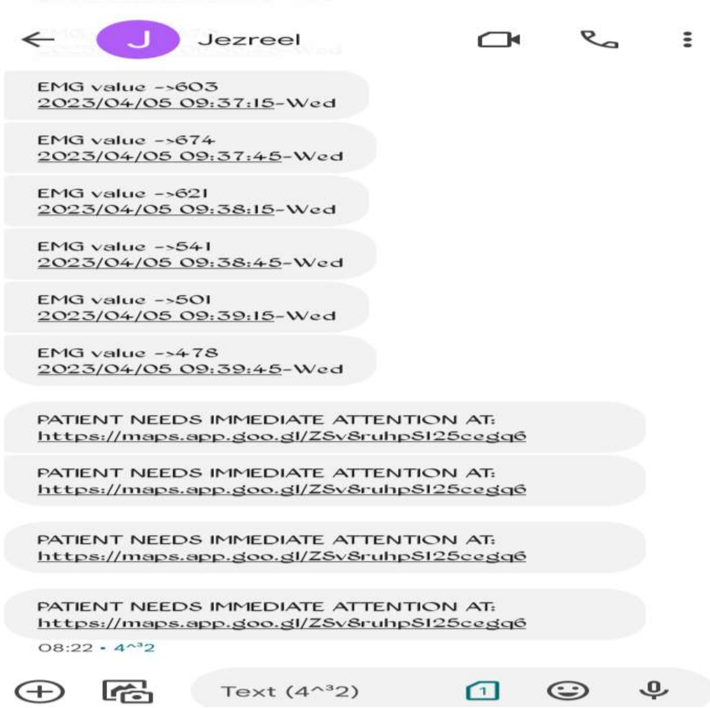

Figure. 9: Alert Messages with location link

5. Conclusions

The project successfully achieved its objectives, as evidenced by the successful implementation of each of the project's steps, from collecting EMG data to transmitting it to the ThingSpeak platform and mobile phone. A simple prototype of remote health monitoring system was developed using NodeMCU which was capable of transmitting data through WiFi and GSM module via SMS. The System was able to transmit data to a web server through the ESP8266 WIFI module. It was also able to send data to a mobile phone via SMS and relay an alert message with GPS coordinates when threshold values were exceeded.

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