IoT Based Stroke Rehabilitation Monitoring System

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IOT BASED STROKE REHABILITATION MONITORING SYSTEM

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***Abstract*— Stroke is a perplexing and lethal neurological condition and is the second leading cause of death worldwide. One of the severe repercussions induced by stroke is hemiparesis. It causes weakness or loss of function on one side of the body. It can be challenging to live with such a disability as it hinders normal day-to-day activities. It takes a multidisciplinary team of physicians, psychiatrists, and caretakers to treat patients suffering from this disorder. Therefore, it is of the utmost importance to constantly monitor and treat the patients to improve their chances of recovery. This process can be complicated due to patient safety concerns during a pandemic such as covid 19. It increases the risk as it increases the possibility of another stroke attack. It also decreases the treatment's effectiveness as physical contact between doctor and patients has been reduced to ensure safety from covid 19. In our work, we developed a remote IoT-based stroke monitoring system that measures the patient's movement. This data is then sent to the cloud servers, where the concerned medical professionals can remotely access them to analyze and monitor the patient's progress.**

Keywords*— *Post-stroke rehabilitation monitoring system, IoT, inertial measurement

I. INTRODUCTION

Stroke is the most debilitating chronic condition. It can concur prolonged damage to the human body and sometimes even be fatal. It is projected to be the second leading cause of death by 2030[1]. It is a cerebrovascular disease that occurs when a blockage or bleed of the blood vessel interrupts or reduces blood supply to the brain[2]. Depending on the severity of the stroke, symptoms may vary from subtle to severe. Some commonly observed symptoms are slurred speech, numbness in the face and arms, blurred vision, nausea, headache, loss of bowel and bladder control, and loss of consciousness[3]. An insufficient supply of oxygen to the brain leads to brain cells and tissue damage as they begin to die within minutes without the necessary supply of oxygen. The restricted blood flow makes it hard for the brain to manage vital bodily functions like breathing, blood pressure, and much more[4]. Once the brain is affected, it is followed by a string of cataclysmic events throughout the body, including the respiratory system, nervous system, digestive system, urinary system, circulatory system, muscular system, and reproductive system[5]. Post-stroke complications also lead to severe and life-threatening repercussions. Complications can vary according to the severity and type of stroke. They can be categorized into neurological complications, cardiovascular complications, and complications of immobility[6]. Hemiparesis causes motor impairment that affects almost 65% of stroke victims[7]. A neurological disorder affects one side of the body[8], making it difficult for patients to perform daily activities efficiently and depend on assistance entirely. To minimize functional disability, improve recovery process and maximize the quality of life, early rehabilitation interventions are very important[5].

Evidence suggests that COVID 19 infections increase an individual's risk of stroke for the young and elderly population alike[9]. Commuting and visiting physiotherapy centers to undergo treatment and therapy cannot be advised for people recovering from a stroke as it increases the chances of worsening the patient's condition and affects the effectiveness of the treatment that needs to be provided to them by the concerned medical professionals. Thus, to overcome this, we propose an IOT based stroke monitoring system that allows the concerned medical personnel to have remote access to the day-to-day progress of their patients. The proposed proprietary system includes two IMU sensors to measure the patient's movement of prescribed physiotherapy exercises during their physiotherapy sessions. The data from these sensors are recorded, processed, and stored in the cloud. This data can be accessed remotely by the physiotherapists to analyze and assess the patient's progress, hence improving the quality of the care provided to the patient from the comfort and safety of their home.

II. METHODOLOGY

The proposed method uses a proprietary motion monitoring system, Stroke Rehabilitation Monitoring System (SRMS). The SRMS comprises two inertial measurement units (MPU6050). The sensors measure the rotational velocity and detect the tilt angle along three axes X, Y, and Z, using an in-built gyro meter and accelerometer units [10]. The set of six values obtained as output data from the MPU6050 determines the motion in the 3D space. The output is obtained through serial communication and saved in analysable .csv form. The data is then sent to the cloud using Node MCU(ESP8266) to enable remote monitoring.

Finally, we present a graphical chart to the medical personnel monitoring the patient to assist them by providing quantifiable data.

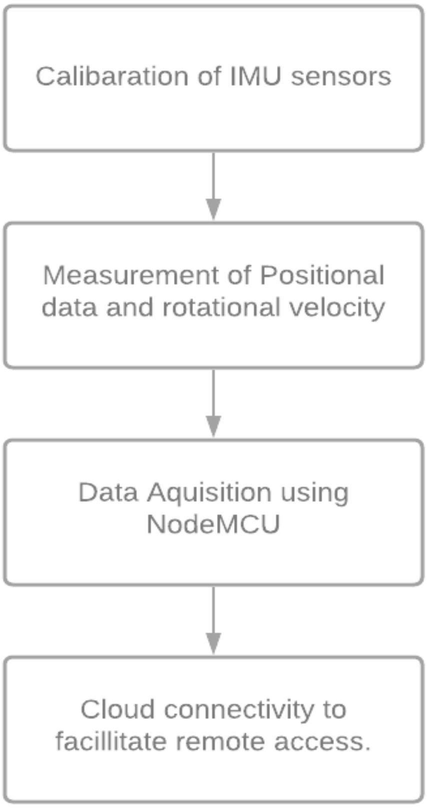

Fig. 1 Methodology Flowchart.

A. Stroke Rehabilitation Monitoring System:

Using the two MPU6050 units, SRMS records unprocessed inertial data. The data consists of six values from each MPU6050 unit. The gyro meter and accelerometer recordings are stored in a .csv file with X, Y, and Y coordinates, as shown in figure 1. The coordinate data is used to generate metrics like the range of motion, the velocity of movement, Restriction in motion, and to derive a graphical representation of the same over a given period.

The data collected are first stored locally in the NodeMCU for processing the data, and then all the data, processed and unprocessed, is uploaded to the MQTT cloud service. In predefined steps, a server requests the data, where it is stored for future use by medical personnel.

B. MPU6050 Calibration:

The inertial sensors have to be calibrated before use. This step is necessary to remove the zero error. Zero error is when the sensor records an angle shift value even when it is in level. To eliminate this, we add an offset to the raw accelerometer and gyroscope sensor values. We then adjust the offset value until the gyroscope readings are 0. The 0 value indicates that there is no rotation and the accelerometer reports only the acceleration due to gravity pointing straight down. Our program uses the proportional and integral part of the PID to find the most suitable offset values. The integral component plays a vital role in calibration. It takes a fraction of the error from the set point (zero) and adds it to the integral value. Subsequent readings reduce the error to the desired offset value. The bigger the deviation from the set

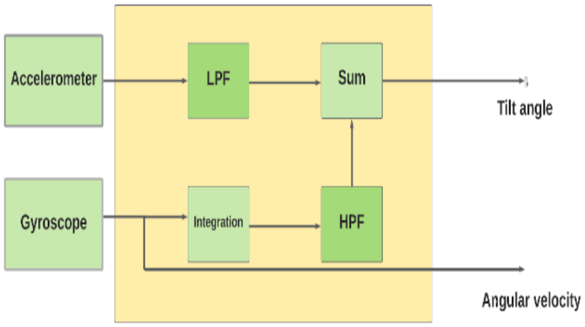

Fig. 2 complementary filter block diagram.

the more the integral value is adjusted. The proportion part plays a role in the integral math by masking the noise. Because of the noise and the immobility of the sensor, the derivative part of the PID is not used. After 600 readings, the integral value lands on a solid offset. With the noise removed. The integral value is used for the actual offsets at the end of each 100 readings, and the last proportional reading is ignored because it is sensitive to noise.

C. Data acquisition using Node MCU:

The MPU6050 communicates with the ESP8266 through the standard I2C protocol. Here the ESP8266 is the master device, and the MPU6050 is the slave device. The master device initiates communication with a slave device. The slave device then responds to the master device when it is addressed. SDA (serial data) wire is being used here for data exchange between master and slave devices. SCL (Serial Clock) establishes a synchronous clock between the master and slave. In the Arduino IDE, we first specify I2C addresses as a parameter and initialize the accelerometer values (ax, ay, az) and gyro values (gx, gy, gz). wire.begin() function begins a transmission to the I2C slave (MPU 6050).

Gravitational force positional information is used to obtain an angular position from the accelerometer. The gyroscope calculates the angular position by integrating the angular velocity over time. Since the accelerometer is sensitive to all the forces acting on a body, every minor disturbance will affect the measurement significantly. However, this is relatively a short-term phenomenon, and over the long term, this data becomes usable. Keeping this in mind, we use a low pass filter to filter out the unreliable data. The integration process that the gyroscope uses to determine the angular velocity introduces a drift over time. To overcome this, we use a complementary filter as shown in the block diagram fig 2. This filter reads data for both short and extended periods.

D. Cloud connectivity:

We use an MQTT cloud service provided by EMO X for this purpose. After the data is collected through the NodeMCU, which is an open-source IOT platform that includes firmware that runs on ESP8266 Wi-Fi SC and hardware based on ESP-12 module, it is sent to the MQTT cloud service in the cloud, and a back-end program written in python handles the processing of the data. When connecting to this cloud service via NodeMCU, a connection method is set according to the target cloud service's requirements, EMO X. After the processed data is sent to the cloud, the concerned medical professionals can remotely access it and analyse the patient's progress.

III. Results

A subject has carried out two physiotherapy exercises involving motion in the upper limb of the body to measure the positional data using two IMU sensors placed on the subject's upper limbs, the first on the forearm and the second sensor was placed on the bicep region. The sensor arrays were strapped in position, and the data from the IMU sensors were recorded as the subject performed the physiotherapy exercises. Before measuring the data, the IMU sensors were calibrated. This calibration is required to eliminate the zero error from the values obtained from the sensors. The calibration offset values are shown in fig 3.Keep your text and graphic files separate until after the text has been formatted and styled.

The first exercise primarily involves movement in the forearm region and the bicep brachii muscle flexion, as shown in fig.4. As the subject demonstrates the exercise, positional data (ax, ay, az) and angular velocity (gx, gy, gz) are plotted graphically.

Fig 5 and 6 are graphical representations of the positional and angular velocity values of the IMU sensor in the forearm, indicating movement in the lower arm.

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COM5
11:19:39.666 -> Send any character to start sketch.
11:19:39.666 ->
11:19:39.666 -> Send any character to start sketch.
11:19:39.666 ->
11:19:41.205 -> Send any character to start sketch.
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11:19:42.660 -> Send any character to start sketch.
11:19:42.707 ->
11:19:44.183 -> Send any character to start sketch.
11:19:44.183 ->
11:19:45.683 ->
11:19:45.683 -> MPU6050 Calibration Sketch
11:19:47.675 ->
11:19:47.675 -> Your MPU6050 should be placed in horizontal position, with package letters facing up.
11:19:47.675 -> Don't touch it until you see a finish message.
11:19:47.675 ->
11:19:50.692 -> MPU6050 connection successful
11:19:51.681 ->
11:19:51.681 -> Reading sensors for first time...
11:19:55.863 ->
11:19:55.863 -> Calculating offsets...
11:19:59.058 -> ...
11:20:02.229 -> ...
11:20:05.393 -> ...
11:20:08.610 -> ...
11:20:11.773 -> ...
11:20:15.969 ->
11:20:15.969 -> FINISHED!
11:20:15.969 ->
11:20:15.969 -> Sensor readings with offsets:   5   -1   16383   0   -1   -2
11:20:15.969 -> Your offsets:   -3126   2308   1170   118   25   -35
11:20:15.969 ->
11:20:15.969 -> Data is printed as: acelX acelY acelZ giroX giroY giroZ
11:20:15.969 -> Check that your sensor readings are close to 0 0 16384 0 0 0
11:20:15.969 -> If calibration was succesful write down your offsets so you can set them in your projects using something similar to mpu.setXAccelOffset(youroffset)
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Fig. 3. calibrating the IMU inertial sensor

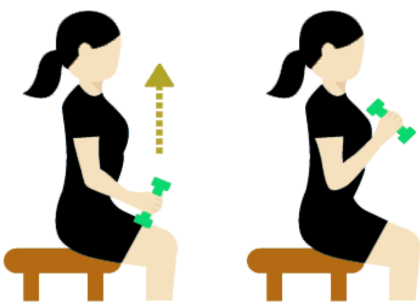

Fig. 4 Exercise 1- Bicep's curl extension.

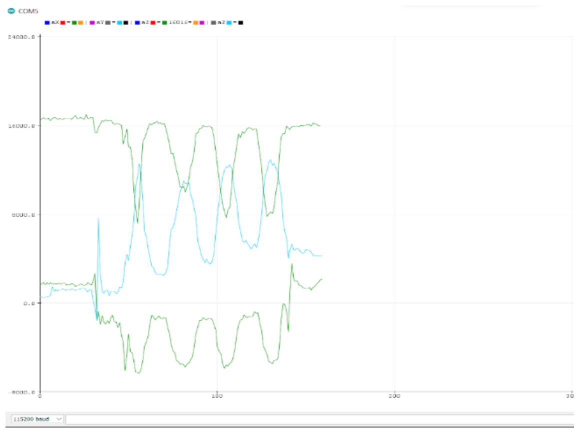

Fig. 5. Exercise 1 (ax, ay, az) forearm positional data.

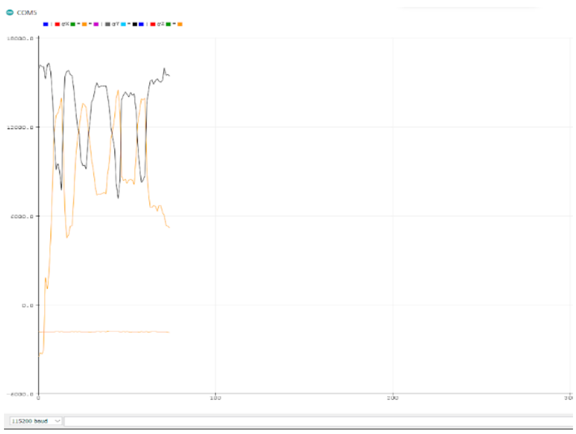

Fig. 6. Exercise 1 (gx, gy, gz) forearm angular velocity reading.

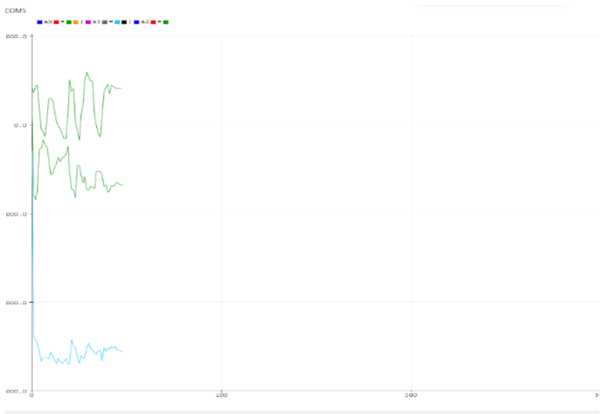

Fig 7: Exercise 1 (ax, ay, az) Upper arm (Bicep) positional data.

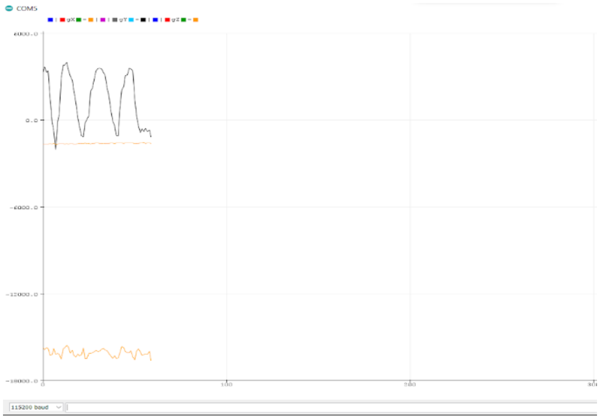

Fig 8: Exercise 1(gx, gy, gz) Upper arm (Bicep) angular velocity reading.

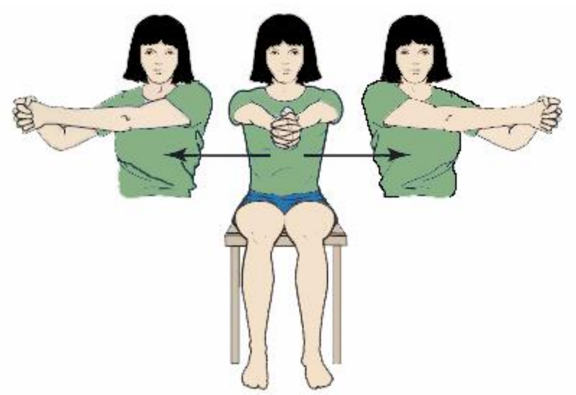

Fig 9: Exercise 2 shoulder flexion

It can be observed from the graph that each peak represents the number of repetitions, and the interval between two consecutive peaks represents the time taken by the subject to complete one complete repetition. The approximately flat region observed at the top is the rest time. The different aspects observed from the graphs help the physiotherapist to understand the patient's movement and make conclusions based on quantifiable observations. Further total time and time spent executing the movement can be understood through the rising and falling slope observed before the upper and lower peaks. The overall rotational and axial movements are shown in fig 6.

Fig 7 and 8 represent the positional and angular velocity values of the IMU sensor placed on the biceps brachii, showing the acceleration and gyro meter values, respectively. It was observed in the process that the more the patient exhibits flexing of muscles, shaking, and twisting movements, the more distorted the angular velocity reading is; this can be justified as the angular velocity is more sensitive to rotational and vibrational noises than the accelerometer. The inertial sensor placed on the biceps shows a small peak because the bicep is almost stationary in this exercise. Particularly as shown in fig 8, gy values exhibit a similar oscillatory pattern with each repetition because the bicep muscle.

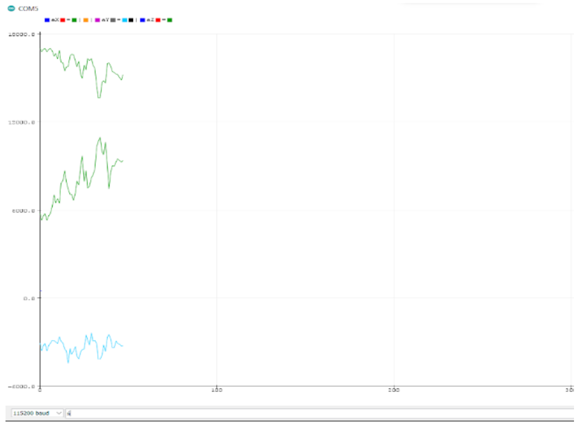

Fig. 10. exercise 2 forearm ax, ay, az.

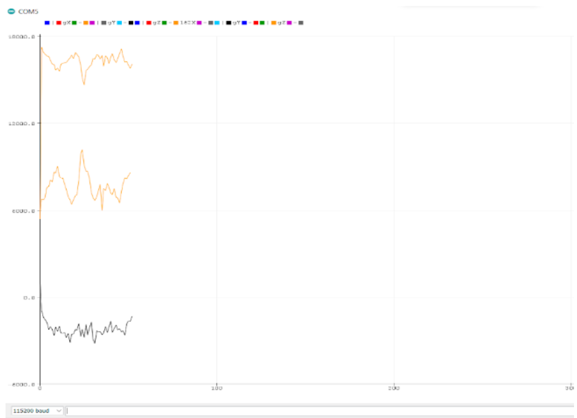

Fig. 11. exercise 2 forearm gx,gy,gz

Fig. 12. exercise 2 upper arm(bicep) emu reading gx,gy,gz

The second exercise commonly known as shoulder flexion shown in fig 9 involves the lateral movement of the arm involving movement of the shoulder muscles (subscapularis, supraspinatus, infraspinatus, and teres minor muscles)[11] and the arm. Similar to the first exercise, the positional data (ax, ay, az) and angular velocity (gx, gy, gz) are plotted graphically. Similarly, we can notice three peaks in the ay value in fig 10. The peak occurs when the patient shifts direction of motion that is from either left to right or from right to left. The different peak heights show that the range of the patient was different in each repetition.

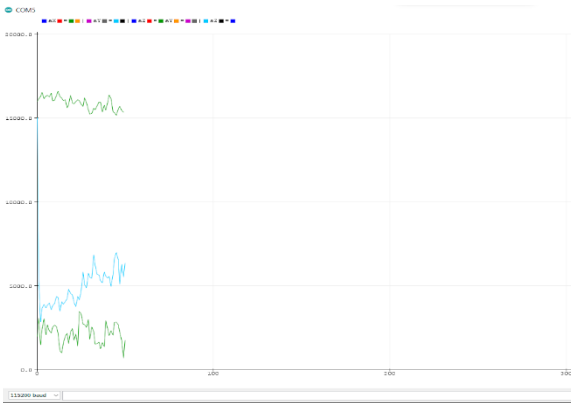

Fig 13: exercise 2 upper arm(bicep) emu reading ax,ay,az

Ideally, the gx, gy, gz graph shown in fig 11, should be constant because exercise two does not involve any axial movements. The observed sharp change in the values shows that the patient might be twisting their elbows or palm during execution. The decline in altitude of the patients upper limbs can be observed as a gradual change in the acceleration in the az direction as it is associated with acceleration in the vertical direction. In exercise 2 the sensors placed on the forearm and bicep should be showing almost the same values as it is just a linear motion.

The data measured by the IMU sensors are sent to an MQTT cloud service via NodeMCU, from where the concerned medical professionals access the graphs and data points remotely and further analyze, give feedback and monitor the progress of the subject. This facility will ease the process of storing data for long term access and analysis. Even if there is a change in the in-charge physiotherapist, this cloud server system proves to be usable and will give some quantifiable data to them.

IV. Conclusion

The proposed method, Stroke Rehabilitation Monitoring System (SRMS), improves the efficiency of physiotherapy for stroke survivors from the comfort and safety of their homes by allowing medical personnel to remotely monitor and analyze the patient's progress. This system conserves the safety and reliability of post-stroke rehabilitation treatment during situations where the patient encounters unforeseeable restrictions.

References

[1] Mathers, Colin D., and Dejan Loncar. "Projections of global mortality and burden of disease from 2002 to 2030." PLoS medicine 3.11 (2006): e442.

[2] Tadi, Prasanna, and Forshing Lui. "Acute stroke (cerebrovascular accident)." StatPearls. Treasure Island, FL: StatPearls Publishing (2020).

[3] Kothari, Rashmi, et al. "Patients' awareness of stroke signs, symptoms, and risk factors." Stroke 28.10 (1997): 1871-1875.

[4] Yew, Kenneth S., and Eric Cheng. "Acute stroke diagnosis." American family physician 80.1 (2009): 33.

[5] *Chueluecha, Chuenchom. "Rehabilitation in stroke." Thammasat Medical Journal 12.1 (2012): 99-111.*

[6] Rohweder, Gitta, et al. "Functional outcome after common poststroke complications occurring in the first 90 days." Stroke 46.1 (2015): 65-70.

[7] Wist, Sophie, Julie Clivaz, and Martin Sattelmayer. "Muscle strengthening for hemiparesis after stroke: A meta-analysis." Annals of Physical and Rehabilitation Medicine 59.2 (2016): 114-124.

[8] Altschuler, Eric Lewin, et al. "Rehabilitation of hemiparesis after stroke with a mirror." The Lancet 353.9169 (1999): 2035-2036.

[9] Merkler, Alexander E., et al. "Risk of ischemic stroke in patients with coronavirus disease 2019 (COVID-19) vs patients with influenza." JAMA neurology 77.11 (2020): 1366-1372.

[10] Fedorov, D. S., et al. "Using of measuring system MPU6050 for the determination of the angular velocities and linear accelerations." Automatics & Software Enginery 11.1 (2015): 75-80.

[11] McCausland, Cassidy, et al. "Anatomy, Shoulder and Upper Limb, Shoulder Muscles." (2018).