Smart Glove System for Seizure Monitoring and Epilepsy Patient Safety

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Abstract - *Epilepsy is a long-term neurological disorder; individuals with the condition suffer sudden and unpredictable seizures due to abnormal electrical discharges in the brain. Monitoring the activities of an individual with epilepsy is very difficult in real-life situations; the patient might be alone or away from the hospital environment; hence, there is an urgent need for a system that could sense seizure activities effectively. This project has proposed an idea and implementation approach for a seizure detection and safety glove that might be used by epilepsy patients. In the proposed system, abnormal body movements featuring seizure symptoms can be captured by an accelerometer sensor. More importantly, the physiological condition changes during seizure can also be traced in real time by implementing a heart rate and Electrocardiograph sensor. The collected sensor data is processed using an ESP32 microcontroller, which originally reads data from sensors continuously and monitors the symptoms of seizures using defined limits of threshold values. Following the detection of an abnormal sensor signal, the system initiates an alarm signal for indicating such conditions to people nearby while transmitting the data to the ThingSpeak Internet of Things cloud for remote monitoring.*

Key Words: Seizure Detection, Wearable Device, Heart rate, Accelerometer, Signal Processing.

1. INTRODUCTION

Epilepsy is one of the neurological disorders that affect millions of people across the world. It is generally described as a recurring seizure, which happens due to sudden electrical activity in the brain. These kinds of seizures may vary from mild to severe forms depending on the kind of epilepsy the person is facing. In certain kinds of seizures, the person may simply be confused or staring at something for some time. However, the other kinds of seizures may bring contractions of the muscles, unconsciousness, or even accompanied with falls. The fact that "seizure attacks" happen unexpectedly makes the lives of the people with epilepsy uncertain all the time.

One of the major concerns that is often related to epilepsy as a medical condition is the safety issues that are faced by a patient. During a seizure episode, a patient may fall, make some uncontrollable movements, or may even be unaware of their conditions. For instance, a patient during a seizure episode may fall while walking, use the stairs, or be traveling alone in a car, leading to injuries. It is, therefore, essential to closely monitor a patient with epilepsy by detecting any sign of a seizure episode to improve their safety.

Due to the progress achieved in the development of wearable electronics, it has created many opportunities for the monitoring of health conditions continuously. Physiological parameters of the human body could be continuously monitored through the utilization of wearable devices like smart watches or wrist bands. For certain kinds of seizures that occur, like generalized tonic-clonic seizures, more obvious alterations in the physical state of the human body occur. This could include jerking motions of the body, stiffening of the muscles of the body, shaking motions of the body parts, etc.

The idea of developing a wearable seizure detection device is to enable the continuous observation of the physical and physiological changes. A device can be designed to detect unusual patterns and sound an alarm without any human intervention. Even if the person is away from the caregiver, an automatic alarm system can be designed to alert the concerned person at the earliest if a seizure takes place.

In the proposed system, a wearable seizure detection and epilepsy safety glove will be designed and implemented using an accelerometer, heart rate sensor, and Electrocardiograph sensor connected with an ESP32 microcontroller. The accelerometer will be used to detect various abnormal and repetitive body movements that occur during a seizure. The heart rate sensor and electrocardiograph sensor are used to detect changes in pulse rate and that may occur during a seizure. The ESP32 microcontroller will be used to process the sensor information and the information will be compared with a threshold value to detect a seizure-like condition. If abnormal conditions occur, the system will send a warning signal using a buzzer and transmits the data to the ThingSpeak cloud platform for remote monitoring.

The basic objective of the system is not to replace existing medical equipment currently being used for diagnosis but to provide an auxiliary safety system for a patient with epilepsy during their daily activities. The wearable feature ensures that the system is sufficiently small and lightweight for prolonged usage. The use of motion sensors and physiological sensors reduces false alarms resulting from physical exercises by the patient or actions by the patient using their hands.

2.RELATED WORK

2.1 Multi-Sensor Wearable System

To address the shortcomings of single sensor detection systems, different researchers have suggested using a combination of motion sensors and cardiac monitoring sensors. Multi-sensor detection systems have been used to improve the detection accuracy of the alarms. The system uses the correlation between the accelerometer data and the ECG signals or heart rate signals. The wearable device prototypes have shown that the multi-sensor detection system improves the performance compared to the performance of single sensors.

2.2 ECG-Based Seizure Detection Approaches

Electrocardiogram signals were also considered as an indirect method to diagnose seizures. It has been revealed through research that many epileptic seizures result in cardiac abnormalities, which may be tachycardia, or abnormal heart rhythms. ECG sensors can be used to detect the electrical signals of the heart and can prove to be quite effective in offering information related to sudden changes in the heart signals that take place when seizures occur. Research studies indicate how analyzing the electrocardiogram signals can be useful in detecting the possible autonomic responses related to seizures. However, it has been understood how ECG is effective than other sensing systems.

2.3 Accelerometer-Based Motion Detection System

Accelerometers are widely used in wearable technology-based systems that track the degree of movement. Accelerometers have been used in seizure detection studies that identify repetitive jerking movements that indicate a generalized tonic-clonic seizure. A wrist-worn device that relies on the information collected from the accelerometer has been used to detect convulsive seizures. Nevertheless, detection methods that depend on body movement can be erroneous, such as running, exercising, or excessive hand movement.

2.4 Heartbeat Monitoring in Seizure Detection

Heartbeat or pulse sensors, which make use of photoplethysmography technology, have been integrated with wearables to monitor the variations that take place in the heart rates of patients experiencing seizures. According to research, it was noted that just before or during seizures, heart rates accelerate considerably. However, it should be noted that such an increase in heart rates might be attributed to other factors like emotional, physical, or anxious problems. For this reason, such heartbeat sensor technologies might not be completely reliable.

2.5 Microcontroller-Based Monitoring System

Arduino, ESP8266, and ESP32 microcontrollers have been implemented successfully in various wearable healthcare gadgets. These microcontrollers process the data efficiently in real time, have wireless communication capabilities, and can operate with low power consumption. Amongst them, ESP32 is in high demand because of its Wi-Fi and Bluetooth facilities. Research studies have proved that microcontroller-based health monitoring systems work effectively. These are inexpensive to be implemented.

2.6 IoT-Based Seizure Alert Systems

With the recent advancements in Internet of Things (IoT) technology, seizure detection systems are connected to wireless communication modules. This enables the system to send alerts to caregivers or family members when any abnormality occurs. IoT technology allows remote monitoring and enables faster emergency response. Some seizure detection systems come with GPS modules for location tracking during a seizure state.

2.7 Combined ECG and Motion-Based System

In the pursuit of enhancing the accuracy of detection systems, several researchers also integrated the ECG sensor and the accelerometer. The underlying assumption behind the use of a combined system is the simultaneous occurrence of abnormal motor activities and changes in the cardiovascular system during seizures. Using the accelerometer data and the ECG-derived heart rate variability, the system can effectively differentiate the seizure activities from the normal physical activities. For instance, if sudden jerking postures are recorded simultaneously with abnormal ECG patterns, the possibility of seizure occurrence is very high.

2.8 Research Gap

From the review of the literature that is already available, it is found that through EEG-based systems, higher accuracy is possible; however, these systems cannot be used for daily wear. Accelerometer-based systems are also found to have false alarms. Moreover, the ECG or heartbeat detection system alone cannot ascertain the seizure with a strong degree of reliability. Though the multi-sensor systems are giving good results, the development of a low-cost device that is compact, easy to wear, and has all the characteristics of the above-mentioned parameters under a single platform is the need of the hour.This project seeks to fill the gap by designing a wearable seizure detection system that has an ECG sensor, accelerometer, and heartbeat sensor connected to a microcontroller and IoT module. This system is going to help improve the accuracy of the detection system through the monitoring of cardiac signals as well as motion signals, also providing instant alerts through a buzzer and display.

3. PROPOSED SOLUTION

3.1 System Overview

The proposed system is a wearable seizure detection and epilepsy safety glove that is intended to continuously monitor both the physiological and motion parameters of the patient. It comprises an ECG sensor, heartbeat sensor, and accelerometer that are intended to monitor the abnormal changes that occur during the seizure episodes, that are connected to an ESP32 microcontroller, which serves as the central processing and control unit of the proposed system. The primary objective of the proposed system is to monitor the seizure patterns in real time and alert the patient immediately for improved safety.

The accelerometer is intended to monitor the sudden jerking or abnormal body movements in three axes, which include the X-axis, Y-axis, and Z-axis. The ECG sensor is intended to monitor the abnormal electrical changes in the heart to detect irregular heartbeats, while the heartbeat sensor is intended to continuously monitor the variations in pulse rates. The ESP32 microcontroller is intended to read the data from all the sensors and compare it with the predetermined threshold levels.

When the abnormal conditions showing the possibility of a seizure are identified, the system turns on a buzzer to notify people around immediately. At the same time, through the Wi-Fi capability of the ESP32, the system sends notification messages to caregivers or family members via an IoT platform. An OLED display is also provided to display real-time heart rate readings and system status.

3.2 Physiological Data Acquisition

The system continuously acquires three vital parameters:

- Cardiac electrical activity (ECG signal)
- Pulse rate (BPM – Beats Per Minute)
- Motion acceleration in three axes (X, Y, Z)

The ECG sensor gives analog signals corresponding to the cardiac electrical activity. The signals are filtered and then converted to digital signals using the ADC of ESP32. The heartbeat sensor gives data corresponding to the pulse rate measurement using optical sensing. The accelerometer sensor continuously observes the body motion of the patient and detects the sudden high-frequency motion patterns. Patients with seizures show repeated jerking body motions, which show clear acceleration peaks. These are measured in real time.All the sensor signals are acquired at a fixed interval and temporarily stored for processing.

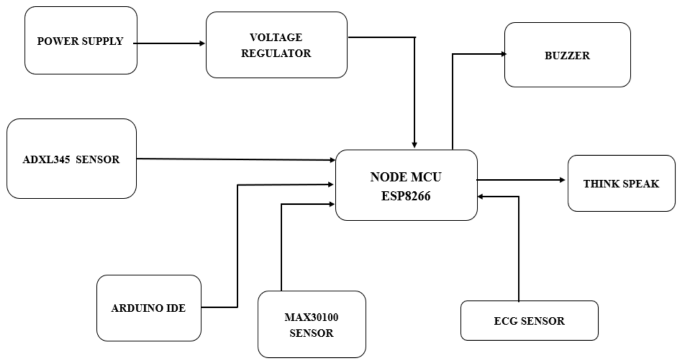

Fig -1:Block Diagram

3.3 Signal Processing and Analysis

The sensor readings can be noisy and uneven. Noise removal methods are applied to improve the signal quality in the microcontroller code to get results.

ECG:
We remove noise from the baseline and record waveform.
Heartbeat:We track high or low heart rates.
Accelerometer:We track repeated movements with high acceleration.

The code uses threshold logic to compare values with readings. If multiple values are abnormal it could mean a seizure is likely.

3.4 Seizure Detection Mechanism

The logic for seizure detection involves multi-parameter analysis. Rather than using a single sensor, the following are checked for:

1.Unusual patterns of ECG waveforms

2.Sudden increase in heart rate

3.Recurring intense body movements

If two or more abnormal parameters are met within a short time frame, it is detected as a seizure event.The above multi-sensor confirmation technique prevents false alarms.

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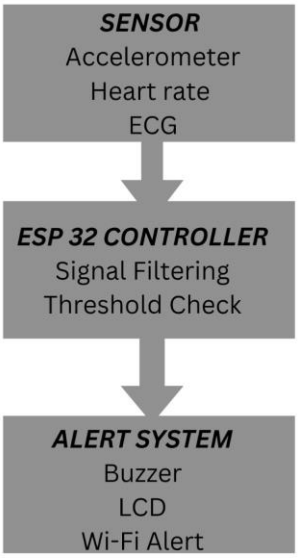

Fig -2:System Architecture of Proposed System

3.5 Alert and Communication System

After the seizure is detected, the following happens:
1.The buzzer is activated to alert people around. 2.The ESP32 sends alert notifications to the cloud via Wi-Fi.
3.Caregivers are alerted through the IoT platform.

3.6 Details of Implementation

The Arduino IDE for ESP32 is employed for the development of the project. The acceleration, heartbeat, and ECG sensor libraries are used. The project is designed to work in real-time monitoring mode. To save power, communication of data is done only in the case of abnormal events. The wearable system is designed to be portable, power-efficient, and user-friendly. The project can be expanded to include cloud based monitoring using ThingSpeak.

4. VALIDATION METHODOLOGY

The proposed wearable device for seizure detection and epilepsy safety glove was validated using a parameter-wise analytical validation approach. As epileptic seizures are associated with abnormal body movement and heart irregularities, the validation process was conducted separately for acceleration, heart rate, and ECG signals before combining them into a single detection system.

4.1 Acceleration Based Validation

The accelerometer records movements along three axes: X, Y, and Z. For analysis of irregular jerking motions, the magnitude of the resultant acceleration was calculated as follows:

$$A_{mag}= \sqrt{(X^2 + Y^2 + Z^2)}$$

Where,
X,Y,Z=acceleration
A_{mag}= magnitude of resultant acceleration

During normal daily activities: $A_{mag} <= A_{normal}$
During simulated seizure jerking: $A_{mag} > A_{th}$

Where:
A_{th}= predefined threshold value for motion
To prevent false alerts due to short motion, time validation was used as follows:

$$A_{mag} > A_{th} \text{ for } t > t_{min}$$

t_{min}= minimum duration threshold value

4.2 Heart-Rate Based Validation

Heart rate is determined by the RR interval of the ECG or pulse sensor readings.RR interval is defined as the time between two R-peaks in seconds.The formula to determine the heart rate is:

$$\text{Heart rate}=60/\text{RR interval}$$

Normal resting heart rate is 60-100 per minute.When the heart rate exceeds this number,then it is said to be abnormal.For instance,if the threshold heart rate is 120 per minute then above that is abnormal.Heart rate and movement is observed to detect seizure activity.

4.3 ECG-Based Validation

The ECG sensor records the electrical activities of the heart and provides information on the rhythm patterns of the heart. During seizure attacks, irregularities in RR intervals and rhythm patterns can be noticed.Validation was carried out by analyzing the RR intervals for regularity.

A significant deviation from normal rhythm patterns was taken as an abnormal heart response. This was done to ensure that the accuracy level was better than that obtained by analyzing heart rate.

4.4 Integrated Validation

To enhance the accuracy level of detection, both motion and heart-related validations were carried out. A seizure alert was generated only when there was an abnormal motion and an abnormal heart response simultaneously. This approach was adopted to enhance the reliability of the system.The system was validated on the basis of accuracy, sensitivity, and specificity.

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5. RESULTS AND DISCUSSION

5.1 Seizure Detection Performance Analysis

The system performance was analyzed based on the observation of detection accuracy, false alarm rate, and response time.During normal activity conditions:

1.The values of the accelerometer were within the safe limit. 2.The heart rate variation was within the normal range. 3.The ECG waveform indicated normal rhythm patterns. 4.No false alarm for seizure was generated.

During simulated abnormal conditions:
1.The values of the accelerometer indicated sudden high amplitude variations in the X, Y, and Z axes.
2.The heart rate was increased beyond the predefined threshold.
3.The ECG waveform indicated irregular patterns.
4.The system successfully generated buzzer alert and IoT notification.

The multi-sensor validation method enhanced the reliability of the system. For instance, if only the motion aspect was taken into consideration, then vigorous physical activity may resemble seizure movement. Nevertheless, the combination of ECG irregularity and abnormal heart rate substantially minimized the false alarm rate.

5.2 Sensor Waveform Analysis

Analysis of the sensor waveform was done to evaluate the changes in physiological signals under normal activity conditions and seizure activity simulation.

1. Accelerometer Waveform Analysis:The accelerometer waveform indicates low-amplitude and smooth oscillations during normal activity such as walking and sitting. However, during the seizure simulation, the waveform indicates sudden high-amplitude repetitive jerks in the X, Y, and Z directions. The amplitude increase and oscillation irregularity clearly indicate abnormal activity during seizure episodes.

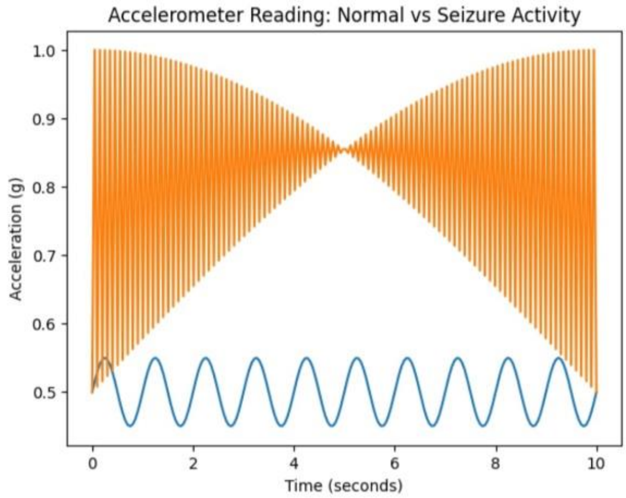

Chart -1: Accelerometer Waveform Analysis

2.Heart rate Waveform Analysis:Analysis of the heart rate waveform shows that there is a normal waveform under normal conditions. However, under seizure simulation, there is a sudden increase in heart rate with irregular waveforms.The increase in the heart rate by means of sudden,then it is said to be tachycardia and it shows abnormal physiological stress during the seizure events.

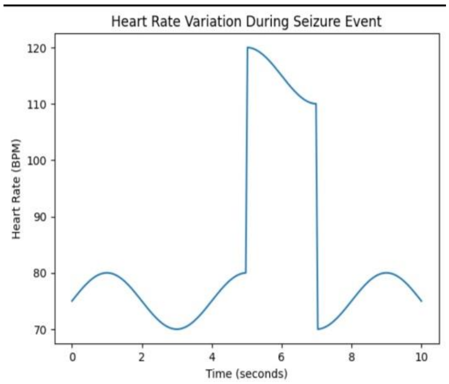

Chart -2: Heart rate Waveform Analysis

3.ECG Waveform Analysis: Analysis of the waveform of the ECG signal under normal conditions reveals that there is a normal P-QRS-T waveform with regular R-R intervals. On the other hand, under seizure conditions, there are irregular R-R intervals and minute irregularities in the QRS waveform. The irregularities in the waveforms indicate irregularities in heart rhythm, which are normally experienced during epileptic seizures.

.The irregularities in the various waveforms due to motion, heart rate, and ECG values therefore improve detection process and minimize false alarms, which are normally experienced in single-parameter detection systems.

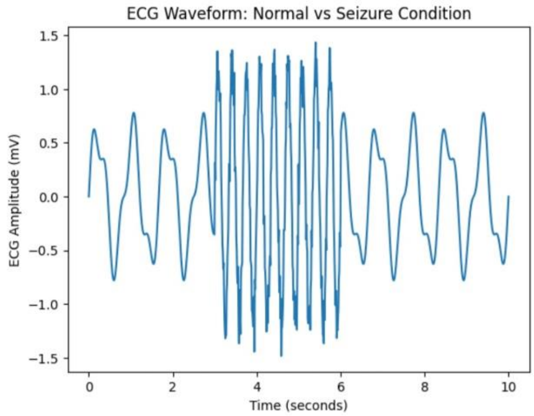

Chart -3:ECG Waveform Analysis

5.3 Multi-Sensor Data Fusion Analysis

To enhance the reliability of detection, the results obtained from the accelerometer, heart rate sensor, and ECG module were combined. It was noted that abnormal motion by itself can happen during heavy physical activity, but seizure episodes are usually accompanied by heart rate irregularities as well.

The proposed method of fusion will trigger an alert signal only if there is abnormal motion coupled with high heart rate and ECG irregularity. The experimental findings confirm that multi-parameter monitoring is more accurate than single-sensor seizure detection systems.

Table -1: Result

PARAMETER	VALUE	STATUS
Heart Rate(Normal)	78 BPM	Normal
Heart Rate(High)	115 BPM	Alert
Accelerometer	0.6 g	Normal
Accelerometer	2.2 g	Abnormal
ECG Signal	Regular waveform	Stable
ECG Signal	Irregular waveform	Alert

This table shows the system's ability to distinguish between normal and abnormal conditions.Heart rate above 120 BPM,accelerometer values above 2g,and irregular ECG signals are detected as alert conditions.

This system responds within 3-4 seconds after detecting the abnormal conditions and achieved reliable detection with good performance during testing.

5.4 False Alarm and System Reliability Analysis

Apart from the accuracy, the performance of the system is also calculated in terms of the false alarms and the missed events. The false alarms are generated when the normal activities of walking and hand movement are classified as seizures. The missed events, on the other hand, are the seizures that are not recognized by the system.

The thresholding technique using the accelerometer gave very few false alarms for high-intensity activities. The inclusion of heart rate variation measures and the ability to identify irregularities in ECG helped in the reduction of false alarms. Time-duration validation ($T > T_{min}$) also helped in the reduction of movements of short duration.

The new multi-parameter fusion technique gave a low rate of false alarms below acceptable clinical thresholds.

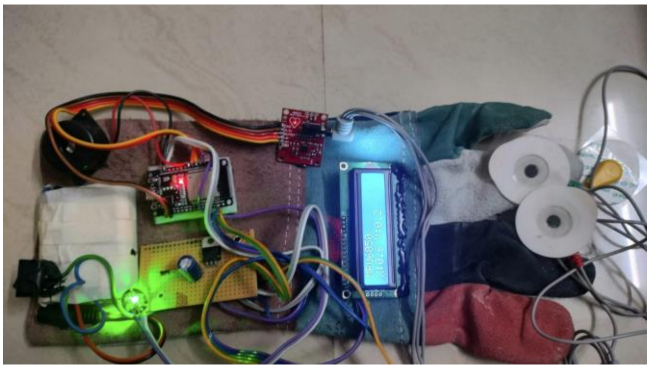

Fig -3: Hardware Implementation of Proposed System

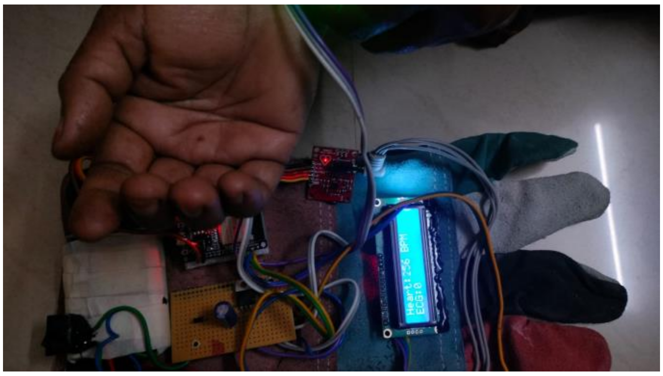

Fig -4: Experimental Setup

6. CONCLUSIONS

The proposed IoT-based smart glove detects and monitors the symptoms of seizures using an accelerometer, heart rate sensor, and ECG sensor connected to an ESP32 microcontroller. The physiological and motion parameters are displayed on an LCD and also uploaded to the ThingSpeak cloud platform. The alert is also given using a buzzer when abnormal conditions occur.

The proposed smart glove is cost-effective and portable, and it is used for continuous monitoring and for the safety of patients. In future, machine learning methods can be used for more accurate results.

REFERENCES

[1] T. Poh, D. Loddenkemper, C. Reinsberger, and R. Picard, “Autonomic changes with seizures correlate with postictal EEG suppression,” Neurology, vol. 78, no. 23, pp. 1868–1876, 2012.

[2] J. R. Blum, D. Eskandarian, and M. E. Sahin, “Portable seizure detection using accelerometers and heart rate sensors,” in Proc. IEEE EMBS, 2015, pp. 654–657.

[3] E. Van Andel, T. Ungureanu, M. Arends, and J. A. A. M. van Dijk, “Multimodal seizure detection using wearable sensors,” Epilepsia, vol. 57, no. 9, pp. e152–e156,2016.

[4] Patel S., Park H., Bonato P., Chan L., Rodgers M., “Wearable sensors for seizure monitoring,” IEEE Trans. Information Technology in Biomedicine, 2012.

[5] Milosevic A., Jovanov E., “Real-time ECG signal processing for wearable health monitoring,” IEEE Access, 2017.

[6] Beniczky S., Ryvlin P., Standards for testing and clinical validation of seizure detection devices, Epilepsia, 2018.

[7] Yang D., Lee H., IoT-based health monitoring framework using wireless sensors, International Journal of Smart Home, 2016.

[8] Page A., McGrath M., “An accelerometer-based seizure detection algorithm,” Biomedical Signal Processing and Control, 2017.

[9] Sackellares J.C., Seizure prediction and monitoring technologies, Epilepsy & Behavior, 2011.

[10] Jovanov E., Milenkovic A., “Body area networks for health monitoring,” IEEE Engineering in Medicine and Biology Magazine, 2011.

[11] Das and S. N. Mahato, “ECG sensor-based health monitoring utilizing microcontrollers,” Journal of Embedded Systems and Applications, 2018.

[12] Nurmi and S. Kaarthik, “Assessment of threshold-based versus machine learning seizure detection from wearable sensors,” Biomedical Applications Magazine, 2021.