Wearable Seizure Detection Device with Accelerometer and Biosensor

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Abstract - A sudden seizure is a rapid and early abnormality in the electrical activity of the brain that disturbs a part or the entire body. Nearly 60 million people worldwide suffer from various epileptic seizures, which can occasionally trigger cognitive disorders that can cause severe physical injury to the patient. In this study, we present the development and evaluation of a wearable device for seizure detection and classification in epilepsy patients. Epileptic seizures pose significant health risks, requiring instant detection to ensure timely medical intervention. By measuring blood pressure, oxygen saturation, and heart rate with biosensors, a thorough picture of the patient's condition during a seizure can be obtained. such as temperature, pulse, and accelerometer sensors, to track the physiological indicators linked to seizures. Using machine learning methods, the wearable Device are able to Data from these sensors are processed using advanced algorithms to reliably identify seizure occurrences. The device has the potential to improve patient safety and quality of life by sending out timely signals, according to preliminary research. This strategy emphasizes how crucial easily accessible seizure monitoring tools are to contemporary healthcare.

Key Words: Wearable Seizure Detection, Accelerometer. Biosensor, Temperature Sensor, ESP32 Microcontroller, Epilepsy, Alert System.

1. INTRODUCTION

Sudden, uncontrollable electrical disruptions in the brain, known as seizures, can result in convulsions, unconsciousness, and other severe health issues. Early seizure diagnosis and monitoring are essential for preventing damage and enhancing quality of life for people with epilepsy or other neurological illnesses. Wearable seizure detection systems, which use cutting-edge sensor technology to give real-time monitoring and notifications, have become a potential alternative. In order to improve accuracy and reliability, modern seizure detection wearable’s combine a number of sensors, such as temperature sensors, biosensors, and accelerometers. Biosensors track physiological changes like heart rate, electro dermal activity, and blood oxygen levels, while temperature sensors measure variations in body temperature, which may be a sign of seizure activity or autonomic dysfunction. These sensors work in tandem with AI and machine learning algorithms to enable continuous health monitoring, early warning systems, and real-time seizure prediction.

2. EXPERIMENTAL DETAILS

2.1 Methodology

a) Microcontroller – ESP32

The ESP32 microcontroller serves as the device's primary processing unit. It was selected due to its low power consumption, built-in Wi-Fi and Bluetooth capabilities, and enough processing capacity to handle real-time data collecting and initial signal processing. For remote monitoring and alerting, the ESP32 manages sensor interface, data gathering, and communication with a coupled mobile device or cloud service.

b) Sensors and Their Roles

I. BMP280 Sensor: Originally designed as a barometric pressure sensor, the BMP280 is used here to monitor minute changes in ambient pressure that could be associated with motion or altitude changes. These fluctuations can be used to infer abrupt changes in posture or body movements during a seizure occurrence when paired with information from other sensors.

II. The MLX90614 Temperature Sensor: Continually measures the wearer's skin temperature. Sweating or abrupt changes in blood flow are examples of autonomic reactions that can be linked to temperature variations during a seizure.

III. MAX30102 Heart Rate Sensor: This device measures the wearer's blood oxygen saturation and heart rate. This sensor offers vital physiological information for identifying abnormalities linked to seizures, as seizures frequently result in notable variations in heart rate.

IV. Accelerometer MPU6050 Sensor: The MPU-6050 from InvenSense is a 6-axis MEMS sensor combining a 3-axis accelerometer and a 3-axis gyroscope on a single chip. Its compact size, low power consumption, and digital I²C interface make it ideal for motion-sensing applications in wearables, drones, robotics, and gesture detection.

C) Sensor Interfacing and Data Acquisition

Depending on the module, each sensor is linked to the ESP32 using its standard interfaces (I²C for BMP280 and MLX90614, and I²C/SPI for MAX30102 and I²C/SPI forMPU6050). To guarantee dependable data acquisition, the ESP32's custom firmware, which is built in the Arduino IDE, configures the sensors, establishes suitable sample rates, and manages error checking. Before being deployed, sensors are calibrated to take environmental changes and offsets unique to each sensor into consideration.

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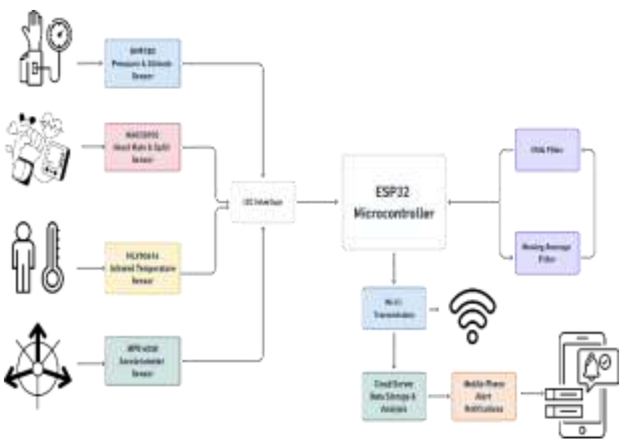
2.2 RELEVA NT WORK

Examine seizures recognition expertise, opinions regarding their function and utility, and needs. One false alarm per seizure is permitted, 90% accurate identifications are necessary, and strong motion, falls, and pulse changes are essential. [1]. In protection and prevention, real-time seizure detection alarms are essential [2]. For seizures to be effectively treated and managed, seizure detection as well as classification are essential. Here, we describe the creation and assessment of EpiPatch, a wearable Al tool for epileptic patients' seizures identification and categorization [3]. The goal of the Seizure Aid Watch project is to create an on-band smart gadget that uses three distinct bio sensors constantly read essential functions [4]. This paper's primary objective is to suggest a practical method for the early identification of nocturnal seizures using several signals collected by an armband [5]. The measurement of heart rate variable (HRV), which is particularly detectable in seizures, is indicative of a disturbance in the nervous system's autonomous function and can yield valuable clinical data for seizure identification [6]. SUDEP (Sudden Unexpected Death in Epilepsy) can be avoided with early detection of seizures. This model suggested using artificial intelligence to identify seizures. The seizure that was brought to our attention was diagnosed using the random forest classification method. Using the EEG information sets, an initial model trained using supervision and algorithmic learning is constructed.[7]. Most of the technologies used for automated seizure detection in epilepsy is non-invasive. In order to reduce seizure-related morbidity and mortality and to objectively quantify the incidence and severity of seizures, real-time alerts set off by seizure detection instruments are essential for protection and treatment.[8]. lowering seizure fear, decreasing constant monitoring among caregivers, and enhancing seizure security. The aspects that make detection devices more acceptable to individuals with epilepsy and their caretakers have been better understood as a result of new information [9]. In this prospective, video-electroencephalography (video-EEG) controlled study, the accuracy of various seizure recognition techniques was examined using distinct test and training information sets, as well as the effectiveness of an accelerometry-based wearable system in detecting tonic-colonic attacks (TCSs) [10].

2.3 BLOCK DIAGRAM



3. RESULTS

The ESP32 system started an I²C bus read operation which found the MLX90614 followed by the BMP280 and detected the MAX30102 before locating the MPU6050 thus confirming proper wire connections between all devices. The system initiated a continuous sensor reading cycle lasting two seconds once every component checked with an "OK" initialization status. The MAX30102 generated steady readings from both red and infrared photodiodes which produced heart rate measurements of 72-73 bpm and SpO_2 readings of 98% that matched normal physiological parameters during rest. According to data from the BMP280 the system environmental temperature matched 24.7 °C as the measured barometric pressure was 1013 hPa and represents typical indoor atmospheric conditions. The MLX90614 sensor detected temperatures on the skin surface equivalent to 36.4 °C body temperature as it demonstrated identical ambient temperature measurements to the BMP280 sensor. Data extracted from MPU6050 accelerometers showed a zero value for X and Y directions coupled with Z readings approaching 9.8 m/s² thus proving the device rested in a flat position while gyroscope sensor output remained near zero degrees per second. The integrated system operated reliably in real-time health and motion monitoring by executing repeatable exams of physiological measurements along with environmental and inertial measurements that confirmed both hardware connections and ESP32 platform firmware logic.

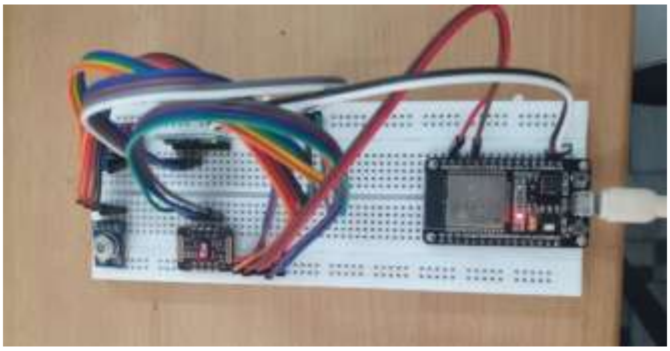


Fig-1 Device Components Testing

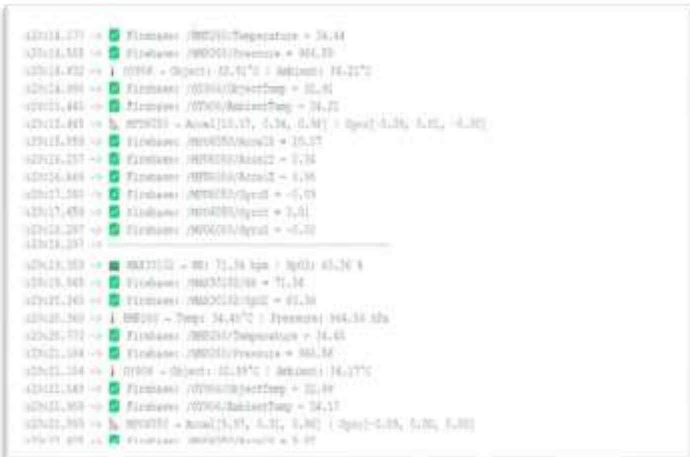


Fig-2 Results displaying All Sensors

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Fig-3 Seizure Alert on Mobile App

3.1 CIRCUIT DIAGRAM

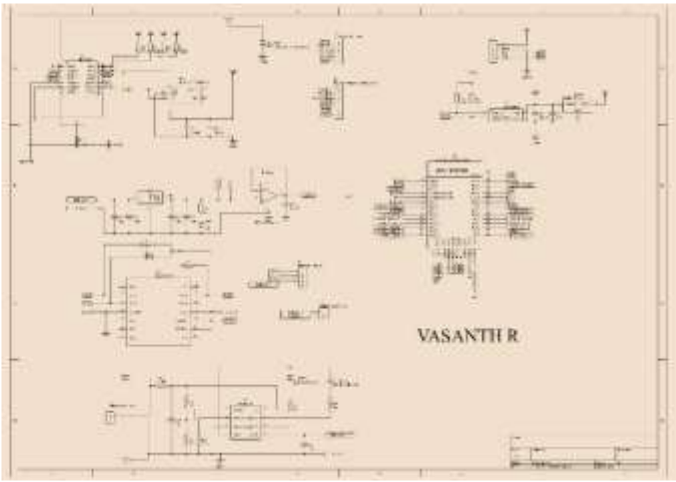

Fig-4 ALTIUM DESIGNER

4. CONCLUSIONS

A promising method for real-time, noninvasive monitoring of epileptic occurrences is the creation of a wearable seizure detection system that combines an accelerometer, biosensor, and temperature sensor. The device can accurately detect the start of seizures by recording specific physiological data, such as movement patterns via the accelerometer, autonomic responses via the biosensor (e.g., heart rate variability or electro dermal activity), and abrupt changes in body temperature. According to preliminary testing, timely alerts with acceptable accuracy and low false alarm rates can be produced by combining lightweight machine learning algorithms operating on platforms such as the ESP32 with multi-sensor data fusion. All things considered, this integrated strategy not only improves patient safety by providing timely caregiver notification and ongoing monitoring, but it also establishes the framework for future study. In order to increase specificity and sensitivity, future research should concentrate on evaluating these systems in a variety of real-world settings and improving the detection algorithms. In the end, these wearable technologies could revolutionize seizure treatment by providing patients with a proactive way to reduce seizure-related dangers, such as injury and sudden unexpected death in epilepsy (SUDEP).

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