Design Document

EpiCap - a wearable EEG

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1. Introduction

1.1 Problem Statement

Electroencephalograms (EEGs) are procedures that measure electrical activity at the very perimeter of the brain. Physicians use the results of these tests to diagnose and determine courses of treatment for abnormal brain behavior, such as epilepsy. A typical EEG test, however, presents difficulties to the patient and physician. Patients can be admitted to a hospital, occupying an inpatient bed, while sleep-deprived and off medication, in hopes a seizure occurs and can be assessed; which leads to an increase in healthcare resource utilization [1]. Epilepsy or convulsion diagnoses have led to more than 1 million emergency department visits and 280,000 hospital admissions [2]. As the average hospital stay for epilepsy patients is 3.6 days, the accumulated hospital costs for epilepsy annually totaled approximately $2.5 billion [2]. Additionally, it is surveyed that the average annual cost of epilepsy per person was $15,414 [3]; which includes outpatient, inpatient, ED, and treatment costs.

Ambulatory options, which are more cost-effective than outpatient/inpatient treatments, do exist. Patients are sent home with equipment and are tasked with wearing a very visible net of electrodes, head stocking that protects the electrodes and their leads, and the measurement is performed by a device that fits in a fanny pack. However, as many of these ambulatory types of equipment are bulky, not portable, or discreet, patients are forced to stay home and surrender important responsibilities that impact the patient's normal everyday activity such as work. People with a history of epilepsy were observed to have a lower annual income and a higher probability of being employed [4].

1.2 Solution

If the present ambulatory technology was further miniaturized, we can create a device as discreet as a baseball cap that allows the wearer to carry on about their day while remaining monitored for EEG activity. A device such as this would eliminate the bulky, inconvenient present ambulatory systems, and draw less attention in public. EEG patients would have the ability to wear it to work and would be able to record important EEG data if a seizure was to occur. Children who are suspected or diagnosed with the condition can wear something that doesn't interfere with their self-esteem or most daily activities.

We propose a discrete ambulatory EEG that can monitor patients, come off standby when an event is occurring, and measure brain activity while also utilizing a camera to further record muscle activity (or inactivity), essential data to arrive at a diagnosis and severity of an event. The benefit of having a seizure captured on video is the seamless synchronization to the patient's brain waves recorded from the EEG data. Moreover, the device will include on-board storage, as well as GSM connectivity, to alert patient contacts or even emergency services of an event. We can then use the onboard SD card to have the EEG data and camera footage can be viewed on a physician's PC.

1.3 Visual Aid

Figure 1. Pictorial Representation of the EpiCap

1.4 High-Level Requirements

- The EEG cap must be discreet and all the main devices components must be within the cap and cap visor.
- Record EEG data at 240 Hz sampling rate for at least 24 hours and be able to store EEG data– electrical activity of the brain during a seizure on the flash storage.
- The EEG cap will track the patient's eye and arm movement to shoulder height by using the wide-angle camera (minimum 240p) located in the cap visor.

2. Design

The EpiCap requires the following subsystems in order to operate successfully: power subsystem, microcontroller/processing subsystem, wireless interface, on-board flash storage, and a camera subsystem as shown in Figure 2. The EpiCap would also require a software platform that allows certified physicians and the patient itself to view EEG data reports. The power supply would provide the proper 3.3V to the board EpiCap to ensure that the system can be running for at least 24 hours. The microcontroller subsystem would be the central processing unit of the system and would be dealing with commands of saving EEG traces and saving camera footage to on-board storage when detected seizure, sending a distress signal to the SIM800 GSM when detected seizure, and commanding conversion of EEG data using the ADC conversion. The wireless interface consists of a GSM chip and SIM card that would send emergency messages to the wearer's emergency contacts in the event of a seizure. The on-board flash storage woud store EEG data and eye/arm movement camera footage during the seizure. Lastly, the camera subsystem consists of a wide-angle camera in order to track patient's eye and arm movements. By implementing each of these design specifications, we can ensure that all of the high-level requirements would be satisfied.

[insert NEW block diagram here - FIGURE 2]

2.2 Requirements & Verification Tables

2.2.1 Rechargeable 7200 mAh Lithium Polymer Battery

Requirements	**Verification**
1. Provide reasonably low noise (<uV). 2. Must be readily rechargeable, and not provide too much weight (<220g) or bulk to the whole device. 3. During discharging at maximum current and voltage, the temperature of the Li-Po battery would be less than 27℃.	1. Take oscilloscope measurements to measure the output voltage ripple signal is less than 1 uV. 2. a. Discharge the Li-Po battery entirely to 3.2V and charge the battery to 4.2V in order to ensure the battery cell voltage drops between 3.5-3.7V. b. Weigh the battery using a weighing scale to ensure the battery is less than 220g. 3. a. Charge the Li-Po battery entirely to 4.2V to ensure that the cell voltage is at its highest. b. Discharge the battery and use an IR thermometer to ensure

	that the battery does not discharge at a temperature greater than 27℃.

2.2.2 Low Drop Voltage Regulator

Requirements	**Verification**
1. Provide 3.3V+/- 5% from a 3.5-4.2V source. 2. Can operate at currents within 0-1A 3. Maintain a temperature range of 20℃ to 27℃.	1. Measure output voltage using an oscilloscope to ensure that the output voltage stays within 5% of 3.3V 2. a. Use a constant-current test circuit and connect the output of the voltage regulator to the VDD node. b. Adjust the Rs (potentiometer) value to deliver 1A to the load, measured by the multimeter. c. Use an oscilloscope to measure the output voltage to make sure it stays within 5% of 3.3V. 3. Use the IR thermometer to make sure the voltage regulator stays in the temperature range of 20℃ to 27℃.

2.3 Plots

2.4 Circuit Schematics

4. Tolerance Analysis

One important consideration is that we must ensure that dry electrodes can collect EEG data properly in the event of a seizure.

In order to illustrate this, we can compare the normal EEG signal to the seizure EEG signal. The following data were collected from seven different recordings. Non-seizure data was recorded 5 minutes before seizure data. The seizure segment is a 5s sliding window with a 2.5s interval. All of them show variable patterns.

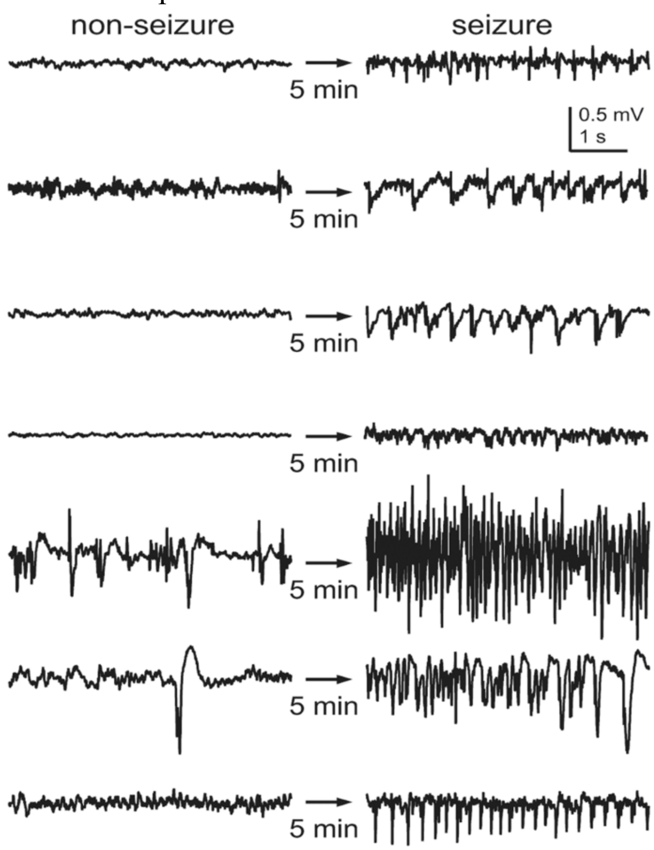

Figure 2. EEG change during 5 minutes from non-seizure to seizure [8]

As we can see clearly from the figure above, the seizure signal changes more severely than the non-seizure signal does. Since we need a criterion to determine the seizure, we chose to regard the current EEG as the seizure signal by considering the seizure signal which had a 1.2 times higher mean absolute amplitude compared with the nearby EEG data [10]. If there was no large amplitude change, the data was not regarded as a seizure signal.

The second step is to consider which part of the brain to put our dry electrodes on. The following image displays the internationally recognized EEG locations on the brain.

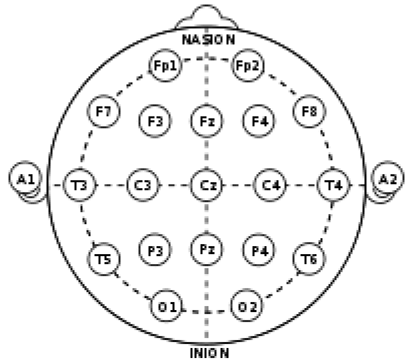

Figure 3. Electrode locations of the International 10-20 system for EEG recording [9]

Since our cap will use at least 10 dry electrodes, we want to attach our electrodes at the vertex area which includes Fz, C3, C4, Pz, F3, F4, P3, P4, and Cz. We will place one electrode on the first nine areas, and then two electrodes to the Cz area for more accurate data.

The third step is to consider possible detection glitches and the time that the system sends emergency texts to the patients' emergency contacts. As discussed above, we chose to pick a 5s time interval. We want to compare this data with the nearby EEG data, in order to see the amplitude difference between them. Therefore, the nearby EEG signal is also needed for a basic judgment. We want to pick 5-10s data to sample in order to determine whether the patients are currently having a seizure. Therefore, considering the negligible computation time, the time glitch here should be 15s or so. The time that the system sends emergency text to patients' emergency contacts should also be done within a few seconds. We estimate the total time should be around 20s-30s.

7. Ethics and Safety

There could be several concerns regarding our project. The cap confronts several risks and vulnerabilities as a result of the use of rechargeable lithium-ion batteries, electrodes, cables, chips, flash storage, camera, and the possibility of a patient's unexpected fall.

First, there are electrodes that remain in contact with the scalp in the event of a seizure. Even though this is a special hat that collects medical EEG information, we still need to make sure patients do not feel any difference or discomfort wearing the hat compared to a regular hat. As stated in the subsystem requirements, the electrodes must be readily adapted to different ball caps and different hat sizes. We must also take precautions that our device does not create more danger for a patient in the event of a fall. In order to solve these issues, we will adjust the gap between the cap and the patient's head by using one of the most common ways of fixing an ordinary cap: an elastic strap, which can better keep the cap on the patient’s head steadily and capture important EEG information in the scenario that the patient falls. We will also line up our wires and chips so that they are distributed around the edge of the hat so that the patient will not be injured by these parts if they fall.

The second concern is that EpiCap is a wearable gear, and patients will need to wear it for long periods to get complete EEG data. If any materials are mixed with chemicals that are harmful to the human body, it is potentially dangerous for the patient and may lead to an erroneous diagnosis from doctors. In order to solve this problem, we need to ensure that both the battery and board present no hazard to the patient - especially in the event of high heat, moisture, and any sort of mechanical shock where according to the IEEE Code of ethics I.1: we must “hold paramount the safety, health, and welfare of the public…” [5].

The third concern is that the EpiCap will collect highly confidential EEG data of the patient. We must ensure that patient information can only be accessed by the doctor and is kept confidential to visitors, as according to the IEEE Code of ethics I.1 we must “hold paramount the safety, health, and welfare of the public…”[6]. In order to solve this issue, we can design a password system for doctors and encrypt all patient information. For example, each doctor will have separate accounts and passwords. When the doctor receives data from the GSM chip, they will give their patient an identification number. As a result, only the corresponding physician has the patient's EEG data, which cannot be viewed by the outside viewer.

We will rigorously test our design to ensure that the final product is safe for patients and doctors alike. We intend to comply with the IEEE code and the corresponding safety or regulator standards such as OSHA or FCC. Additionally, we will seek and accept any improvements regarding our project and due to the nature of our design, will need to work with the medical school, so that we will appropriately credit others' efforts, according to IEEE code of ethics I.5: “to seek, accept, and offer honest criticism of technical work…” [7].

8. References

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