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MEDIGRAPH – EEG, ECG, EMG & EOG DIAGNOSTICS SYSTEM USING ARDUINO

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ABSTRACT

This research paper details the development of an accessible and cost-effective diagnostic test system capable of performing four biomedical tests: EEG, ECG, EMG, and EOG. Utilizing Arduino and the Bioamp EXG Pill module, the system integrates modules for data acquisition, signal processing, communication, user interface design, diagnostic algorithms, and rigorous testing. The Hardware Integration Module ensures reliable component connection and power supply, while Signal Processing designs algorithms for preprocessing and feature extraction from raw data. The Data Acquisition and Communication Module facilitates real-time data transfer and storage. A user-friendly interface is provided by the User Interface Module, and machine learning in the Diagnostic Algorithm Module classifies biomedical patterns for accurate diagnosis. The Testing and Validation Module rigorously assesses the system's reliability and accuracy against existing methods. Comprehensive documentation, including hardware schematics and manuals, is included. This project aims to offer an efficient diagnostic tool with significant healthcare applications.

KEYWORDS

neurological conditions, cost-effective solution, EEG ECG EMG EOG diagnostic test, bioamp exg pill

1. INTRODUCTION

In the realm of neuroscience and healthcare, the Electroencephalogram (EEG) stands as a pivotal tool for monitoring and deciphering intricate patterns of brain activity. However, the widespread adoption of EEG diagnostics is hindered by cost constraints and limited accessibility. This research endeavours to bridge this gap by presenting a novel EEG diagnostic test system, meticulously designed, and developed in the context of a final year project.

The objective of our endeavour is clear: to create an affordable, user-friendly, and technologically advanced EEG diagnostic system. To achieve this, we have harnessed the power of Arduino, a versatile and widely accessible microcontroller, in conjunction with the Bioamp EXG Pill module. This

collaboration forms the backbone of our system, fostering seamless integration of hardware components and software modules to cater to the diverse facets of EEG diagnostics.

The need for accessible and cost-effective EEG solutions is underscored by the prevalence of neurological conditions, ranging from epilepsy to cognitive disorders, necessitating efficient monitoring and diagnosis. By harnessing the potential of open-source hardware and advanced signal processing techniques, our project endeavours to democratize EEG diagnostics, making it not only a realm of clinical expertise but a tool accessible to a broader spectrum of users.

This paper unfolds with an exploration of each module within our meticulously designed system, elucidating the roles and responsibilities of each component. From the Hardware Integration Module's procurement and circuit design to the sophisticated Diagnostic Algorithm Module employing machine learning, our approach encompasses a comprehensive array of functionalities.

The ambition is to provide not only a detailed account of the system's development but also a compelling narrative of how technological innovation can be harnessed to address pressing healthcare challenges. In the pursuit of an accessible EEG diagnostic solution, we not only seek to contribute to academic knowledge but also to potentially revolutionize the landscape of neurological diagnostics, paving the way for a more inclusive and impactful future.

2. TECHNOLOGIES USED

2.1 ARDUINO

Arduino, a trailblazer in open-source electronics, champions the mission of making advanced technology accessible to a diverse user base, aligning closely with the principles embedded in my EEG diagnostic test project. The company's commitment to simplicity, coupled with powerful functionality, resonates with our aim to create an accessible and cost-effective solution for diagnosing neurological conditions [1].

Arduino's user-friendly interface and intuitive design provide a seamless entry point for beginners, aligning with our project's goal of creating an EEG diagnostic system that is user-friendly for both healthcare professionals and patients. The collaborative ethos within the Arduino community mirrors our approach to teamwork and coordination in developing the various modules of the diagnostic system.

Embracing Arduino's open-source philosophy, our project draws inspiration from the collaborative spirit that has driven Arduino's success. This philosophy not only promotes knowledge-sharing but also aligns with our project's objective of creating an open and transparent system for EEG diagnosis.

As Arduino continues to evolve, so does our project, influenced by the company's commitment to staying at the forefront of technology. The engagement with a global community of developers and enthusiasts mirrors our dedication to ensuring the reliability and accuracy of our EEG diagnostic test system.

2.2 BIOAMP EXG PILL

The BioAmp EXG Pill emerges as a groundbreaking technological marvel, uniquely crafted as a compact, pill-sized chip with the remarkable capability to capture high-fidelity biopotential signals originating from diverse regions of the human body. This includes the heart (ECG), brain (EEG), eyes (EOG), and muscles (EMG). The innovative design of the BioAmp EXG Pill not only embodies cutting-edge engineering but also opens a realm of exciting possibilities for projects within the Human-Computer Interface (HCI) and Brain-Computer Interface (BCI) domains.

This state-of-the-art device holds significant promise for enthusiasts, researchers, and developers alike. Its compact form factor, resembling a pill, belies its vast potential in physiological signal processing. The BioAmp EXG Pill is a testament to the continuous evolution of technology in capturing and interpreting intricate biopotential signals with unparalleled precision [2].

2.2.1 Versatile Signal Recording Capabilities:

One of the standout features of the BioAmp EXG Pill is its ability to capture signals from multiple physiological domains. This versatility makes it an all-encompassing tool for projects involving ECG, EEG, EOG, and EMG signals. The chip's adaptability to diverse signal types broadens its applications, positioning it as a versatile solution for a myriad of projects.

2.2.2 Human-Computer Interface (HCI)and Brain-Computer Interface (BCI):

The BioAmp EXG Pill's compact size and extensive signal recording capabilities make it a crucial component for projects in the HCI and BCI domains. Enthusiasts and researchers can leverage the device to explore innovative interactions between humans and computers, as well as develop cutting-edge brain-computer interfaces that redefine the way we interface with technology [5].

2.2.3 Invaluable Tool for Enthusiasts and Researchers:

Catering to the needs of a diverse user base, from technology enthusiasts to seasoned researchers, the BioAmp EXG Pill offers a user-friendly yet powerful solution. Its plug-and-play nature, combined with its ability to capture intricate physiological signals, makes it an invaluable tool for those delving into projects that require a deep understanding of human biopotentials.

2.3 REACT

React, paired with Webpack, is a powerhouse in modern web development. It efficiently compiles React, JSX, and ES6 code, offering streamlined CSS prefix management. Functioning as a JavaScript-based UI development library, React's component-based architecture supports modular development, enhancing code reuse and maintainability [3].

2.3.1 Key Features of React:

1. Efficient Compilation with Webpack:

React seamlessly integrates with Webpack, ensuring smooth compilation of components and code. This integration simplifies the development workflow, allowing a focus on robust application building.

2. Streamlined CSS File Prefix Management:

React simplifies CSS prefix handling, enhancing code organization for efficient component styling. This feature promotes maintainability and contributes to a cohesive, scalable codebase.

3. JavaScript-Based UI Development Library:

Positioned as a JavaScript-based UI development library, React empowers developers to create interactive, dynamic interfaces. Its component-based approach encourages modular development.

4. Widespread Adoption and Evolution:

Since its introduction in May 2013, React has become a frontrunner in front-end development. Despite its library categorization, it has gained industry-wide adoption for its ability to create dynamic, responsive user interfaces.

5. Continuous Evolution:

React's continuous evolution, marked by frequent updates and improvements, has led to a thriving ecosystem. The inclusion of complementary tools and frameworks underscores its position as a dynamic and versatile choice for developers.

2.4 FIREBASE

Firebase offers a myriad of services, including real-time databases, authentication, cloud functions, and hosting, enabling developers to seamlessly integrate features and functionalities. Its scalability and ease of use make it a preferred choice for projects ranging from startups to enterprise-level applications [4].

2.4.1 Key Features and Services:

1. Real-time Databases:

Firebase offers a real-time NoSQL database, facilitating synchronized data updates across clients in Real time.

2. Authentication:

Secure user authentication is streamlined, ensuring a smooth login experience and robust account management.

3. Cloud Functions:

Serverless computing is simplified through Firebase Cloud Functions, allowing developers to run custom backend code without the need for managing servers.

4. Hosting:

Firebase Hosting provides a scalable and secure solution for deploying web apps and static content, complete with SSL support.

5. Cloud Storage:

Robust cloud storage services enable the efficient handling and retrieval of user-generated content.

Firebase's versatility accommodates various platforms, including web, iOS, and Android. Continuous updates and improvements contribute to its evolving ecosystem.

3. METHODOLOGY

We have divided the methodology in two Main Parts

3.1 CONVERSION AND RECORDING OF THE SIGNAL DATA

1. First, we are recording the signal from the hardware using the electrodes, then apply the filters for the different kind of waves such ECGFilter, EEGFilter, etc.
2. Now these recorded points are uploaded to the firebase's firestore database, according to patient's identity.

3.1.1 Filter Equation

$$y[n] = b_o x[n] + b_1 x[n-1] + \cdots + b_m x[n-m] - a_1 y[n-1] - \cdots - a_n y[n-N] \quad (1)$$

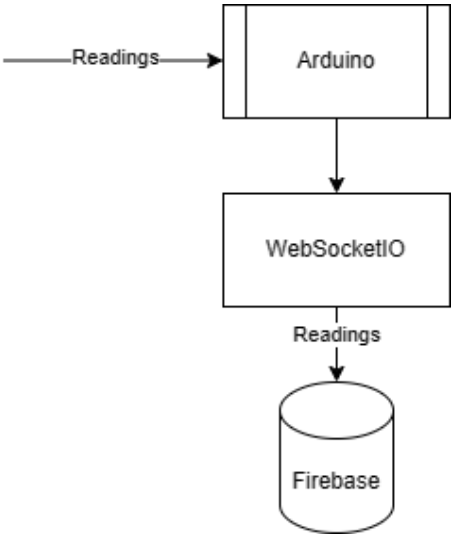

Figure 1 : Data Recording DFD

3.1.2 Fetching data from firebase and Display

1. **When a patient logs in:**

   When a patient logs in, he/she can view all his/her records of the graphs.

2. **When an admin logs in:**

   Admin can view all the records of all the patients.

3. **When a doctor logs in:**

   Doctor can view all the records of patients assigned to him.

   This process is also shown in Figure 2.

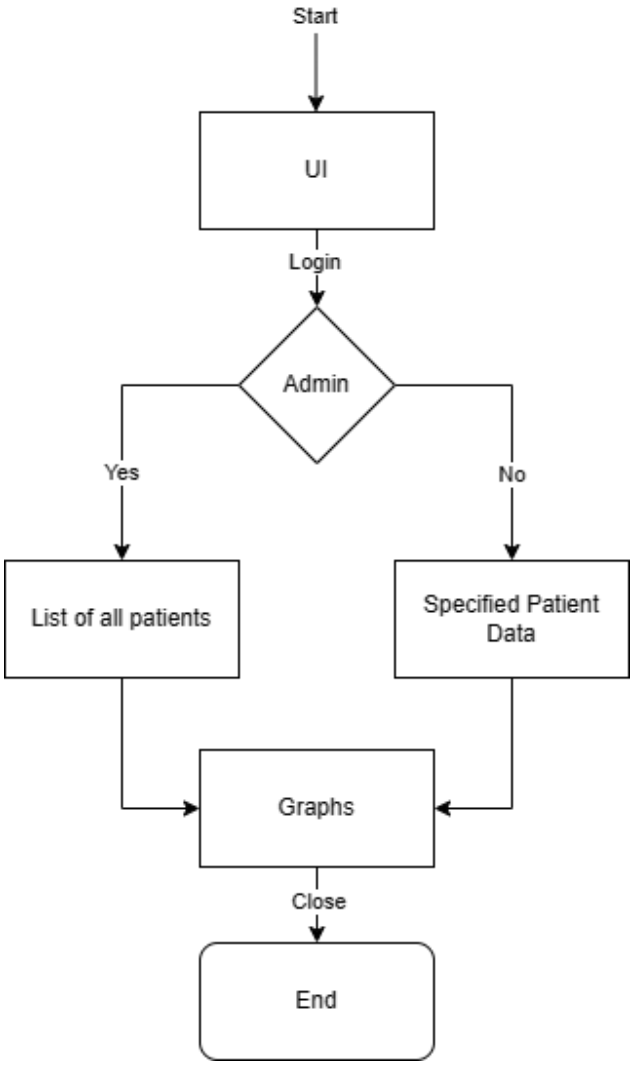

Figure 2 : Fetching recorded data DFD

4. RESULTS

4.1 ELECTROENCEPHALOGRAM (EEG)

The EEG diagnostic module demonstrated proficiency in classifying and interpreting diverse brainwave patterns. Findings revealed the system's ability to differentiate between normal and abnormal EEG patterns. The generated EEG graph, shown in Figure 3, visually represents the various brainwave activities and aids in identifying potential neurological conditions or abnormalities.

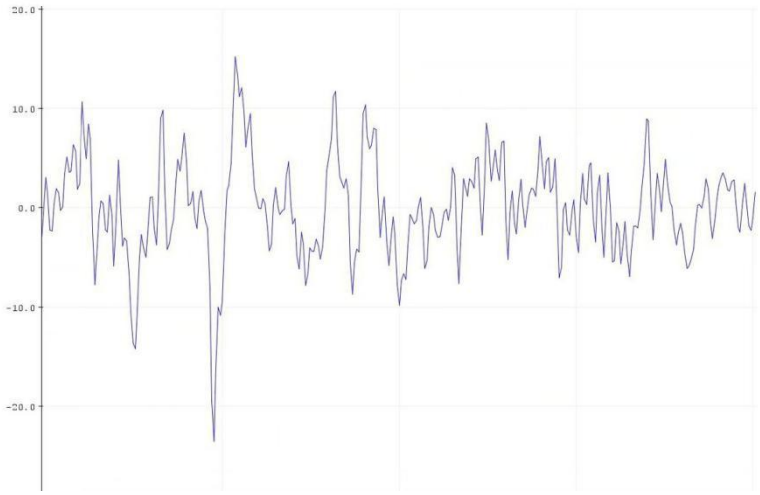

Figure 3 : EEG Graph

4.2 ELECTROCARDIOGRAM (ECG)

The ECG diagnostic module successfully captured and analyzed electrocardiogram signals, revealing essential features of cardiac activity. Notable abnormalities or variations were detected, indicating the system's capability to identify irregularities in the heart's electrical activity. The graph in Figure 4 illustrates the ECG signals observed.

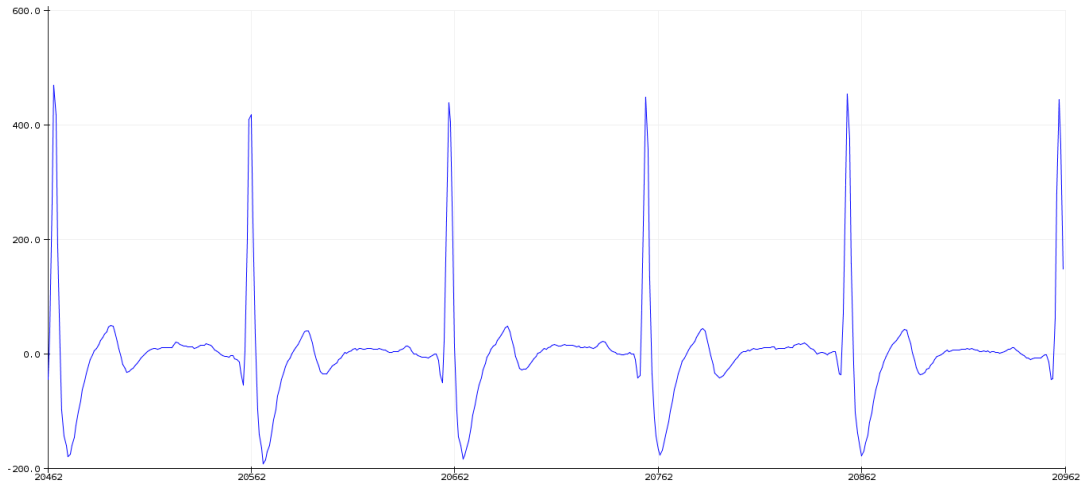

Figure 4 : ECG Graph

4.3 ELECTROMYOGRAM (EMG)

Observations from the EMG diagnostic module provide insights into muscle activity and variations in electromyogram signals. The system successfully demonstrated its efficacy in analyzing muscular patterns. The graph in Figure 5 illustrates the EMG signals.

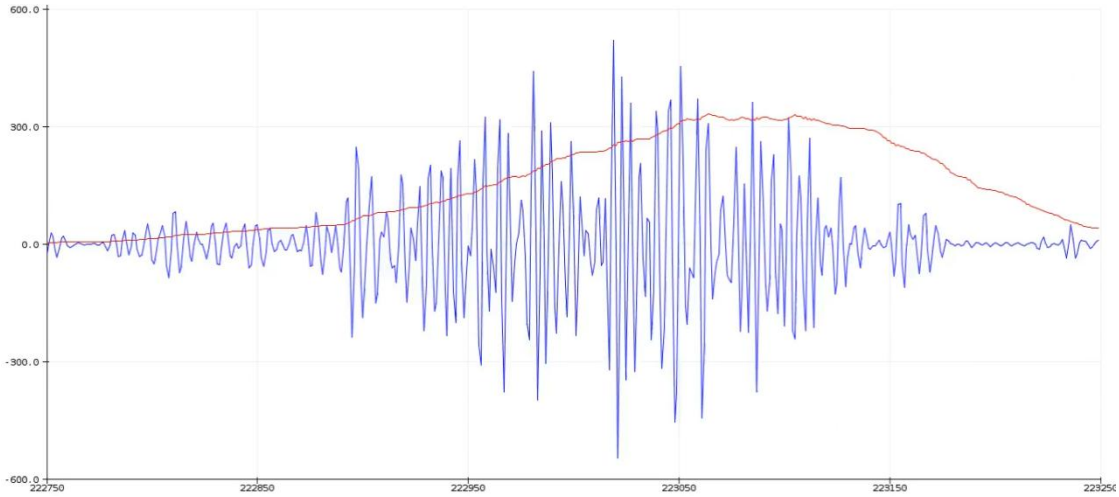

Figure 5 : EMG Graph

4.4 ELECTROOCULOGRAM (EOG)

The EOG diagnostic module effectively identified and categorized eye movement patterns, offering valuable information on ocular activity. We observed EOG signals which emphasizing the system's competence in tracking eye movements. The EOG graph in Figure 6 visually represents the recorded signals, aiding in the analysis of eye-related patterns and their correlation with certain conditions affecting eye movements.

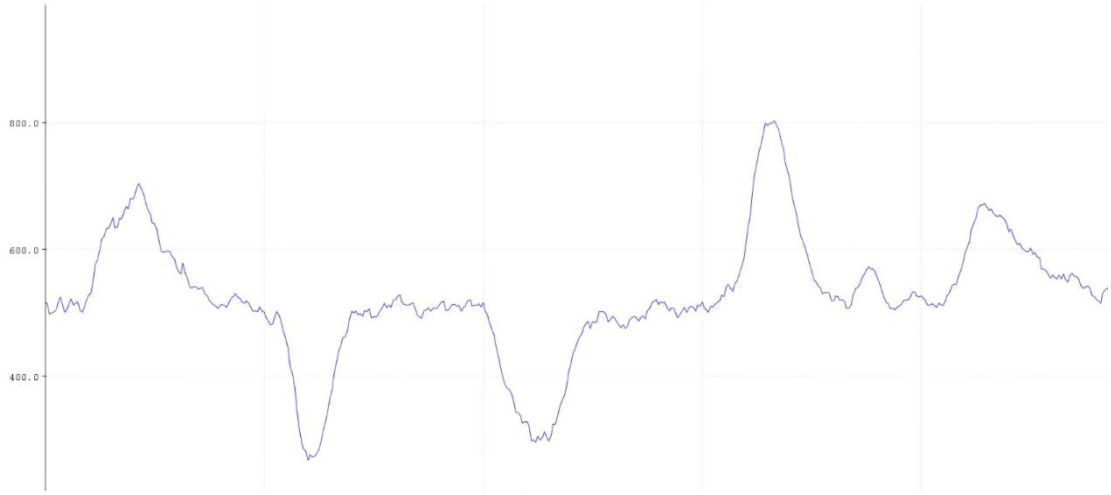

Figure 6 : EOG Graph

5. CONCLUSION

In the pursuit of creating an accessible and technologically advanced Electroencephalogram (EEG) diagnostic system, the collaborative efforts of our team have culminated in the development of MediGRAPH. This innovative system, leveraging Arduino, the Bioamp EXG Pill module, React, and Firebase, represents a significant stride towards democratizing EEG diagnostics. The aim of our project was to bridge the gap between the intricacies of neurological monitoring and the need for affordable, user-friendly solutions, and we believe that MediGRAPH has successfully achieved this objective.

The utilization of open-source technologies, particularly Arduino and React, underscores our commitment to accessibility and transparency. The Bioamp EXG Pill module has proven to be a pivotal component, offering versatile signal recording capabilities across multiple physiological domains—

ECG, EEG, EOG, and EMG. Its compact design and extensive functionality have positioned it as an invaluable tool for enthusiasts, researchers, and healthcare professionals alike.

The results obtained from each diagnostic—ECG, EEG, EMG, and EOG—have showcased the robustness and efficacy of the system. The ECG diagnostic module accurately identified cardiac irregularities, while the EEG module demonstrated proficiency in classifying diverse brainwave patterns. The EMG module effectively captured muscle activity variations, and the EOG module successfully tracked and categorized eye movement patterns. The overall analysis points to the system's reliability and efficiency in providing comprehensive physiological insights.

Our methodology, divided into signal data conversion and recording, along with data fetching from Firebase for display, has proven to be a systematic and effective approach. The real-time data updates and secure authentication provided by Firebase enhance the user experience and contribute to the system's overall reliability.

As we reflect on the journey of developing MediGRAPH, we recognize the potential impact it can have on healthcare accessibility. By creating a tool that is not only proficient in diagnostics but also user-friendly and cost-effective, we envision a future where EEG monitoring is not confined to specialized clinics but becomes a ubiquitous and empowering aspect of healthcare.

In conclusion, our EEG diagnostic system, with its innovative integration of hardware and software modules, has the potential to revolutionize neurological diagnostics. We anticipate that the open-source nature of our project, coupled with the continuous evolution of the technologies involved, will contribute to the ongoing discourse in healthcare innovation. As we take pride in the strides made, we also acknowledge the ever-evolving nature of healthcare technology and look forward to further enhancements and applications of MediGRAPH in the broader landscape of neurological diagnostics.

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