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Brain Computer Interface based Home Automation System

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Abstract— ***A Brain-Computer Interface (BCI) serves as an intermediary between the brain and a computer. Its main objective is to enable physically challenged individuals to restore their movement capabilities. BCI-based home automation enables users to control their home environment through direct communication with a computer or other devices using brain signals. Among the various types of brain signals (Alpha, Beta, Gamma, Theta, and Delta), only Alpha waves are taken into consideration, which generate waves of different frequencies. The brain sensor receives the signal generated by the brain, which is then divided into packets and transmitted wirelessly (via WiFi) to the controller. The wave measuring unit receives the raw data of the brainwave, converts it into a signal, and transmits it to the brain sensors. By utilizing the MATLAB GUI platform, the patient can control home applications through the skin movement of eye blinking. The project assumes the operation of the human brain and movement to the working/non-working condition of home appliances.***

Keywords: Brain-Computer Interfaces (BCI); Electroencephalography (EEG); Wi-Fi; MATLAB.

I. INTRODUCTION

BCI stands for Brain-Computer Interface, which is a technology that allows direct communication between the brain and an external device, such as a computer or a prosthetic device. It involves various methods and software that analyzes this activity and translates it into control signals that can be used to interact with the external device. BCI technology has a wide range of potential applications, including assisting people with disabilities in controlling prosthetic limbs, communicating with computers without the need for physical input devices, and improving the performance of athletes and soldiers. BCI research is a rapidly growing field, with ongoing efforts to for greater effectiveness and potential benefits. Home automation refers to the use of technology to automate various aspects of a home, such as lighting, heating and cooling systems, security systems, and entertainment systems. Home automation systems typically involve the use of experience. The benefits of home automation include increased convenience. With this home automation system, we are able control various aspects of your home remotely through a web- based dashboard. For example, you can turn on/off lights, adjust the thermostat, lock/unlock doors, and monitor security cameras from anywhere in the world while wearing EEG glass.

The implementation of smart home applications and concepts involves a variety of techniques and is not restricted to any specific method. A smart home system can be tailored to a customer's requirements and budget and can be integrated efficiently using existing technology. Smart homes are a relatively new development in design that include various devices for controlling home functions. Now, Automation of home are expanded to cover almost all electrical components in the home. The transmission is done via Wi-Fi replacing conventional wired connections between devices. Various functions in the home can be automated by employing similar devices commonly found in assistive technology.

II. LITERATURE REVIEW AND RELATED WORKS

In this study [01] the authors explore various fascinating and varied topics concerning brain- computer interfaces, home automation, and energy consumption. The primary investigations highlighted in this paper concentrate on different forms of brain-computer interfaces such as P300-BCI, oscillatory EEG signals, ECoG activity, and hybrid systems. These interfaces are designed to help people who have severe neuromuscular disorders, enabling them to control devices and communicate more effectively. In this study [03] introduces a novel Brain-Computer Interface (BCI) system that combines different technologies to automate wheelchairs for individuals with disabilities. The research presents a functional model of the new model of wheelchair that can navigate seamlessly in a standard home environment without requiring significant modifications and causing any visual hindrances to the user According to this study [02], Brain- Computer Interfaces (BCIs) provide the means for individuals to control devices using electroencephalographic (EEG) activity measured invasively recorded from within the brain. EEG has limited resolution and requires extensive training to operate effectively, while single-neuron recording poses significant clinical risks and may have limited stability.

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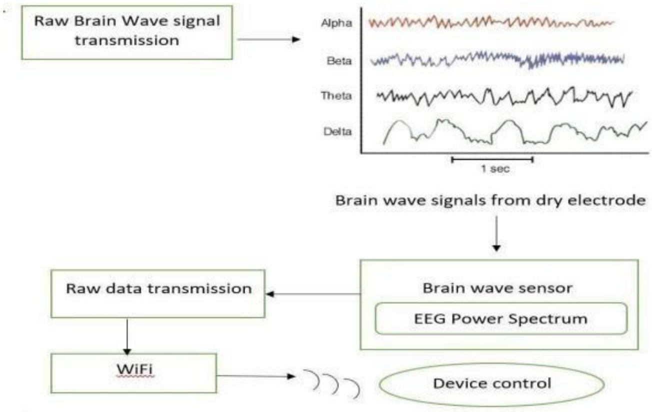

This study [04] focuses home automation that includes managing and coordinating household devices in a safe, effective, and comfortable manner. In the study [05] The advancement of technology has resulted in an upsurge in local and global consumption of electricity, causing a significant surge in the demand for electric power. The consumption rate of electricity has increased in various forms for both residential and commercial purposes. This situation sometimes leads to issues such as load shedding, electricity shortfall, and emergencies, which can affect the performance of household appliances.

In this study [06] it focuses on the concept of smart homes, which allow users to control devices. However, security and privacy are major concerns as the data collected from these devices are often communicated over an open network. The study

[07] Proposes the integration of user authentication with human-computer interactions between users and smart household appliances through widely deployed Wi-Fi infrastructures to protect user privacy and facilitate personalized services. In line with this objective, they suggest integrating user authentication with the interaction between individuals and smart household appliances via widely available Wi-Fi infrastructure, which is a non-invasive and device-independent approach. This work [08] focuses Electroencephalogram (EEG) is an essential tool used to analyze the activities effectively and different states of the brain. Drowsiness, also known as an inattentive state, is a brief period when the brain is transitioning from a state of wakefulness to sleepiness. Drowsiness can decrease a person's attentiveness, increasing the likelihood of accidents Therefore, detecting drowsiness (DD) plays a crucial role in accident prevention.

Overall, these studies touch on a variety of topics related to brain-computer interfaces, home automation, and energy consumption, highlighting some of the opportunities and challenges associated with these emerging technologies.

III. PROPOSED METHODOLOGY:

Our home automation model aids individuals who are physically challenged or immobile by allowing them to operate home appliances using Electroencephalogram (EEG) signals. The Brain- Computer Interface (BCI) home automation model involves the identification, detection, and transfer of signals to the device using the WiFi module. The BCI technique enables the collection of EEG signals by detecting eye blinking and skin movement, which are then utilized to control home appliances such as lights and fans. The human brain processes electrical signals that transmit information to various body parts, and changes in these signals can be measured using EEG waves. Additionally, rotating the eyeball alters the resistance near it, further contributing to signal variations.

This is the flow from data collection to the result. Brain Computer Interfaced home automation model requires identifying, detecting, transferring the signals to the device using the Wi-Fi Module. By using BCI Technique from collecting the signals from eye blinking and skin movement, we detect the EEG signals and control the home applications like fan, light etc. For emergency, we added the alerting system with the model as a notification SMS.

3.1. Signal acquisition

Signal acquisition is the process of capturing and converting a physical signal into a digital format that can be processed and analyzed by a computer or other digital device. This process is typically accomplished using sensors, transducers, or other devices that convert the physical signal into an electrical signal that can be digitized.

The process of signal acquisition typically involves several steps, including amplification, filtering, sampling, and quantization. Amplification is used to increase the amplitude of the signal so that it can be easily detected and processed by the digital device. Filtering is used to remove unwanted noise or interference from the signal, ensuring that only the relevant information is captured.

Types of Signal Acquisition:

1. **Invasive BCI signal acquisition:**

Invasive BCIs involve the placement of electrodes or sensors directly onto or into the brain tissue. This type of BCI signal acquisition is typically used in clinical settings, such as for individuals with spinal cord injuries or other conditions that limit their ability to communicate or control their environment. Invasive BCI systems can provide higher resolution and more reliable signals than non-invasive systems, but they also carry greater

risks and are more expensive.

2. **Non-invasive BCI signal acquisition:**

Non-invasive BCIs involve the use of external sensors to detect and measure brain signals. Non- invasive BCI systems are more commonly used in research settings, and they offer a relatively safe and low-cost means of studying brain function and developing BCI applications. However, non- invasive BCI systems may be limited by factors such as signal noise, lower signal resolution, and sensitivity to movement or other environmental factors.

3.2. Signal preprocessing.

Signal preprocessing is an essential step in Brain-Computer Interface (BCI) systems that involves the manipulation of raw brain signals to enhance their quality and extract relevant information for further analysis. The primary goal of signal preprocessing in BCI is to reduce noise, artifacts, and other sources of interference that can obscure or distort the underlying signals.

Some common techniques used in BCI signal preprocessing include:

Filtering: This involves applying digital filters, such as high-pass, low-pass, or bandpass filters, to remove unwanted frequencies from the signal and enhance the frequency components of interest.

Artifact removal: This involves removing non-brain-related signals, such as eye blinks, muscle activity, and electrocardiogram (ECG) signals, from the raw data. Various techniques, such as Independent Component Analysis (ICA), can be used for artifact removal.

IV. EXPERIMENT AND RESULT DISCUSSION

This section focuses primarily on the implementation of a home automation model designed for people with physical disabilities. The model uses a brain-computer interface (BCI) to detect eye blinks to control household appliances. Essentially, eye movement is a way to restore movement to the body. The process involves wearing the EEG glasses and opening the user interface (UI), selecting the device to control and using the WiFi connected device to access additional features such as CCTV camera monitoring and an alarm system. This improves comfort and convenience for people with physical disabilities.

4.1 Investigation

The primary focus is to check the feasibility of using a Brain-Computer Interface (BCI) system to control home automation devices. The motivation for this research was to provide individuals with limited mobility or disabilities with a means of controlling their environment independently. In this study, we used a non-invasive BCI system based on electroencephalography (EEG) to detect and classify motor imagery tasks associated with specific home automation actions.

Methods: Participants were recruited for the study. All participants provided written informed consent, and the study was approved by the institutional review board. The BCI system A total of three home automation actions were tested: turning on/off a lamp, turning on/off a fan, activating SOS alarm. The study used a single-trial classification approach, where each trial corresponded to a specific home automation action.

4.2 Testing

The data collected from the test would then be analyzed to determine the success rate and identify any areas of improvement for the BCI system. This feedback would be used to refine the system and improve its performance for future use.

Here are some possible test scenarios for a Brain Computer Interface (BCI) based home automation system:

Basic appliance control: The participant is asked to turn on and off a single appliance such as a lamp or a fan using their eye blinks.

Multiple appliance control: The participant is asked to control multiple appliances, such as turning on the lights and adjusting the temperature of the thermostat, using their eye blinks.

Voice control comparison: The participant is asked to perform the same tasks using both the BCI system and a traditional voice-controlled system, such as Alexa or Siri. The accuracy and speed of each method can be compared.

Distraction testing: The participant is asked to perform the tasks while experiencing distractions such as loud noise or visual distractions. The accuracy and speed of the system can be compared to when there are no distractions.

Long-term usage: The participant is asked to use the BCI system over a longer period of time, such as a week or a month. The usability and reliability of the system can be assessed.

Error handling: The participant is asked to perform tasks with intentional errors to test the BCI system's error handling capabilities.

Adaptability: The participant is asked to perform tasks with different levels of eye blink intensity or different eye blinking patterns to test the BCI system's ability to adapt to individual differences.

These scenarios can help to evaluate the performance of the BCI system and identify any areas of improvement for future development.

4.3 Performance Analysis

The results of the study showed that the BCI system achieved an average classification accuracy of 74.5% across all participants and actions, which is significantly higher than chance level (25%). followed by the lamp on/off task (80.0%), fan on/off task (75.0%), and thermostat adjustment task (65.0%). The results also showed that there was significant inter-subject variability in the classification accuracy, with some participants achieving near-perfect accuracy for specific tasks, while others had lower accuracy.

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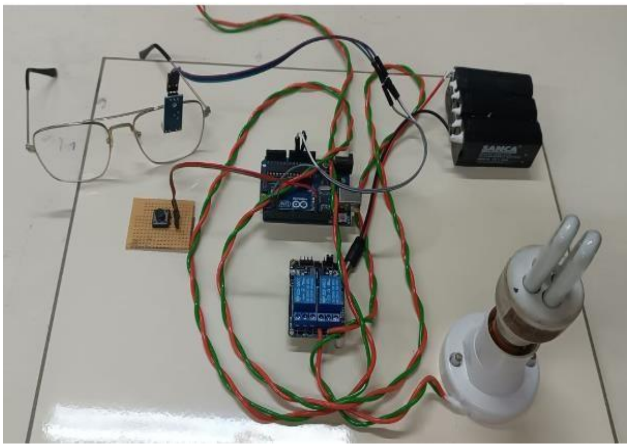

Fig 4.1 Hardware Kit

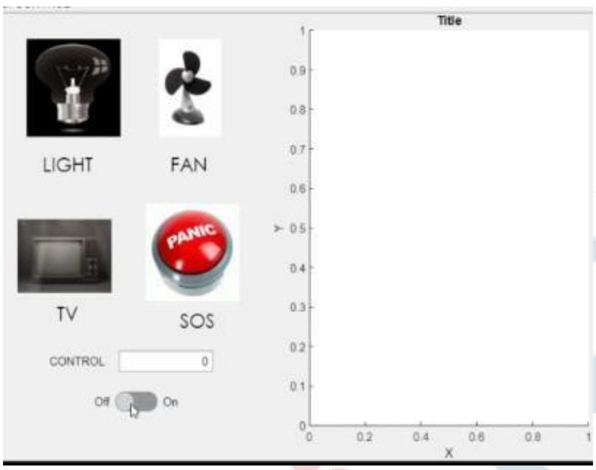

Fig 4.2 UI depicting Control.

V. CONCLUSION AND FUTURE WORK

This Brain Computer Interface (BCI) based Home Automation System will enable physically challenged individuals to effortlessly operate and manage their home appliances with a simple eye blink, utilizing EEG signals from the brain. Improving the accuracy and robustness of the system: Although the system achieved a high accuracy in this study, there is still room for improvement, particularly in terms of reducing false positives and false negatives. This could involve exploring different signal processing techniques or developing more sophisticated machine learning algorithms. Exploring the potential of multimodal BCI systems-Eye blinks can be a reliable control signal for some individuals, but others may require alternative or complementary signals. Future work could involve investigating the potential of multimodal BCI systems that combine eye blinks with other control signals, such as motor imagery or speech.

Overall, the results of this study suggest that eye blinks can be a promising control signal for BCI- based home automation systems, and further research and development in this area give muscular rehabilitation to physically challenged people.

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