A Review on Brain-Controlled Home Automation

Rajesh Rishi[1], Shakuntala Laskar[2]

[1,2] Department of Electrical and Electronics Engineering, School of Technology, Assam Don Bosco University
Airport Road, Azara, Guwahati-781017, Assam, INDIA.
[1]rajeshrishi26@gmail.com, [2]shakuntala.laskar@dbuniversity.ac.in*

Abstract: ***A "smart home" employs ambient intelligence to keep tabs on things around the house so that the owner may get services tailored to their specific needs and control their home appliances from afar. Home automation for the elderly and handicapped focuses on enabling older persons and those with disabilities to live safely and comfortably at home. Additionally, the integration of this technology with a brain-computer interface (BCI) is perhaps of tremendous usefulness to those who are either old or disabled. These BCI-based brain-controlled home automation (BCHA) systems have emerged as a viable option for people with neuro disorders to remain in their homes rather than move to assisted living facilities. To summarize, BCI-based BCHA for the elderly and handicapped people is transforming people's lives every day. Most individuals prefer a simple approach to save time and effort. Automating the house is the simplest way for individuals to save time and effort. The brain-computer interface, often known as a BCI, is an innovative method of human-computer connection that does not rely on conventional output channels (muscle tissue and peripheral nerve). Over the course of the last three decades, it has attracted the attention of industry experts and developed into a thriving centre for research. Brain-controlled home automation (BCHA), as a typical BCI application, may provide physically challenged people with a new communication route with the outside world. However, the primary challenge that BCHA faces is to rapidly decipher multi-degree-of-freedom control instructions extracted from an electroencephalogram (EEG). The BCHA's research has made significant headway in a short amount of time during the last fifteen years. This study investigates the BCHA from several viewpoints, including the pattern of instructions for the control system, the type of signal acquisition, and the operational mechanism of the control system itself. This paper a concise description of the building blocks of smart homes and how they may be used to construct BCI-controlled home automation to assist disabled individuals. It is a compilation of information pertaining to communication protocols, multimedia devices, sensors, and systems that are often used in the process of putting smart homes into action. A comprehensive strategy for developing a functional and sustainable BCI-controlled home automation system is laid out in this paper as well, which could be useful to researchers in the future.***

Keywords: Brain-computer interface (BCI); BCI-based brain-controlled home automation (BCHA); Home automation; neuro disorders; rehabilitative medicine.

Article history- Received: 28 October 2022 and Accepted: 16 December 2022.

1. Introduction

Smart houses are a subset of ubiquitous computing that includes embedding intelligence into homes for purposes such as healthcare, comfort, security, energy saving, and safety. A common feature of smart homes is the incorporation of remote monitoring systems. These systems integrate telecoms and web applications to allow remote management of the home as well as remote patient care from institutions devoted only to providing aid. Smart homes help the elderly and people with disabilities live better lives by having automated appliance control, brain-computer interfaces, and other help services. Brain-controlled home automation (BCHA) refers to the combination of smart home automation with BCI. They do this by understanding the context and applying rules that have already been set up based on the user's home environment. A user has the ability to remotely handle household appliances and equipment, which enables the user to finish tasks before returning to their actual residence. There is a chance that the technologies that use ambient intelligence to keep an eye on smart homes could sometimes make the house use less energy. By the year 2050, over 20% of the total population of the globe will be over the age of 60 years old [1]. This age group will have a hard time maintaining their independence and is more likely to develop chronic diseases. The World Health Organization (WHO) estimates that 650 million individuals throughout the world are impaired [2]. Chronic illnesses such as cardiovascular disease, cancer, and diabetes are the most prevalent causes of disability, as are injuries from automobile accidents, falls, wars, landmines, birth abnormalities, mental impairments, HIV/AIDS, malnutrition and other infectious diseases.

Still today, there remains a worldwide shortage of accessible facilities for individuals with disabilities. The degeneration of motor neurons is a contributing factor in amyotrophic lateral sclerosis (ALS), which results in a gradual loss of motor function in the muscles [3]. In addition, those who have suffered a spinal cord injury (SCI) often struggle with a variety of motor, sensory, and sphincter dysfunctions [4]. As a result of these diseases, the number of motor neurons in the brain gradually decreases, leading to a decrease in intermuscular communication and control. As a result, the brain eventually loses the ability to perform any deliberate actions or regulate activities. After suffering an injury, the central nervous system (CNS) is capable of undergoing functional and structural plasticity, but this plasticity is contingent on the CNS's capacity for functional compensation. It is not going to be created automatically, and it is going to need particular learning and training [5]. The central nervous system's typical output may be replaced, repaired, enhanced, supplied, and improved by employing a brain-computer interface (BCI). Methods for doing this include monitoring the central nervous system and translating that monitoring into simulated action [6]. As a consequence, BCIs are able to facilitate the restoration of a patient's physical and cognitive capabilities, in addition to realizing the direct link that exists between the brain and the outside environment [7].

Numerous researchers created several technologies based on Bluetooth technology, the ZigBee system, and WiFi technology. However, these topologies do not provide enough assistance for impaired persons. Rui Zhang and and Kai Li *et al.* proposed context-aware technologies to assist the handicapped by incorporating BCI to develop BCHA [8]. This paper provides a high-level overview of the rule-based BCHA architecture, as well as its community systems and context-aware gateways.

2. Smart Home Definition

One use of ubiquitous or pervasive computing is the "smart home," also known as the "connected home." There are several synonyms for "smart home," including "intelligent home," "adaptive home," and "conscious house". Other names for smart homes include home automation, domotique, intelligent home, and adaptive home.

Lutolf [9] offered one of the first definitions of what we now refer to as smart houses. According to Lutolf, "the concept of a smart house is the combination of several services inside a residence through a single communication system." It ensures that the house will be operated in an economical, safe, and pleasant manner, and it incorporates a high level of intelligence , adaptability and functionality. The vocabulary of house automation has a significant impact on the definition, whereas home intelligence is completely absent from the discussion.

House intelligence is implicitly included as an automated control by Berlo *et al.*, who describe a smart home as "an environment, whether a house or a place of business, that is equipped with the technology necessary to allow the devices and systems to be operated automatically" [10].

A "smart house," according to Winkler, is one that can proactively adapt its surroundings to deliver services that support independent living for older people [11]. Winkler only allows the elderly to utilize smart homes.

According to Briere *et al.* definition's [12], a smart home is one that is in perfect harmony and consists of a collection of devices and capabilities that are enabled by home networking. Nevertheless, the notion of a smart house cannot be adequately expressed using this term.

Intertek, a company that participated in the smart house initiative run by the Department of Trade and Industry (DTI) in the United Kingdom, issued a more in-depth description of a smart home in the year 2003 [13]. According to Intertek, a "smart home" is a dwelling equipped with a communications network that interconnects essential electrical equipment and services and enables remote monitoring, control, or access. A smart home is sometimes referred to as a connected home.

Recent work by Satpathy offers a definition of "smart houses" that is more accurate and comprehensive. According to Satpathy, "A house is considered to be smart if it is capable of assisting its residents in living freely and in comfort with the assistance of technology. A smart house" is defined as " a smart home is one in which electrical and mechanical components are networked to create a system that can communicate both with itself and the occupants ". According to the author, remote access does not fall within this criterion." [14]. The definition does not encompass access from a remote location, as stated by the author.

3. EEG Definition

According to S. A. Khoshnevis *et al.* definition's [15], electroencephalography, often known as EEG, is a method of electrophysiological monitoring that does not need any intrusive procedures. The method involves attaching electrodes to the scalp in order to record and analyze brain electrical activity. The electroencephalogram (EEG) is not only an indispensable instrument for the diagnosis of conditions and illnesses that affect the brain, but it also contributes to our development of a deeper comprehension of the activities and structures of the brain.

According to definition of Subha, D. Puthankattil *et al.* [16], the synaptic potentials between brain cells are recorded by electroencephalography (EEG). On a larger scale, one synaptic potential represents a large group of neurons, yet synaptic potentials are unique to each individual neuron. The difference in electrical potential that exists between the two sides of the membrane at a neuron's postsynaptic terminal is called its synaptic potential. As a result, it is referred to as the "incoming" signal of a neuron. There is always a transmitter, also known as the presynaptic neuron, and a receiver, also known as the postsynaptic neuron, in every transaction. Data derived from EEG are highly nonlinear, not Gaussian, and nonstationary in nature. There are two types of EEGs, both of which are distinguished by the reference electrode: 1. Mono-polar 2. Bipolar.

The electroencephalogram, according to N. Birbaumer *et al.* [17], often known as an EEG, is a method that is widely used for the purpose of assessing the electrical activity that occurs inside the brain. The electroencephalogram (EEG) may be used to investigate various stimuli and environmental variables in the brain and provide insight into a wide range of neuroscientific problems. It is also possible to utilize it to operate a brain-computer interface (also known as a BCI), which is a tool for controlling electronic devices, such as a computer, by altering one's brain's electrical activity.

Electroencephalography, more often known as EEG, is a technique for analyzing the electrical activity in the brain Delorme *et al.* [18]. It is often used as a method for conducting analyses of data, including time series analysis and frequency analysis. The ionic current that is present in the neurons of the brain is what causes the voltage variations that may be measured by an EEG. This electrical activity occurs on its own, and it is recorded continuously over a period of time from a number of scalp electrodes in order to produce an EEG signal.

According to J. Kaur *et al.* [19], the electroencephalogram, often known as an EEG, sheds light on the status of the brain by revealing the electrical activity that is taking place inside it. The electroencephalogram (EEG) records voltage fluctuations across the brain to provide insight into the brain's electrical activity. In general, the characteristic of these signals is that they fluctuate with time and are not stationary. To learn more about these signals, a number of signal processing techniques may be used. In this study, a limited number of statistical methods for analyzing EEG data are compared and contrasted.

4. Review of the projects

4.1 Home Automation

The research being done on "smart homes" has one of its primary goals to be to make a living, in general, easier by improving the level of user comfort. This may be accomplished in two different ways. The first is the identification of linked human actions and the automation of occurrences in specific local settings. The second option is to manage one's house remotely from another place.

Das *et al.* [20] were the ones who first presented the Mav Home (Managing an Adaptive Versatile Home), a project that is now being carried out at the Texas University in Arlington. Artificial intelligence, mobile computing, multimedia technology, and robotics are some of the areas of study that are represented in Mav Home's implementation of cutting-edge technology. Its structure consists of four separate layers: the information layer, the communication layer, the decision layer, and the physical layer.

More than 60 X10 gadgets that are integrated into the electrical wiring system of the home may be controlled and monitored via the usage of the X10 protocol [21]. An algorithm known as active LeZi (ALZ) is put into operation. Using a Markov model of finite order, this approach produces a decision tree. The prediction of future actions by ALZ is accomplished by the use of the prediction by partial matching (PPM) approach [22], which involves computing the likelihood of all prior actions. Mav Home is only capable of accurately predicting the actions of a single resident [23], despite the fact that it makes use of AI algorithms to make accurate predictions and judgments.

An intelligent room that may assist its inhabitants with their day-to-day activities was created by Noguchi *et al.* at the University of Tokyo. There are primarily three parts to the system, and they are the data collection, data processing, and data integration. It does this by gathering information from the sensors that are connected to various objects in the surroundings, such as beds, floors, tables, and switches. To monitor and keep track of any changes made to the system, a summarization technique is utilized. At points when there are noticeable changes in sensor output (i.e., switches or sensors are suddenly switched out, or pressure data appears out of nowhere), the algorithm splits the collected sensory data into subsets. These sections have been given the name "room states." The algorithm combines the states of all of the segments to quantify the data that has been gathered and to make sense of the new circumstances [24]. The summarization technique that has been suggested can identify user actions, and this capability has been validated for a single room. This method has not yet been used in the implementation of any autonomous services.

The "Ubiquitous Home" that Yamazaki has created is a test bed for context-aware services that may be used in real life. Through the interconnection of various gadgets, sensors, and appliances through a local area network, the system makes it possible to develop new services for the house. At the door and above the ceiling, a mix of active and passive RFID receivers are set up to find and identify people as they enter and leave the building. Pressure sensors are used to detect the motions of users as well as the placement of furniture. The smart home has LCDs, plasma screens and a microphone to facilitate conversation among the residents. In order to carry out a selection of domestic chores, a network robot is used. The authors came to the conclusion that the objective of the study into the so-called "smart house" goal is not to build a fully automated home, but rather to cultivate a setting where humans may interact with the system [25]. Although the researchers did install a significant number of interface devices and sensors, the system is only usable for automating a select few functions like program selection, recipe display, and lost-and-found services.

Core Lab is the name given to the prototype of a smart house that was constructed by Lu *et al.* at National Taiwan University. These same authors also designed a technique to identify actions taking place within an Attentive Home based on their precise geographical position. Core Lab does not rely on traditional sensors but rather on integrated components known as Ambient Intelligence Compliant Objects (AICO). There are several distinct categories of AICOs, each of which is designed to serve a specific function. These categories include power consumption, pressure, location, contact, and motion detection. In order to identify the actions of residents that are aware of their location, an improved version of the Naive Bayes classification algorithm is used. The suggested approach is capable of ADL classification with a high degree of confidence. The authors created a program known as "Activity Map" in order to display in graphical form the contextual information that pertains to persons and the environments in which they live. Only the tracking of a single occupant may be accomplished using this method [26].

In order to deliver automated services in smart homes, Ma *et al.* emphasized the need of context awareness. Case-Based Reasoning, often known as CBR, was utilized by the authors to tailor their offerings that were more suitable. CBR derives potential answers to present issues from past interactions and experiences in order to function properly. By altering the case data, the system is able to accommodate any human alteration [27]. In the first stages of the project, a few different situations, including the interactions between an air conditioner, television, and light, are tested. The authors want to enhance the case tables in the future by adding additional contexts and expanding the available features.

Perumal *et al.* from the University Putra Malaysia's Institute of Advanced Technology (UPM) presented a concept and implementation of the SOAP (Simple Object Access Protocol) -based smart homes [28]. They came up with a control module based on SOAP to make it possible for household appliances in smart homes to communicate with one another. Within the framework of a residential management system, the development of fifteen web-based feedback control channels was carried out. In the case that the server is not accessible, the system may also be remotely controlled by means of an SMS module. It provides a full-fledged smart home management and monitoring system that operates in real-time and in both directions. This system was built using relay-based switches that does not adhere to any standard communication protocols and were used in its construction. Additionally, this system has been implemented using normal communication protocols.

The authors' Wu *et al.* [29] presented a mobile agent and OSGi (Open Service Gateway Initiative) as the foundation for a service-oriented architecture for a smart home. The architecture is based on a wide variety of OSGi platforms and employs a Peer-to-Peer methodology in its construction. Specification for Mobile Agents. Markup Language (MASML), is the language used to interact with a mobile agent through the internet. A web service bundle is installed in each OSGi platform, which enables the publication of inter-compatible services and provides for their distribution. P2P (peer-to-peer) networking, which makes use of a variety of OSGi platforms, was recommended by the authors in lieu of a server-centric model since it displays improved performance owing to scattered resource utilization. In order to put the recommended design into action, they utilized Knopflerfish [30], an open-source OSGi R3 application. The findings suggest that running local services and using parallel task processing both help to reduce the time it takes to accomplish tasks. In addition to this, the authors provided a comprehensive analysis of the planned smart home's architectural design.

Following the DSL forum's standardization procedure, Nikolaidis *et al.* [31] combined UPnP and CWMP (CPE Wide area network Management Protocol). The authors examined a UPnP-to-CWMP method. CWMP client sends information to UPnP control point. Control and management of the UPnP network are handled by the UPnP control point. The service provider may make use of a remote diagnostic solution provided by this architecture. Their next projects will involve securing the home network and allowing access from many service providers.

An embedded web server was built by Yongping *et al.* [32] in order to operate devices that make use of the Zigbee protocol. They accomplished this by using an S3C2410 CPU that has the Linux 2.6 kernel pre-installed on it. A lightweight web server known as Boa, which is just 60 KB in size, was set up so that users may access the internet. An interface that allows for communication with the Zigbee module has been created by the authors (MC13192). This is a project that involves automating your house remotely. The system is completely devoid of any kind of intelligence.

Chen *et al.* [33] constructed a smart home at the Industrial Technology Research Institute (ITRI) in Taiwan. Their smart home uses a multitude of communication protocols. A (Smart Appliance Alliance Net) SAA Net was developed by the author, and the (UPnP) Universal Plug and Play networking standards and (DLNA) Digital Living Network Alliance was collaborated to create this hybrid networking protocol. To integrate several types of hardware, middleware in the form of the OSGi framework is used. In addition to that, the researchers created intelligent household gadgets. Microcontrollers are what allow these home appliances to respond to orders and report their status to the larger system. In order to cut down on unnecessary energy use, they built a home laboratory for smart energy. The study presented here is a fantastic illustration of a smart house that makes use of distributed intelligence.

Table 4.1: Smart Home Automation and Services

Sl. No.	Category	Services	Function
1	Comfort	To provide comfort	Home appliance control [20]
2	Home automation	Automation of household appliances	Next activity prediction [21]
3	Repository	Data repository	Recognition of activities of daily life (ADL) [24]
4	Repository	Data repository	Reminding smart home systems about neglected property services [25]
5	Repository	Activity Map	Activity detection based on location [26]
6	Home automation	Hybrid	Context awareness [27]
7	Remote access	Controlling, monitoring, and accessing devices remotely	Controlling and monitoring household appliances from a distance [28]
8	Home automation	Automation of household appliances	Monitoring and management of intelligent appliances [29]
9	Remote access	Remote access, monitoring, and control	Controls speech recognition through the phone line [31]
10	Remote access	Controlling, monitoring, and accessing devices remotely	Monitoring and controlling appliances from a remote location using a web browser [32]
11	Home automation	Automate home appliances control	Automatic home appliance tracking and management [33]

4.2 BCI Based Applications

According to Balkis Solehah Zainuddin *et al.* [34] stroke is caused by a shortage of oxygen when there is a blockage in the blood flow, and as a result, brain cells die. Stroke causes loss of ability to read and communicate, memory loss, and paralysis of one side of the body. Physical therapy may help restore this, but the patient's sluggish and emotional behavior makes this treatment challenging. It is examined using an EEG headset with 14 electrodes to determine the brainwaves of stroke patients before and after functional electrical stimulation in order to enhance stroke patient restoration tactics. It has been determined that the examination of alpha and beta waves is the most convenient and appropriate form of data collecting for this investigation of stroke patient health.

Zuzana Koudelková *et al.* [35] employed a non-invasive approach called an EEG headset, which is a brain-computer interface, to study brain parameters for academic purposes. The frequency of brain waves is mostly monitored using an application called Emotive Brain Map. This study focuses on two actions: first, they measure a person's brain activity while solving a problem, and second, they measure a person's brain wave when resting. It has been established that using this raw EEG signal, patients with chronic neurological abnormalities may be improved by introducing this technology into neuro-rehabilitation treatment in order to boost the health and well-being of the patient.

Mahtab Roohi-Azizi *et al.* [36] addressed an acknowledged approach in neurophysiology called an electroencephalogram, which is used to study various forms of brain activity. It was used to probe bioelectrical brain activity, which might be affected by physical and mental states. Sleep, consciousness, cognition, and mental diseases all have different frequencies. Autism, sleep apnea, brain death, brain tumors, encephalitis, depression, brain tumors, ADHD, and OCD, are all associated with slow brain waves, while rapid brain waves are associated with post-traumatic stress disorder (PTSD), anxiety, epilepsy, and drug addiction. The amplitude of the EEG waves in people's brain activity rises while they are working at their maximum degree of consciousness. Any mental disease is indicated by an aberrant pattern of brain wave activity.

Noppadon Jatupaiboon *et al.* [37] utilize real-time EEG data to discern between happy and sad emotions while seeing images and listening to classical music. The results are superior to those obtained in other areas because, unlike in other regions, the results are obtained utilizing a range of frequency bands, the pair of channels of each pair of devices, and the temporal pair of channels, which are not taken into consideration in other regions. In terms of performance, it has been observed that high frequency bands outperform low frequency bands. Following these findings, a system for automatic emotion recognition in real-time was built and implemented. The use of electroencephalography (EEG) in conjunction with other metrics such as skin temperature (ST), electrocardiogram (ECG), and galvanic skin response may significantly increase the efficacy of an emotion detection system (GSR).

K. Suresh Manic *et al.* [38] developed a technique for real-time EEG wave capture by applying known frequencies to various function generators. The efficiency of this system is 5.27%. Testing this technique under various situations revealed that 60% of alpha waves dominate during relaxation and 70% during heavy mental thought. The whole system operates on a single channel that spans a tiny region. It has been determined that adding additional channels across a wide region will aid in obtaining more accurate findings.

Table 4.2: EEG Application and Services

Sl. No.	Waves	Function
1	Alpha and beta waves	Analyze the brainwaves of stroke patients before and after functional electrical stimulation in order to enhance stroke patient restoration tactics [34]
2	Raw EEG waves	Treatment is aimed at restoring a person's physical and emotional well-being via neuro-rehabilitation. [35]
3	Rapid brain waves	To treat post-traumatic stress disorder (PTSD), anxiety, epilepsy, and drug addiction [37]
4	Raw EEG waves	To discern between happy and sad emotions while seeing images and listening to classical music [37]
5	Raw EEG waves	Real-time EEG wave capture [38]

4.3 BCI-based brain-controlled home automation

An intelligent brain machine Interface (BMI) based system has been built by Christian I. Penaloza and Yasushi Mae et al [39]. With the help of a Bayes Point Machine learning algorithm module, this system is able to learn and identify errors. This approach makes it possible to reduce the amount of mental exhaustion or stress that may be brought on as a result of continually regulating gadgets using a BMI. Using the electromyogram (EMG) signals that are produced by brow movement over the course of a certain time period, and this device gives individuals the ability to operate equipment inside a hospital room setting (100 − 300 s). By keeping an eye on data from brain sensors and error-related negativity (ERN) signals in addition to user inputs, this system achieves an overall learning performance of over 90% after numerous experimental sessions (such as turning on and off appliances), which involve turning on and off appliances.

To compensate for difficulties with voice and movements, Marco Solis and Kiran George *et al.* [40] have developed a home automation system that makes use of an Open BCI board and is based on auditory steady-state response. The main Arduino, which is also a proximity sensor, serves as the starting point for the system. A tone is produced that is determined, in part, by the physical separation of the body from the sensor. After a tone is produced, an ultra-cortex headset and an Open BCI board are used to record the patient's EEG. (with electrodes). This data is gathered from the subject's brain in certain areas. The processed EEG signals are then utilized to determine the serial command that will be delivered from the processing IDE to a separate Arduino. The speakers will play the appropriate voice instructions according to the serial command that was given. An SD card module records the user's voice commands. The device that is operated by speech (Alexa) listens for these voice instructions and then carries out the action that was supposed to ON fan attached to a smart lamp or smart socket. The findings of the experiment indicate that an individual's ASSR may be used to run the home automation devices in a manner that is both efficient and effective. The application of this suggested system is meant for persons who have disabilities; nevertheless, it is adaptable enough to be used by a larger user base, including those who may not have any impairments.

Using brain-computer interface (BCI) technology, Rui Zhang, Qihong Wang, Kai Li, *et al.* [41] created an ERP-based environmental control system. This innovation provides day-to-day assistance to patients who are paralyzed as a consequence of severe spinal cord injuries (SCIs) by integrating a hospital bed, an intelligent wheelchair, and home electrical gadgets into a single, convenient package. An asynchronous mode may be used to activate or deactivate the environmental control system, or it can be used to choose a device (like a Television) that allows for self-paced control. In order to improve the rate and precision of BCI recognition, a synchronous mode is triggered when the user selects a device function. This occurs anytime the user selects a new feature, like a TV channel, for the device. This mode is activated when the user chooses a device function, enabling it to perform that function. This technique is very reliant on the users' capacity to maintain control over the direction in which they are looking. The results suggest that patients are able to make efficient use of the ERP BCI-based environmental control system. This might be of benefit to completely paralyzed patients who have spinal cord injuries in their day-to-day living.

Anupama A. Ghodake *et al.* [42] employ a mindwave headset to read the user's attention level, which is then sent to a computer to control the fan and light. This system requires a certain threshold value in order for the peripherals to function properly. This approach makes operations simpler, which is advantageous not only to elderly persons but also to individuals with hearing impairments. This configuration requires a high degree of mental focus on the part of the user, which can only be achieved by strong concentration and focused (yet unwavering) mental activity.

A virtual reality brain-computer interface (BCI) system has been designed by Hyun-sang Cho and Jayoung Goo *et al.* [43]. The user is provided with the ability to interact with real-world objects that are often present in the home environment. Motor imagery (such as the human imagination of right- or left-rand movement) brain signals from the EEG device allow users to change right direction or left direction turns in order to maneuver the virtual world and make forward progress with the help of an auxiliary control device, making their system ideal for people with mobility impairments. This system, on the other hand, has a foot pedal that functions as a direction-locking mechanism so that the direction may be locked and unlocked.

Ulrich Hoffmann and Jean-Marc Vesin *et al.* [44] developed a brain-computer interface (BCI) capable of obtaining high classification accuracy and bitrates for people who are either impaired or able-bodied. The P300 evoked potential serves as the foundation for this system. Different electrode arrangements and machine learning classification technique algorithms (such as Fisher's Linear Discriminant Analysis (FLDA) and Bayesian Linear Discriminant Analysis (BLDA)) accuracy were implemented with MATLAB. The EEG signals were initially amplified using two bio semi-active amplifiers., and after the signals had been amplified, they were converted from analog to digital. On the screen of their system, one picture of each appliance was flashed in random sequences at a time, and patients were instructed to count the flashes in their minds silently. If the number of flashes corresponds with the number of flashes counted by the patients, the corresponding appliance will be activated.

Table 4.3: BCI-based brain-controlled home automation and Services

Sl. No.	Waves	Disadvantage
1	Attention level	Patients may suffer from mental fatigue, frustration, or discomfort [42].
2	Imagination level	Users feel fatigued or have cybersickness induced by their unwilling wander in the virtual environment [43].
3	Raw EEG waves	Using of BLDA and FLDA by makes this setup more complex, which takes more time and space to execute. [44].

5. Conclusions and discussions

The home automation model that [20], [21], [24], [25], [26], [27], [28], [29], [31], [32], [33] suggested provides a high-level overview of several smart home development project that is organized according to the services that they are meant to provide. It also examines the relevance of the building blocks of the smart home as well as the constraints of using them. An enlightening analysis of the interrelationships between the various technologies is provided by the taxonomy of media, devices, protocols, algorithms, services, and methodologies. These new versions have the ability to control all of the household appliances from a single location. The degree of convenience offered here is really high. It is a significant step forward for both technology and the administration of homes because users will soon be able to keep all of the technology in their homes linked via a single interface.

But these technical advances will not help persons with severe neuromuscular problems, elderly people, or those who have severe dyskinesia caused by conditions such as amyotrophic lateral sclerosis or spinal cord injury. Individuals who suffer from severe neuromuscular impairments are able to communicate or carry out everyday duties only by utilizing their brain waves, thanks to the BCI system, which makes use of EEG. There are primarily two categories, which are referred to as one-way and two-way BCIs. One-way BCIs can either receive signals from the patient's brain or give signals to the patient, but not both at the same time. Two-way BCIs make it possible for the brain and other devices to communicate with one another in both ways. People who are disabled may now control prosthetic limbs with their minds instead of their hands. Transmitting pictures of the outside world into the mind of a blind individual may give them the ability to sight. It is possible to allow a person who is deaf the ability to hear by sending auditory data to their mind. It gives players the ability to use their thoughts to control the video games they play. It gave mute people the ability to have their ideas displayed on a screen and pronounced aloud by a computer.

Balkis Solehah Zainuddin *et al.* [36] have described many strategies for classifying Alpha and Beta EEG brainwave signals. Zuzana Koudelková *et al.* [37] discusses the frequency-based detection of brain waves. Mahtab Roohi-Azizi *et al.* [36] examines alterations in the bioelectrical activity of the brain in awareness, cognition, and some mental diseases. Noppadon Jatupaiboon *et al.* [37] address Real-Time EEG-Based Happiness Detection. K. Suresh Manic *et al.* [38] have defined several brainwave signals and outlined the process for signal separation. Using the approaches mentioned, various models may be developed to make the everyday lives of disabled patients easier by meeting all of their core needs using their brainwaves.

These disabled impaired individuals are able to engage with the outside world and experience an overall improvement in their quality of life as a result of [39], [40], [41], [42], [43], [44] BCI-based brain-controlled home automation proposal. They utilize signals from the user's attention level or imagination level to control the appliances in their homes using a device called a mindwave headset. The technology that they have presented gives individuals in a medical setting the ability to operate various equipment. The headset may be worn over the head with little effort, and doing so won't do any damage to your hair or ears. As a consequence, this leads to a significant shift in the nature and quality of life experienced by individuals, as well as persons who are handicapped or old. Additionally, as a consequence of this, there will be a rise in the need for consumer electronics products that are capable of being readily interfaced with BCI systems.

References

[1] "Ageing and health", *World Health Organization*, 1 Oct. 2022. [Online]. Available: https://www.who.int/news-room/fact-sheets/detail/ageing-and-health. [Accessed: Oct. 14, 2022]

[2] "World Report on Disability 2011", *World Health Organization*, 14 Dec. 2011. [Online]. Available: https://www.who.int/teams/noncommunicable-diseases/sensory-functions-disability-and-rehabilitation/world-report-on-disability [Accessed: Oct. 1, 2022]

[3] L. C. Wijesekera and P. Nigel Leigh, "Amyotrophic lateral sclerosis," *Orphanet Journal of Rare Diseases*, vol. 4, no. 1, p. 3, Feb. 2009, doi: https://doi.org/10.1186/1750-1172-4-3

[4] S. C. Kirshblum et al., "International Standards for Neurological Classification of Spinal Cord Injury: Cases with classification challenges," *The Journal of Spinal Cord Medicine*, vol. 37, no. 2, pp. 120–127, Mar. 2014, doi: 10.1179/2045772314Y.0000000196

[5] P. Bach-y-Rita, "Brain plasticity as a basis for recovery of function in humans," *Neuropsychologia*, vol. 28, no. 6, pp. 547–554, Jan. 1990, doi: 10.1016/0028-3932(90)90033-K

[6] J. R. Wolpaw and E. W. Wolpaw (Eds.), *Brain-Computer Interfaces: Principles and Practice*, Oxford University Press, 2012.

[7] J. R. Wolpaw *et al.*, "Brain-computer interface technology: a review of the first international meeting," *IEEE Transactions on Rehabilitation Engineering*, vol. 8, no. 2, pp. 164–173, Jun. 2000, doi: 10.1109/TRE.2000.847807.

[8] R. Zhang et al., "A BCI-Based Environmental Control System for Patients With Severe Spinal Cord Injuries," *IEEE Transactions on Biomedical Engineering*, vol. 64, no. 8, pp. 1959–1971, Aug. 2017, doi: 10.1109/TBME.2016.2628861.

[9] R. Lutolf, "Smart Home concept and the integration of energy meters into a home based system," in *Seventh International Conference on Metering Apparatus and Tariffs for Electricity Supply 1992*, Nov. 1992, pp. 277–278. Available: https://ieeexplore.ieee.org/document/187310

[10] V. Berlo, A. Bob, E. Jan, F. Klaus, H. Maik, W. Charles, *Design Guidelines on Smart Homes, A COST 219bis Guidebook*, European Commission, 1999.

[11] B. Winkler, *An implementation of an ultrasonic indoor tracking system supporting the OSGI architecture of the ICTA lab*, Doctoral dissertation, University of Florida, 2002.

[12] D. D. Briere and P. J. Hurley, *Smart homes for dummies*, 2nd ed., New York: Wiley Pub, 2003.

[13] SMART HOME – A DEFINITION, Housing *LIN intro factsheet, Housing Learning & Improvement Network*. [Online]. Avilable: https://www.housinglin.org.uk/_assets/Resources/Housing/Housing_advice/Smart_Home_-_A_definition_September_2003.pdf [Accessed: Feb. 04, 2023]

[14] L. Satpathy, "Smart Housing: Technology to Aid Aging in Place - New Opportunities and Challenges," *M.Sc Thesis, 3967, College of Architecture, Art and Design, Mississippi State University*, August 2006. [Online]. Available: https://scholarsjunction.msstate.edu/td/3967/

[15] S. A. Khoshnevis and R. Sankar, "Applications of Higher Order Statistics in Electroencephalography Signal Processing: A Comprehensive Survey," *IEEE Reviews in Biomedical Engineering*, vol. 13, pp. 169–183, 2020, doi: 10.1109/RBME.2019.2951328.

[16] D. P. Subha, P. K. Joseph, R. Acharya U, and C. M. Lim, "EEG Signal Analysis: A Survey," *J Med Syst*, vol. 34, no. 2, pp. 195–212, Apr. 2010, doi: 10.1007/s10916-008-9231-z

[17] J. R. Wolpaw, "Brain-computer interfaces (BCIs) for communication and control," in *Proceedings of the 9th international ACM SIGACCESS conference on Computers and accessibility*, New York, NY, USA, Oct. 2007, pp. 1–2, doi: 10.1145/1296843.1296845

[18] A. Delorme and S. Makeig, "EEGLAB: an open source toolbox for analysis of single-trial EEG dynamics including independent component analysis," *Journal of*

Neuroscience Methods, vol. 134, no. 1, pp. 9–21, Mar. 2004, doi: 10.1016/j.jneumeth.2003.10.009

[19] J. Kaur and A. Kaur, "A review on analysis of EEG signals," in *2015 International Conference on Advances in Computer Engineering and Applications*, Mar. 2015, pp. 957–960, doi: 10.1109/ICACEA.2015.7164844.

[20] S. K. Das, D. J. Cook, A. Battacharya, E. O. Heierman, and T.-Y. Lin, "The role of prediction algorithms in the MavHome smart home architecture," *IEEE Wireless Communications*, vol. 9, no. 6, pp. 77–84, Dec. 2002, doi: 10.1109/MWC.2002.1160085.

[21] G. M. Youngblood, D. J. Cook, and L. B. Holder, "Managing Adaptive Versatile environments," *Pervasive and Mobile Computing*, vol. 1, no. 4, pp. 373–403, Dec. 2005, doi: 10.1016/j.pmcj.2005.08.004

[22] K. Gopalratnam and D. J. Cook, "Online Sequential Prediction via Incremental Parsing: The Active LeZi Algorithm," *IEEE Intelligent Systems*, vol. 22, no. 1, pp. 52–58, Jan. 2007, doi: 10.1109/MIS.2007.15.

[23] G. M. Youngblood and D. J. Cook, "Data Mining for Hierarchical Model Creation," *IEEE Transactions on Systems, Man, and Cybernetics*, Part C (Applications and Reviews), vol. 37, no. 4, pp. 561–572, Jul. 2007, doi: 10.1109/TSMCC.2007.897341.

[24] H. Noguchi, T. Mori, and T. Sato, "Construction of network system and the first step of summarization for human daily action data in the sensing room," in *Proceedings. IEEE Workshop on Knowledge Media Networking*, Jul. 2002, pp. 17–22, doi: 10.1109/KMN.2002.1115157.

[25] T. Yamazaki, "Beyond the Smart Home," in *2006 International Conference on Hybrid Information Technology*, Nov. 2006, vol. 2, pp. 350–355, doi: 10.1109/ICHIT.2006.253633.

[26] C.-H. Lu and L.-C. Fu, "Robust Location-Aware Activity Recognition Using Wireless Sensor Network in an Attentive Home," *IEEE Transactions on Automation Science and Engineering*, vol. 6, no. 4, pp. 598–609, Oct. 2009, doi: 10.1109/TASE.2009.2021981.

[27] T. Ma, Y.-D. Kim, Q. Ma, M. Tang, and W. Zhou, "Context-aware implementation based on CBR for smart home," in *WiMob'2005, IEEE International Conference on Wireless And Mobile Computing, Networking And Communications*, 2005., Aug. 2005, vol. 4, pp. 112-115 Vol. 4, doi: 10.1109/WIMOB.2005.1512957.

[28] T. Perumal, A. R. Ramli, and C. Y. Leong, "Design and implementation of SOAP-based residential management for smart home systems," *IEEE Transactions on Consumer Electronics*, vol. 54, no. 2, pp. 453–459, May 2008, doi: 10.1109/TCE.2008.4560114.

[29] C.-L. Wu, C.-F. Liao, and L.-C. Fu, "Service-Oriented Smart-Home Architecture Based on OSGi and Mobile-Agent Technology," *IEEE Transactions on Systems, Man, and Cybernetics*, Part C (Applications and Reviews), vol. 37, no. 2, pp. 193–205, Mar. 2007, doi: 10.1109/TSMCC.2006.886997.

[30] Knopflerfish - Open Source OSGi SDK and run-time container [Online]. Avilable: http://www.knopflerfish.org/ [Accessed: Feb. 06, 2023]

[31] A. E. Nikolaidis, S. Papastefanos, G. A. Doumenis, G. I. Stassinopoulos, and M. P. K. Drakos, "Local and remote management integration for flexible service provisioning to the home," *IEEE Communications Magazine*, vol. 45, no. 10, pp. 130–138, Oct. 2007, doi: 10.1109/MCOM.2007.4342828..

[32] J. Yongping, F. Zehao, and X. Du, "Design and Application of Wirless Sensor Network Web Server Based on S3C2410 and Zigbee Protocol," in *2009 International Conference on Networks Security, Wireless Communications and Trusted Computing*, Apr. 2009, vol. 2, pp. 28–31, doi: 10.1109/NSWCTC.2009.404.

[33] C.-Y. Chen, Y.-P. Tsoul, S.-C. Liao, and C.-T. Lin, "Implementing the design of smart home and achieving energy conservation," in *2009 7th IEEE International Conference on Industrial Informatics*, Jun. 2009, pp. 273–276, doi: 10.1109/INDIN.2009.5195816.

[34] B. S. Zainuddin, Z. Hussain, and I. S. Isa, "Alpha and beta EEG brainwave signal classification technique: A conceptual study," in *2014 IEEE 10th International Colloquium on Signal Processing and its Applications*, Mar. 2014, pp. 233–237, doi: 10.1109/CSPA.2014.6805755.

[35] Z. Koudelková and M. Strmiska, "Introduction to the identification of brain waves based on their frequency," *MATEC Web Conf.*, vol. 210, p. 05012, 2018, doi: https://www.matec-conferences.org/10.1051/matecconf/201821005012

[36] M. Roohi-Azizi, L. Azimi, S. Heysieattalab, and M. Aamidfar, "Changes of the brain's bioelectrical activity in cognition, consciousness, and some mental disorders," Medical Journal of The Islamic Republic of Iran (MJIRI), vol. 31, no. 1, pp. 307–312, Dec. 2017. Available: https://mjiri.iums.ac.ir/article-1-4337-en.html

[37] N. Jatupaiboon, S. Pan-ngum, and P. Israsena, "Real-Time EEG-Based Happiness Detection System," *The Scientific World Journal*, vol. 2013, pp. 1–12, 2013, doi: 10.1155/2013/618649

[38] K. S. Manic, A. Saadha, K. Pirapaharan, and Aravind CV. "Characterisation and separation of brainwave signals." *Journal Of Engineering Science And Technology, EURECA (2014)*, pp. 32-44. Available: https://www.researchgate.net/publication/292544490_Characterisation_and_separation_of_brainwave_signals

[39] C. I. Penaloza, Y. Mae, F. F. Cuellar, M. Kojima, and T. Arai, "Brain Machine Interface System Automation Considering User Preferences and Error Perception Feedback," *IEEE Transactions on Automation Science and Engineering*, vol. 11, no. 4, pp. 1275–1281, Oct. 2014, doi: 10.1109/TASE.2014.2339354.

[40] V. K. K. Shivappa, B. Luu, M. Solis, and K. George, "Home automation system using brain computer interface paradigm based on auditory selection attention," in *2018 IEEE International Instrumentation and Measurement Technology Conference (I2MTC)*, May 2018, pp. 1–6, doi: 10.1109/I2MTC.2018.8409863.

[41] R. Zhang *et al.*, "A BCI-Based Environmental Control System for Patients With Severe Spinal Cord Injuries," IEEE Transactions on Biomedical Engineering, vol. 64, no. 8, pp. 1959–1971, Aug. 2017, doi: 10.1109/TBME.2016.2628861.

[42] A. A. Ghodake and S. D. Shelke, "Brain controlled home automation system," in *2016 10th International Conference on Intelligent Systems and Control (ISCO)*, Jan. 2016, pp. 1–4, doi: 10.1109/ISCO.2016.7727050.

[43] H. Cho, J. Goo, D. Suh, K. S. Park, and M. Hahn, "The Virtual Reality Brain-Computer Interface System for Ubiquitous Home Control," in *AI 2006: Advances in Artificial Intelligence*, Berlin, Heidelberg, 2006, pp. 992–996, doi: 10.1007/11941439_110.

[44] U. Hoffmann, J.-M. Vesin, T. Ebrahimi, and K. Diserens, "An efficient P300-based brain–computer interface for disabled subjects," *Journal of Neuroscience Methods*, vol. 167, no. 1, pp. 115–125, Jan. 2008, doi: 10.1016/j.jneumeth.2007.03.005

Authors' Profiles

Er. Rajesh Rishi is pursuing M.Tech (EEE) at Assam Don Bosco University, India. He received his graduation degree in B.Tech (EEE) from the same university (India) in 2021. His fields of interest are smart grid control, renewable energy, power quality, microgrid, electrical machines and drives, and sensor-less motor control. He is also interested in microcontrollers, IoT, electroencephalography (EEG), and artificial intelligence.

Dr. Shakuntala Laskar is presently working as Professor in the Electrical and Electronics Engineering Department, School of Technology, Assam Don Bosco University, Assam-781017. She received her bachelor degree in Electrical Engineering from Assam Engineering College, Guwahati University, and M.Tech and Ph.D. degrees from IIT Kharagpur. Her research interest includes electro-optics and optical sensors.sensor based instrumentation