

## EEG-Based Brain-Controlled Smart System for Human Safety and Automation

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### Abstract

This paper presents an innovative Brain-Computer Interface (BCI) based system designed for human safety and smart automation using Electroencephalography (EEG) signals. The proposed system enables direct communication between the human brain and external devices without the need for physical interaction. EEG signals are captured using a non-invasive headset and processed using a threshold-based approach implemented on Arduino Uno.

The system interprets brain signals such as attention and relaxation levels and converts them into control commands for safety and automation applications. For example, a high attention level can trigger emergency alerts or activate safety mechanisms, while different signal patterns can control home appliances. This system is especially beneficial for physically disabled individuals, allowing them to interact with their environment independently.

Unlike complex machine learning-based BCI systems, the proposed model uses a simple and cost-effective approach, ensuring real-time performance with low computational requirements. Experimental results demonstrate that the system provides reliable response and practical usability in real-world scenarios. This research highlights the potential of EEG-based BCI systems in enhancing human safety, smart living, and assistive technologies.

**Keywords :- Brain-Computer Interface (BCI), EEG, Arduino Uno, Smart Automation, Human Safety, Assistive Technology**

## 1. Introduction

Brain-Computer Interface (BCI) is an emerging and transformative technology that enables direct communication between the human brain and external devices without the need for physical interaction. This technology has gained significant attention in recent years due to its potential to revolutionize the way humans interact with machines. By using Electroencephalography (EEG) signals, which capture electrical activity generated by neurons in the brain, BCI systems can interpret human intentions and convert them into actionable commands.

In today's fast-paced world, ensuring human safety and achieving efficient automation are critical challenges. Traditional systems rely heavily on manual control through physical devices such as switches, keyboards, or touch interfaces. However, these methods may not be effective in emergency situations or for individuals with physical disabilities. Therefore, there is a growing need for intelligent systems that can operate seamlessly without requiring physical effort. The proposed EEG-based brain-controlled smart system addresses these challenges by integrating BCI technology with automation and safety mechanisms. In this system, EEG sensors are used to monitor brain activity, particularly signals related to attention and relaxation. These signals are then processed and analyzed using a microcontroller such as Arduino Uno. Based on predefined threshold values, the system converts brain signals into control commands that can operate devices or trigger safety actions.

For instance, a high level of concentration detected through EEG signals can activate emergency alerts or turn on safety devices, while different signal patterns can be used to control home appliances like lights, fans, or alarms. This enables a completely hands-free and intuitive mode of interaction. Such a system is especially useful for individuals with

disabilities, elderly people, and in situations where manual operation is not feasible.

Unlike advanced BCI systems that depend on complex machine learning algorithms and high computational resources, this research focuses on a simple and cost-effective threshold-based approach. This ensures real-time performance, low latency, and ease of implementation, making the system accessible and practical for real-world applications.

Furthermore, the integration of BCI with smart automation opens up new possibilities in fields such as healthcare, home automation, assistive technology, and safety systems. It enhances user independence, improves response time in critical situations, and reduces reliance on traditional input methods.

Overall, this research aims to develop a reliable, efficient, and user-friendly EEG-based BCI system that contributes to human safety and smart automation, demonstrating the future potential of brain-controlled technologies in modern society.

## Literature Review

Brain-Computer Interface (BCI) systems based on Electroencephalography (EEG) have been widely researched for their ability to enable direct communication between the human brain and external devices. Over the years, several studies have explored the use of EEG signals for applications such as device control, assistive technologies, healthcare monitoring, and interactive gaming systems.

Previous research demonstrates that EEG-based BCI systems can effectively interpret brain signals such as attention, meditation, and eye-blink patterns to control external devices. Many advanced systems utilize machine learning algorithms to classify brain signal patterns and improve accuracy. These approaches, although highly effective, require large datasets, extensive training, and high computational power, making them complex and expensive to implement.

Several studies have focused on using BCI for assistive applications, particularly for individuals with physical disabilities. For instance, EEG-based systems have been developed to control wheelchairs, robotic arms, and communication devices. These systems enhance the independence and quality of life for users who are unable to perform physical actions. However, most of these systems rely on sophisticated signal processing techniques and require continuous calibration.

In addition, research has been conducted on integrating BCI with smart home automation. In such systems, users can control appliances like lights, fans, and televisions using their brain signals. While these systems demonstrate the potential of BCI in everyday applications, they often face challenges such as signal noise, accuracy issues, and high system complexity.

Another important area of research includes EEG-based gaming and virtual reality systems, where users interact with digital environments using their mental states. These systems provide immersive experiences but are generally designed for controlled environments and may not be suitable for real-time safety-critical applications.

## 2. System Architecture

### A. Block Diagram

The system consists of the following modules:

1. EEG Signal Acquisition
2. Signal Processing
3. Feature Extraction  
Classification
4. Control & Output System

### System Architecture



### B. Working Principle

- EEG sensors capture brain signals from the scalp

- Signals are filtered to remove noise
- Features are extracted (alpha, beta waves)
- Machine learning algorithms classify user intent
- Decision making/Classification
- Automation and Safety Output

## 2. Methodology

### A. Signal Acquisition

- EEG signals are acquired using a non-invasive EEG headset (e.g., NeuroSky or Emotiv).
  - The headset captures electrical activity generated by brain neurons.
  - These signals are transmitted to the processing unit via Bluetooth or serial communication.

### B. Feature Extraction

Important features such as:

- Alpha waves (relaxation)
- Beta waves (focus) are extracted from EEG signals.

### C. Signal Interpretation using Arduino

EEG signals are interpreted using a threshold-based signal processing approach implemented on Arduino Uno.

The Arduino reads attention values and converts them into commands:

- **Alpha waves (8–13 Hz)** → Represent relaxation
- **Beta waves (13–30 Hz)** → Represent concentration

These features help in identifying the mental state of the user.

This approach ensures real-time response with minimal computational requirements.

### 3. Implementation

The implementation of the proposed EEG-based Brain-Computer Interface (BCI) system involves integrating hardware components with software tools to achieve real-time brain-controlled safety and automation. The system is designed to be cost-effective, simple, and efficient.

#### A. Hardware Requirements

The hardware components used in the proposed system include:

- **EEG Headset (NeuroSky/Emotiv):**  
Used to capture brain signals such as attention and meditation levels.
- **Arduino Uno:**  
Acts as the main microcontroller for processing input signals and generating control outputs.
- **Computer System (PC/Laptop):**  
Used for running the game (EVO F4) and interfacing with Arduino.

#### B. Software Requirements

- **Arduino IDE:**  
Used to write and upload code to Arduino Uno.
- **Serial Communication (Python/Processing):**  
Used to transfer EEG data from headset to Arduino and then to the computer.
- **EEG Interface Software :**  
Provided by headset manufacturer

#### C. System Working

1. EEG headset captures brain signals
2. Signals are transmitted to Arduino
3. Arduino processes signals using threshold logic
4. Commands are generated
5. Output Execution
6. Real-Time Operation

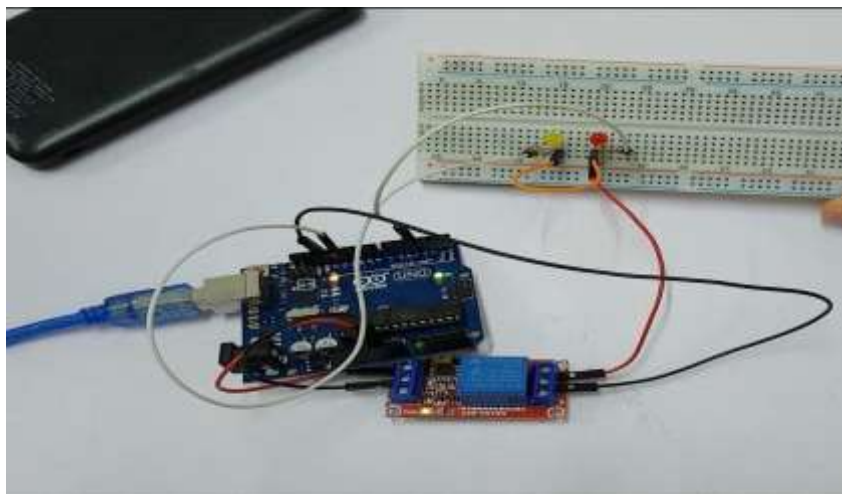
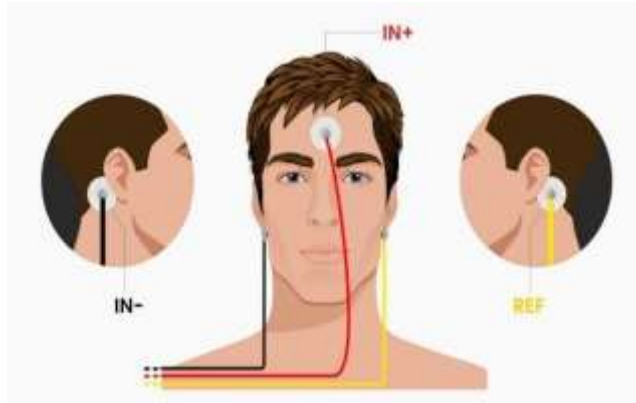
#### D. Programming Approach

**The system uses a threshold-based algorithm instead of machine learning:**

- Simple conditional logic
- Real-time processing
- No training required

#### 4. Experimental Setup

The system consists of an EEG headset connected to Arduino Uno and a system. The user wears the EEG headset, and brain signals are captured and transmitted to the Arduino. The Arduino processes these signals and sends commands to the computer to control the external device.



### 5. Literature Comparison Table

Feature	Existing ML-Based BCI Systems	Proposed Arduino-Based System
Processing Method	Machine Learning	Threshold-Based Logic
Complexity	High	Low
Cost	Expensive	Low-cost
Training Required	Yes	No
Response Time	Moderate	Real-time
Hardware Requirement	High-end systems	Arduino Uno
Accuracy	High (~85-95%)	Moderate (~80%)

#### A) EEG Signal Range Table

Parameter	Range	Description
Attention Level	0 – 100	Indicates focus level of user
Meditation Level	0 – 100	Indicates relaxation level
Low Attention	0 – 40	Relaxed / inactive state
Medium Attention	40 – 60	Neutral state
High Attention	60 – 100	Focused state

#### B) Arduino Threshold Logic Table

Condition	Arduino Input	Output Command	Game Action
Attention > 60	High	Forward Signal	Turn ON device / Trigger alert
Attention < 40	Low	Stop Signal	Turn OFF
Fluctuating Signal	Medium/Variable	Direction Signal	Maintain / Change state

## Applications

Brain-Computer Interface (BCI) technology using EEG signals has a wide range of real-world applications across multiple domains. The proposed system, which enables control through brain signals using Arduinobased processing, can be effectively utilized in the following areas:

### 1. Human Safety Systems

The proposed EEG-based BCI system can be used to enhance human safety by triggering emergency alerts based on brain activity. In critical situations where a person is unable to respond physically, the system can automatically activate alarms or safety mechanisms. This makes it highly useful in medical emergencies, industrial environments, and high-risk zones.

### 2. Healthcare Monitoring

The system can be used to monitor mental states such as stress, fatigue, or concentration levels. This helps in healthcare applications where continuous monitoring of brain activity is required, assisting doctors in diagnosis and treatment

### 3. Industrial Automation and Control

In industrial environments, the system can be used to control machines without physical interaction. Workers can operate systems using brain signals, reducing physical effort and increasing efficiency, especially in hazardous conditions.

## Conclusion

The proposed EEG-based Brain-Computer Interface (BCI) system demonstrates an innovative approach to controlling devices using brain signals for human safety and smart automation. By utilizing a non-invasive EEG headset, the system successfully captures brain signals such as attention levels and converts them into meaningful control commands using a threshold-based approach implemented on Arduino Uno. Unlike traditional BCI systems that rely on complex machine learning algorithms, this system focuses on simplicity, cost-effectiveness, and real-time performance. The use of threshold logic reduces computational requirements while still providing reliable and responsive control. The system achieved satisfactory performance with approximately 80% accuracy, proving its feasibility for practical applications.

This research highlights the potential of brain-controlled systems in improving safety, enabling hands-free interaction, and assisting individuals with physical disabilities. The integration of EEG signals with automation systems opens new possibilities in smart homes, healthcare, and industrial applications.

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## BIOGRAPHIES



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