NEURO-SKY BASED BRAIN COMPUTER INTERFACE FOR HANDS-FREE DRONE FLIGHT CONTROL

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Keywords:

Brain–Computer Interface, EEG Signals, Autonomous Drone, Robotics, Embedded Systems.

Introduction:

1. Recent advancements in robotics and embedded systems have enabled the development of intelligent machines capable of performing complex tasks. However, most existing systems rely heavily on manual interfaces such as joysticks, controllers, or touch-based inputs. This limits usability in situations where physical interaction is difficult or unsafe.
2. Brain–Computer Interface (BCI) technology offers a promising solution by enabling direct communication between human cognitive signals and machines. EEG-based systems can capture brainwave patterns and convert them into actionable commands, eliminating the need for physical control.
3. This project focuses on the development of a **thought-controlled nano-drone** using non-invasive EEG signals. The system integrates NeuroSky MindWave Mobile 2 for signal acquisition, ESP32 for processing, and MPU6050 for stabilization. The drone serves as a proof-of-concept platform demonstrating real-time cognitive control.
4. The work is significant as it explores practical implementation of BCI in **robotics and industrial automation**, where human intent can directly control machines. This approach has potential applications in assistive technology, hazardous environments, and next-generation human–machine interaction systems.

Objectives:

1. To Acquire brain signals based on subject attention using the EEG signal capturing device.
2. To Analyze single-channel EEG (attention) with basic hardware filtering and shielding.
3. To Map detected mental states (e.g., focused, blink, relaxed) to core drone actions: take-off, land, move, hover, emergency stop.

Methodology:

1. The system begins with the acquisition of EEG signals using the NeuroSky MindWave Mobile 2 headset. The headset captures attention-based brainwave data and transmits it wirelessly via Bluetooth to the ESP32 microcontroller.
2. The ESP32 acts as the central processing unit, decoding incoming EEG data using the ThinkGear protocol. A threshold-based algorithm is implemented to detect significant attention levels and trigger drone activation.
3. An MPU6050 inertial measurement unit is interfaced with the ESP32 through the I^2C protocol to provide real-time orientation data such as pitch and roll. This data is processed using complementary filtering techniques.
4. PID control algorithms are implemented to ensure stability and balance of the drone during flight. Based on sensor feedback, the ESP32 generates PWM signals to control motor speed.
5. Two dual-channel motor driver modules are used to drive four brushed DC motors mounted on a nano-drone frame. The motors are arranged in a quadcopter configuration to enable controlled lift and balance.
6. The system is powered using a 3.7V Li-Po battery, with careful power management to ensure stable operation. The project is developed in stages, including component testing, sensor calibration, PID tuning, and full system integration.

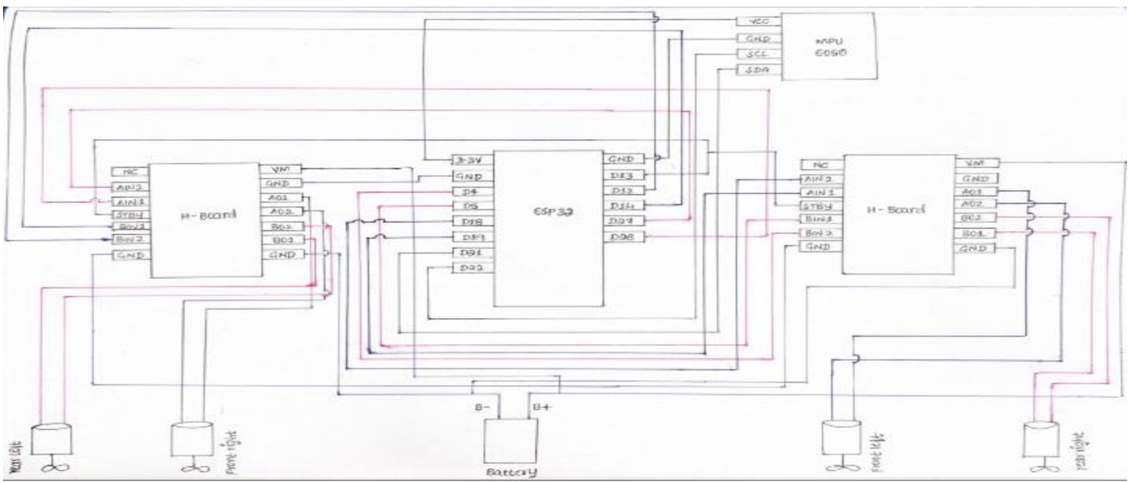

Fig 1.1 Complete circuit diagram of the working model.

Result and Conclusion:

1. In conclusion, the developed system successfully demonstrates the feasibility of controlling a drone using EEG attention signals. The ESP32 reliably processes brainwave data and triggers drone lift-off based on predefined thresholds.
2. The integration of MPU6050 and PID control ensures stable flight and balanced motor operation. Experimental testing confirms that the system can achieve hands-free activation and controlled hovering.
3. The results validate that non-invasive BCI systems can be effectively integrated with embedded drone platforms. This project proves that thought-driven control is practically achievable using low-cost hardware.

Project Outcome & Industry Relevance:

1. The project results in a working prototype of a **brain-controlled drone system**, demonstrating real-time interaction between human cognition and robotic systems.
2. It has strong relevance in industries such as **robotics, automation, defense, and healthcare**. In industrial environments, similar systems can be used for supervisory control of robotic arms without physical interaction.
3. The concept is also applicable in assistive technology, enabling differently-abled individuals to control machines using brain signals. It aligns with Industry 4.0 and future human–machine interaction systems.

Project Outcomes and Learnings:

1. The project successfully demonstrates EEG-based drone control and real-time stabilization. Key learnings include EEG signal processing, embedded system design, sensor integration, and PID-based control.
2. The project also provided experience in hardware integration, debugging, and system-level design. It enhanced understanding of human–machine interaction and real-time robotics.

Future Scope:

The future scope of this project includes:

1. Future work includes extending the system for full directional control using EEG signals combined with machine learning techniques. Advanced signal processing methods can improve accuracy and reliability.
2. The system can be integrated with robotic arms for industrial automation, enabling thought-based initiation of tasks. Integration with IoT systems can enable smart environment control.
3. Further development can include AI-based classification of brain signals, improving responsiveness and enabling multi-command control. The concept can also be expanded for applications in medical rehabilitation, defense systems, and smart manufacturing.