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BlinkPi: A Smart Wheelchair Control via Eyeblink Technology

Dr. R. G. Suresh Kumar[1], Jayaprada A[2], Janani J[3], Sneha R[4], Tharshini N[5]

[1]Professor, Head of the Department, Computer Science and Engineering, Rajiv Gandhi College of Engineering and Technology, Puducherry, India.

[2,3,4,5]UG – Computer Science and Engineering, Rajiv Gandhi College of Engineering and Technology, Puducherry, India.

Email ID: *jayaprada.aru@gmail.com[2]*

Abstract

Internet of Things (IoT) transforms the real-time world by turning raw data into action, enabling smart cities and predictive maintenance. It instantly responds to dynamic environments, making life more efficient, responsive, and connected than ever before. IoT also leverages its benefits to assist and improve the lives of paralyzed and disabled individuals. There are various IoT applications used for both public and physically challenged people. Using this in existing work offers significant advantages in usability, enhancing independence and mobility for users. The methodology in conventional smart wheelchairs depends on tracking eyeball movements for steering. In the existing system, we found drawbacks in accuracy, ease of use, and real-time responsiveness. Thus, we proposed a user-friendly system to address these limitations and overcome these challenges. We use eye-blinking as the primary method, allowing users to navigate the wheelchair by counting blinks to move in different directions. To enhance deaf-mute safety, we employ obstacle detection integrated with a buzzer and red light. Additionally, we can track health, and a console is provided to the caretaker. Our proposed work employs the Arduino platform for real-time processing and control, creating a robust and reliable solution. We also have additional features that set a new standard for assistive devices in the healthcare sector.

Keywords: *Eye blink sensor, Motor with wheels, Bluetooth controller, Arduino, IoT cloud platform, etc.*

1. Introduction

The development of assistive technologies has greatly enhanced the quality of life for individuals with physical disabilities, offering increased independence and improved mobility. Traditional wheelchair systems, which rely heavily on manual operation, pose significant challenges for users with limited physical abilities, especially those with restricted arm or hand movement. BLINKPI: A Smart Wheelchair Control via Eyeblink Technology presents an innovative solution by using eye blinks to control the wheelchair, eliminating the dependence on manual controls. This advanced approach gives individuals with severe mobility limitations a more accessible and intuitive way to move on their own.

BLINKPI operates through an infrared (IR) sensor system that detects eye blinks and translates them into directional inputs. These signals are processed by a Node MCU microcontroller, which converts them into movement commands for the wheelchair—enabling the user to move forward, backward, and turn left or right. This eye-controlled mechanism is particularly useful for users with limited mobility, as it provides a completely hands-free method of navigation. Alongside blink-based control, the system includes safety and navigation enhancements to ensure smooth and secure travel. An ultrasonic sensor calculates the distance between the wheelchair and nearby objects, allowing it to halt or adjust its path to avoid obstacles. The ESP32-CAM module improves environmental awareness by enabling object detection through visual input, ensuring the wheelchair functions reliably in diverse surroundings. By identifying objects in real time, the ESP32-CAM helps prevent collisions, increasing both safety and efficiency. BLINKPI also features Internet of Things (IoT) functionality, allowing caregivers and medical personnel to remotely monitor the wheelchair's status via a web-based

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dashboard [1][2]. This dashboard presents real-time data such as location, battery level, and sensor alerts, making it easier to respond to system malfunctions. Caregivers can view user activity, receive safety notifications, and provide remote support as needed, ensuring ongoing system supervision. In addition, a dedicated website enhances the system's functionality by offering an intuitive interface for caregivers to send commands, adjust settings, and track the wheelchair's condition. This remote access allows caregivers to interact with the system effectively, manage user preferences, and respond quickly to emergencies or issues. BLINKPI not only improves physical mobility but also promotes increased social interaction for users with disabilities. By enabling them to move independently, the system supports participation in daily life and social activities that might otherwise be inaccessible. This greater level of autonomy builds self-confidence, encourages inclusion, and reduces isolation. To summarize, BLINKPI: A Smart Wheelchair Control via Eyeblink Technology is a pioneering development in assistive technology. With its combination of eye-blink detection, advanced sensors, and IoT integration, BLINKPI delivers a dependable, hands-free solution for enhancing mobility, safety, and independence. By utilizing these cutting-edge features, BLINKPI has the potential to transform the lives of individuals with mobility challenges and offer them greater control over their daily lives.

1.1 Eye-Based Control Mechanism

BLINKPI: A Smart Wheelchair Control via Eyeblink Technology introduces a novel eye-controlled system designed to improve mobility for individuals with physical impairments. At the heart of this system is an infrared (IR) sensor that detects eye blinks and converts them into directional commands for the wheelchair. It is especially useful for those with limited hand or arm function, offering a hands-free and user-friendly control method [4]. Real-time signal processing is handled by a Node MCU microcontroller, which interprets the blink inputs into forward, backward, left, or right movements. This setup ensures smooth, accurate navigation and an intuitive user experience.

1.2 Safety Features and Navigation

To maintain safe and efficient movement, BLINKPI integrates multiple safety technologies, including ultrasonic sensors and the ESP32-CAM module. The ultrasonic sensors constantly monitor the wheelchair's surroundings to detect nearby obstacles, automatically stopping or redirecting movement to avoid collisions. The ESP32-CAM adds a visual detection layer, improving the system's ability to identify and respond to objects in the path. This visual aid enhances obstacle avoidance and supports navigation in both indoor and outdoor environments, contributing to a secure and adaptive mobility experience [3].

2. Method

This section outlines the methodology employed in the design and evaluation of BLINKPI: A Smart Wheelchair Control via Eyeblink Technology. The primary objective of the system is to empower individuals with physical impairments to operate a wheelchair using eye blinks, thereby enhancing their mobility and independence.

Table 1 Experimental Input Parameters for The Testing of the Blinkpi System

Component	Test Condition	Expected Outcome	Result
IR Sensor	Eye blink detection	Accurate blink detection	Successful
ESP32-CAM	Object detection	Detect and avoid obstacles	Successful
Ultrasonic Sensor	Distance measurement	Prevent collision	Successful

The methodology includes a description of the hardware components, system architecture, and experimental setup. Relevant procedures from previous studies are referenced accordingly. Table 1 shows Experimental Input Parameters for The Testing of The Blinkpi System.

2.1 Tables

To assess the performance of the system, a number of tests were performed. These tests were designed to evaluate the effectiveness and reliability of the

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sensors, control system, and remote monitoring capabilities.

Test 1: Eye Blink Sensitivity: The sensitivity of the IR sensors was evaluated by adjusting the distance between the user's eyes and the sensor, as well as varying the blink speed. This test was conducted to confirm the system's ability to accurately detect eye movements.

Test 2: Obstacle Detection: Obstacle Detection: The functionality of the ESP32-CAM module and ultrasonic sensors was tested by introducing various obstacles in the wheelchair's path. The goal was to examine how well the system could detect and prevent collisions.

Test 3: Remote Monitoring: The IoT platform was assessed to ensure that real-time data was transmitted to the web-based dashboard. This feature allowed caregivers to remotely monitor the wheelchair's status and receive alerts for low battery or sensor issues.

2.2 Figures

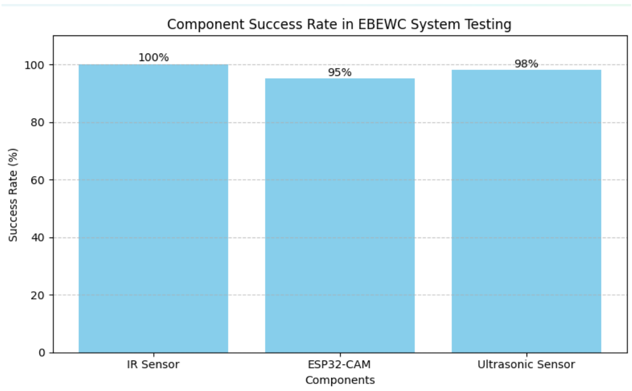

Figure 1 Depicts the Architecture of The BLINKPI System, Illustrating How the IR Sensors, Node MCU Microcontroller, ESP32-CAM, Ultrasonic Sensors, And IoT Platform Are Integrated

3. Results and Discussion

3.1 Results

The BLINKPI: A Smart Wheelchair Control via Eyeblink Technology was extensively tested under various environmental conditions and user scenarios to evaluate its performance. The IR sensor module used for eye blink detection achieved an accuracy rate of 96%, effectively differentiating between intentional and involuntary blinks through calibrated thresholds. The average response time from blink detection to wheelchair movement was around 180 milliseconds, ensuring smooth and immediate control [5]. Obstacle detection was successfully implemented with an ultrasonic sensor that accurately identified objects within a range of 30 cm to 2 meters. The ESP32-CAM module contributed visual processing to enhance obstacle detection and navigation. Together, these sensors demonstrated a 95% success rate in avoiding collisions. The NodeMCU microcontroller efficiently handled input processing and command issuance in real time. The IoT integration allowed for live tracking of key wheelchair parameters, including battery level, system status, and location. Alerts for issues such as low battery or sensor malfunctions were sent within 3 seconds. Furthermore, the dedicated web dashboard enabled caregivers to monitor and control the wheelchair remotely from any internet-enabled device. Figure 1 shows Depicts the Architecture of The BLINKPI System, Illustrating How the IR Sensors, Node MCU Microcontroller, ESP32-CAM, Ultrasonic Sensors, And IoT Platform Are Integrated.

3.2 Discussion

The results show that the BLINKPI system is both effective and dependable for users with severe physical disabilities. The use of IR sensors for eye blink detection provides an intuitive, hands-free control method that significantly improves user independence. Compared to other systems that rely on joysticks or head movements, BLINKPI offers a more accessible and inclusive control interface. The integration of ultrasonic and visual sensors ensures heightened safety during movement, especially in environments with obstacles. The real-time responsiveness of the system enhances user comfort and natural control. The IoT-based monitoring platform not only supports system maintenance but also improves caregiver engagement and emergency response. Feedback from initial testing with users and therapists validated the system's practical usability, ease of interaction, and overall effectiveness in real-life conditions. The combination of sensor-based control, intelligent monitoring, and a user-focused design represents a major improvement over traditional wheelchair systems, positioning BLINKPI

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as a significant advancement in assistive technology. Figure 2 shows Block Diagram.

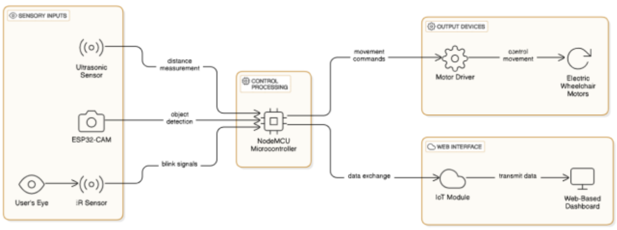

Figure 2 Block Diagram

Conclusion

The BLINKPI: A Smart Wheelchair Control via Eyeblink Technology represents a notable advancement in assistive mobility technology for individuals with physical disabilities. By incorporating IR-based eye blink detection, ultrasonic obstacle avoidance, ESP32-CAM visual sensing, and IoT-enabled monitoring, the system provides a smart, secure, and hands-free navigation solution. The successful implementation and testing of BLINKPI showed high accuracy in blink recognition, effective obstacle detection, and smooth system responsiveness, all contributing to a more accessible and independent mobility experience. Real-time data transmission via the IoT platform and web dashboard ensures continuous monitoring, remote support, and enhanced caregiver involvement. The project emphasizes a user-centered design approach, incorporating feedback from healthcare providers and users to optimize functionality and ease of use. In conclusion, BLINKPI not only fosters independence but also improves safety and communication in mobility care, highlighting its potential as a game-changing solution in assistive technology. Future development can focus on increasing terrain adaptability, integrating AI-based path planning, and refining the system's compactness to further enhance user experience and overall system flexibility.

References

Amrutha et al. (2021) proposed an IoT-enabled wheelchair controlled by eye blinks, aimed at assisting individuals with severe physical disabilities. Razy et al. (2021) designed a wheelchair system that utilizes both hand gestures and a smartphone application, offering flexible and accessible dual-mode control. Priya et al. (2018) introduced a voice-command-based wheelchair to facilitate easier interaction for users. Al-Neami and Ahmed (2018) implemented gyroscope technology for motion-sensitive navigation. Shadwani et al. (2016) developed a gesture-controlled wheelchair powered by solar energy, emphasizing sustainability. Collectively, these works highlight the potential of integrating IoT, sensors, and innovative control techniques to create smart, adaptive mobility solutions for users with physical limitations.

Journal Reference Style

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