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Wireless Assistive Communication Using Head Gestures and Voice Alerts for Paralyzed Patients

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Abstract: The development of innovative communication systems for individuals with severe mobility impairments has made significant progress. This wireless system uses head movement detection, powered by ESP-32 accelerometers, to capture subtle gestures and translate them into predefined commands. These commands are transmitted wirelessly to a receiver, activating a speech alert system that allows effective communication. This solution greatly enhances the quality of life for individuals with paralysis by offering a reliable, intuitive, and non-invasive means of interaction. It reduces dependence on caregivers and promotes greater independence. Beyond communication, the system can also be adapted for home automation, making it a versatile tool for daily living. Designed to meet the critical needs of users with conditions such as ALS, spinal cord injuries, or strokes, the system fills a crucial gap in assistive technology. Its user-friendly, cost-effective design empowers users to express themselves, make decisions, and interact meaningfully with others. Ultimately, this system not only meets a practical need but also advances the field of assistive technology by restoring dignity and autonomy to those with disabilities.

Keywords: Assistive Technology, Speech Alert System, Mobility Impairments, Paralysis, Spinal Cord Injury, Non-invasive Interface, Human-Computer Interaction formatting.

I. INTRODUCTION

The Wearable Automatic Assistance Glove is designed to help individuals with speech and mobility impairments request help without needing to speak. People affected by conditions like stroke, paralysis, or ALS often struggle to communicate, especially during emergencies. Existing tools like mobile apps or call buttons can be difficult to use for those with limited hand movement. This glove addresses that challenge by using a simple gesture-based system—such as touching the thumb to a finger or pressing a small switch—to send alerts.

The glove includes both sound and visual alerts, using a buzzer and an LCD display, ensuring that caregivers can respond quickly in hospitals, care homes, or private residences. It is lightweight, comfortable to wear for long periods, and made using low-cost, widely available electronic components, making it both practical and affordable.
The main objectives are:
To provide a simple and accessible communication method for users with limited mobility.
To ensure reliable alerts through both sound and visual signals.
To prioritize comfort for extended wear.
To keep the design cost-effective.
To enhance user safety and reduce reliance on constant supervision.
To allow future integration with smart home systems, mobile apps, and AI-based gesture recognition.
By achieving these goals, the Wearable Automatic Assistance Glove contributes meaningfully to assistive technology, supporting greater independence, safety, and dignity for users with physical disabilities

II. LITERATURE SURVEY

Craig, D. A. et al. (2005) [1] developed a wireless real-time head movement system using a PDA to control a power wheelchair. The system incorporates artificial intelligence on an embedded LINUX OS to improve usability and independence for individuals with mobility impairments. Ben-Youssef et al. (2014) [2] proposed a speech-driven

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talking head system utilizing estimated articulatory features to facilitate communication for those with severe mobility impairments. Izzuddin, T. A. et al. (2015) [3] introduced a movement intention detection system using neural networks aimed at supporting quadriplegic assistive machines. Kanagasabai, P. S. et al. (2016) [4] developed a BCI learning system using EEG signals, enabling quadriplegic users to interact with computers and devices via brain activity. Sadoughi and Busso (2018) [5] presented a speech-driven head movement generation system using GANs for realistic motion synthesis. C. M. Asad et al. (2018) [6] proposed a hands-free interface controlled by head movements and voice commands, employing the AdaBoost algorithm for motion detection. M. E. Alam et al. (2019) [7] introduced a multi-controlled semi-autonomous wheelchair integrating joystick, voice recognition, and obstacle detection for elderly and physically challenged individuals.

Kader et al. (2019) [8] implemented a head motion-controlled semi-autonomous wheelchair for quadriplegic patients using a 3-axis accelerometer. Sun et al. (2019) [9] presented a phasor measurement-based method for distribution line parameter identification using a novel algorithm. Otsuka and Tsumori (2020) [10] examined head movement multifunctionality in face-to-face communication via deep CNNs, aiding individuals with mobility impairments. Rustagi, S. et al. (2020) [11] developed a touchless typing interface based on head gestures, using a smartphone camera and a bidirectional GRU model. T. Prajwal et al. (2021) [12] designed a head motion-controlled wheelchair using tilt sensors and wireless modules to convert head gestures into navigation commands.

III. SYSTEM DESIGN

The core functionality of the glove is based on touch-activated input. When the user touches a specific finger with their thumb or presses a designated switch, the system is triggered. This action activates a buzzer for five seconds to alert nearby individuals and simultaneously displays the name of the requested item on an LCD screen in fig 1 for ten seconds. The design in prioritizes intuitiveness and responsiveness, making it suitable for users with varying levels of mobility.

The Wearable Automatic Assistance Glove is designed to help individuals with speech or mobility impairments communicate non-verbally through a two-part system: a transmitter glove unit and a receiver display unit. The glove, worn by the user, contains multiple push buttons linked to predefined requests.

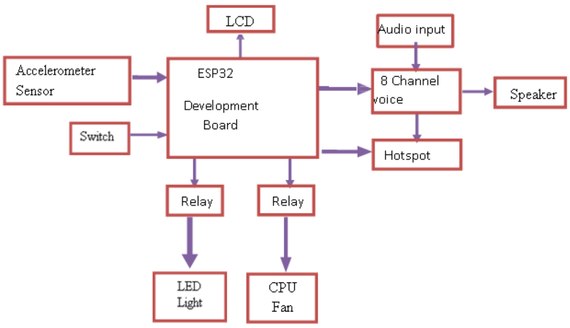

Fig 1: Block diagram of the system

When a button is pressed, the HT12E encoder converts the signal into serial data, which is transmitted via a Bluetooth module. Powered by a 3.7V rechargeable battery, the glove remains lightweight and portable. The receiver unit, powered by a 12V adapter regulated down to 5V using a 7805voltage regulator, consists of a Bluetooth receiver, Arduino Uno microcontroller, a buzzer, and a 16×2 LCD display. Upon receiving the signal, the Arduino triggers the buzzer for auditory alert and displays the request on the LCD for visual notification. This architecture ensures real-time, wireless communication, enhancing the independence and safety of users in environments such as hospitals, homes, and assisted living facilities. Designed with ergonomic comfort, durability, power efficiency, and scalability in mind, the glove system offers a practical, cost-effective, and expandable solution for assistive technology.

IV. DESIGN CONSIDERATION

The design of the Wearable Automatic Assistance Glove was guided by several key factors to ensure both functionality and user comfort. Ergonomics was a primary concern; the glove was designed to be lightweight and comfortable for prolonged use, with components positioned to avoid restricting natural hand movement.

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Durability was also essential, as the glove is intended for daily wear. Therefore, materials and electronic components were chosen for their robustness against physical stress and repeated use. To ensure power efficiency, low-power microcontrollers and sensors were incorporated, minimizing battery drain and extending operational time between charges. Finally, scalability was taken into account by designing the system architecture to accommodate future upgrades—such as wireless connectivity or additional gesture inputs—without requiring a complete redesign.

V. FLOW CHART REPRESENTATION

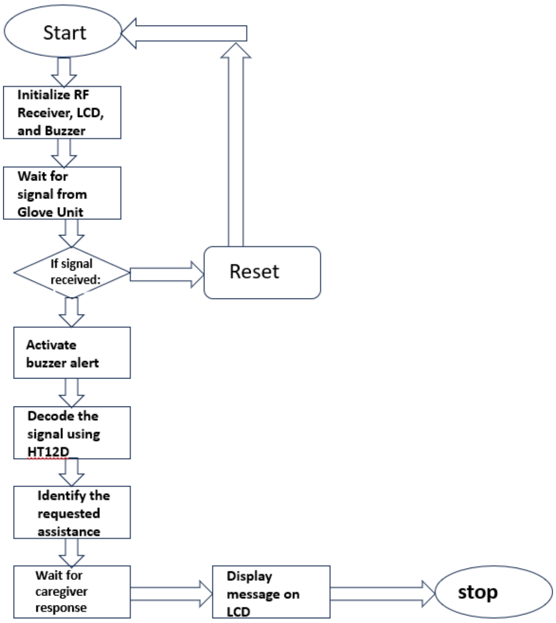

Figure 2: flowchart of the system

VI. RESULTS

The primary objective of this working model is to develop a wireless communication system that utilizes head movements to assist individuals with disabilities in conveying verbal alerts. This innovative approach addresses the communication challenges faced by people with severe physical impairments by offering a simple, hands-free method to interact with their environment effectively in fig 3. The system uses ESP-32 accelerometers mounted on the user's head, chosen for their lightweight and compact design to ensure comfort. These sensors accurately detect even subtle head movements, capturing real-time data regarding movement magnitude and direction. This data is transmitted to a microcontroller, such as the PIC 16F877A, which serves as the system's core processor. It converts the analog signals into digital information and uses a custom algorithm to interpret the head gestures. The algorithm distinguishes between intentional commands—such as nodding, shaking, or tilting—and involuntary movements, significantly reducing the risk of false triggers. Through this integrated process, the device ensures reliable and responsive communication for users with mobility limitations.

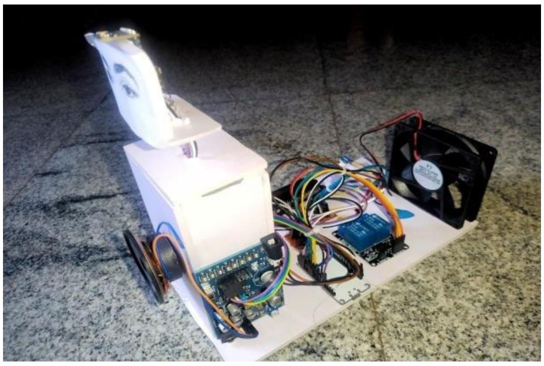

Figure 3: Working model

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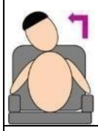
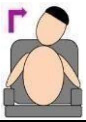
Table 1: Accelerometer Response and Wheel Chair movement

Head movement directions	**Corresponding analog value**	**Wheel chair direction**	**Assistance control mode**	**Application control mode**
	Accelerometer axis Value X > 6	Forward direction	Respiratory support need assistance	Fan off
	Accelerometer axis Value X< -6	Backward direction	Please assist to the washroom	Fan on
	Accelerometer axis Value Y > 6	Right direction	Hungry need assistance	LED on
	Accelerometer axis Value Y < -6	Left direction	I need water	LED off

Speech Alert System
Voice Synthesis: A voice synthesis module is attached to the receiving microcontroller, which processes the commands it has received. The user can hear the system's reactions or notifications thanks to this module, which transforms text-based commands into audible speech alerts.Feedback Mechanism: The system uses auditory notifications to give the user feedback so they are aware of the actions being conducted.

The user interface is designed with a focus on simplicity and accessibility. A built-in LCD screen provides clear visual feedback by displaying command statuses and alerts, enhancing user confidence and interaction. The system's portability is ensured by integrating all components into a lightweight, wearable headband, allowing users to move freely while retaining control in fig 4.

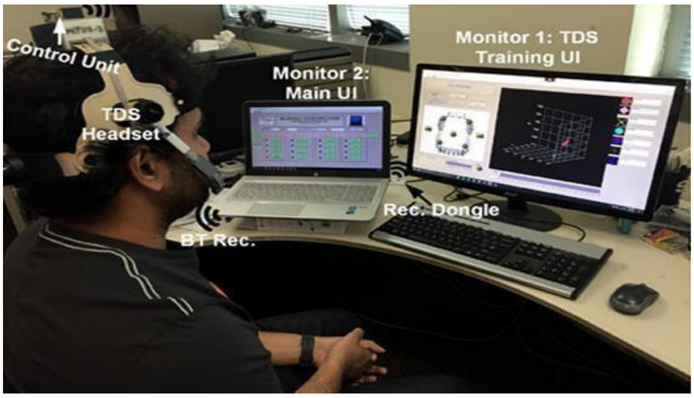


Figure 4: Receiver units and application

To evaluate its reliability and effectiveness, multiple user trials were conducted with individuals experiencing paralysis. These real-world tests offered valuable feedback that contributed to refining the system's performance. Key performance metrics—such as accuracy, response time, and user satisfaction—were used to assess functionality in Table 1. The system demonstrated high accuracy in interpreting head gestures and executing commands, with minimal response delay. Overall, users reported positive experiences, confirming that the solution is practical, intuitive, and supportive in assisting daily communication for individuals with mobility impairments.

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VII. CONCLUSION

This work presents a compact, wearable head movement-based communication system tailored for paralyzed individuals, enabling intuitive, hands-free interaction. By leveraging ESP-32 accelerometers, advanced signal processing, and wireless protocols like Wi-Fi or ZigBee, the system accurately interprets head gestures to execute predefined commands. Integrated speech synthesis and audio feedback further enhance usability, making the solution both responsive and user-friendly. Its lightweight, portable design holds promise for improving the independence and quality of life of users with severe physical impairments.

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