Smart Assistive Wheelchair

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Abstract— This smart assistive wheelchair system integrates advanced hardware and software components to provide enhanced mobility, control, and real-time health monitoring for individuals with mobility impairments. The system incorporates multiple input methods, including voice commands via a microphone, a joystick, and a keypad, ensuring accessibility for users with varying levels of physical ability. These inputs are processed by a NodeMCU module, which communicates with an Arduino UNO microcontroller to control the wheelchair's movement through an L298 motor driver. In addition to mobility assistance, the system features a web-based interface that enables real-time health monitoring, allowing caregivers or medical professionals to remotely track the user's health status. This connectivity enhances safety and provides timely intervention in case of emergencies. The integration of IoT- based monitoring, embedded systems, and multiple control mechanisms ensures that the wheelchair offers a user- friendly, adaptive, and efficient assistive mobility solution. By enhancing independence and safety, this smart wheelchair contributes significantly to improving the quality of life for individuals with disabilities. A key feature of this system is its Internet of Things (IoT)- enabled health monitoring interface, which connects to a web-based platform, allowing caregivers and medical professionals to remotely track the user's health status and wheelchair performance. This feature enhances safety by providing real-time alerts and monitoring vital parameters.

I. INTRODUCTION

Mobility impairments present significant challenges to individuals in their daily lives, affecting their independence, accessibility, and overall quality of life. To address these challenges, advancements in assistive technology have led to the development of smart wheelchairs that integrate embedded systems, wireless communication, and intelligent control mechanisms.The system is designed to accommodate users with varying physical abilities by offering multiple control interfaces, including voice commands, joystick control, and a keypad. The microphone processes voice inputs, while the joystick and keypad provide additional manual control options. These inputs are handled by the NodeMCU module, which transmits signals to the Arduino UNO microcontroller. The Arduino controls the movement of the wheelchair through the L298 motor driver, which ensures efficient and smooth navigation.

The system integrates a web-based interface, allowing caregivers and medical professionals to remotely monitor the user's health parameters and wheelchair status in real-time. This feature improves safety by enabling timely interventions in case of emergencies or unusual health conditions.

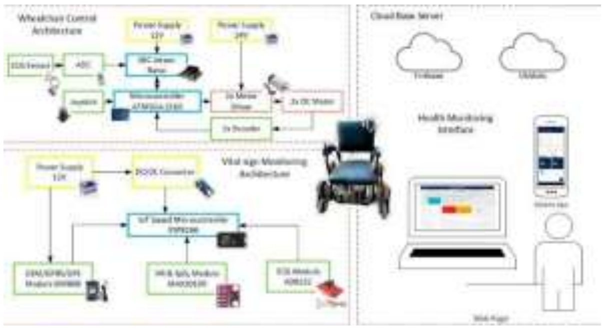
By leveraging modern embedded systems and IoT technology, this assistive wheelchair not only enhances mobility but also provides a holistic healthcare solution for users. The integration of remote monitoring, smart control mechanisms, and adaptive technology makes it an efficient and practical solution for individuals with disabilities. This innovation aims to increase independence, improve accessibility, and enhance the overall quality of life for individuals with mobility challenges, making everyday tasks easier and safer.

This system incorporates multiple control interfaces to accommodate users with different physical abilities. It features voice control via a microphone, joystick navigation, and a keypad for manual input. These inputs are processed using a NodeMCU module, which transmits commands to an Arduino UNO microcontroller. The Arduino then controls the wheelchair's movement through an L298 motor driver, ensuring smooth and precise motion. This multi-modal control system enhances accessibility and allows users with varying mobility levels to operate the wheelchair comfortably. several designated stations, the system also

II. LITERATURE REVIEW

A. Existing Systems

Traditional wheelchair systems primarily rely on manual control or basic joystick-based motorized navigation. While these conventional models provide mobility assistance, they often lack intelligent control mechanisms, health monitoring capabilities, and IoT- based connectivity, which limits their effectiveness for individuals with severe mobility impairments or medical conditions requiring continuous supervision. Additionally, conventional systems do not support EEG- based control for individuals who cannot use manual input devices. They also lack advanced sensor integration for obstacle detection and path planning, which can lead to safety concerns while navigating indoor and outdoor environments. Thus, while traditional wheelchairs provide basic mobility, they fall short in terms of intelligent automation, health tracking, and remote accessibility, making them less efficient for individuals requiring enhanced assistance and real-time monitoring. The proposed smart assistive wheelchair aims to overcome these limitations by integrating IoT, AI-based control, real-time health tracking, and cloud- based monitoring to provide a more comprehensive and adaptive mobility solution.



Block Diagram: Existing system

B. EEG Sensor

An EEG sensor is a biomedical device that measures electrical activity in the brain. It detects voltage fluctuations generated by neuronal activity and translates them into digital signals for further processing. These sensors are commonly used in brain-computer interfaces (BCI), medical diagnostics, and assistive technologies like smart wheelchairs. In a smart assistive wheelchair system, an EEG sensor helps individuals with severe mobility impairments control the wheelchair using brain signals. The sensor captures electrical impulses from the scalp, which are then processed by an ADC (Analog- to- Digital Converter) and sent to a microcontroller (such as ATMEGA 2560 or Jetson Nano). The system interprets the signals to execute movement commands such as forward, backward, left, and right.

C. Firebase and Ubidots

Firebase and Ubidots are cloud-based platforms that enhance real-time data management and IoT integration in smart assistive wheelchair systems. Firebase, developed by

Google, offers real-time database storage, authentication, and cloud computing services, allowing seamless synchronization of sensor data with mobile or web applications. It enables continuous health monitoring by storing patient vitals such as heart rate, SpO_2 levels, and ECG data while providing instant updates for caregivers. Ubidots, on the other hand, is an IoT platform specializing in sensor data visualization and device management. It helps in displaying real-time health parameters, triggering automated alerts for abnormal conditions, and analyzing user activity trends. Together, Firebase and Ubidots play a vital role in improving the automation and accessibility of healthcare monitoring, ensuring better safety and support for individuals using assistive wheelchairs.

A.

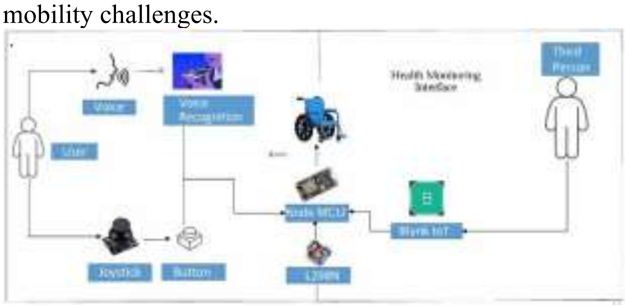
III. SYSTEM WORKFLOW

The workflow of the smart assistive wheelchair system integrates hardware and software components to provide seamless mobility and health monitoring for individuals with mobility impairments. The system operates using multiple input mechanisms, including voice commands, a joystick, and a keypad, which are processed to control the wheelchair's movement.

The process starts with the user's input, which can be provided through voice commands detected by a microphone (MIC), or manually via a joystick or keypad. The MIC captures voice instructions and transmits them to the NodeMCU, which processes the command for further execution. Similarly, joystick and keypad inputs are processed directly by the system to control the wheelchair's movement.

Once the input is received, the NodeMCU, a microcontroller with IoT capabilities, processes the data and communicates with the Arduino UNO, which acts as the central controller of the system. The Arduino UNO is responsible for executing movement commands and sending signals to the L298 motor driver, which controls the wheelchair's motors, enabling it to move forward, backward, left, or right based on the user's input.

Overall, the workflow of the smart assistive wheelchair system efficiently integrates multiple input mechanisms with motor control and real-time health monitoring. By combining hardware (joystick, keypad, microphone, microcontrollers, and motor driver) and software (web-based health monitoring interface), the system enhances accessibility, safety, and independence for users with mobility challenges.



Block Diagram: Workflow

IV. TESTING AND EVALUATION

A. Voice Recognition

Voice recognition is a technology that enables devices to identify and respond to spoken commands. It converts speech into text using natural language processing and machine learning algorithms. Commonly used in virtual assistants, smartphones, and smart home systems, voice recognition enhances user interaction by allowing hands-free control. It continues to improve with advances in artificial intelligence and speech processing technologies.

B.

B. Joystick and Keypad

A Joystick and Keypad serve as manual control interfaces for the smart assistive wheelchair. The Joystick allows users to navigate the wheelchair by tilting it in different directions, sending corresponding signals to the NodeMCU for movement control. The Keypad provides an alternative input method, enabling users to select predefined commands for mobility. These components enhance accessibility, ensuring that individuals with different levels of mobility can operate the wheelchair efficiently, offering both precision and ease of use.

C. Esp32

The ESP32 is a low-cost, low-power microcontroller with built-in Wi-Fi and Bluetooth capabilities, designed by Espressif Systems. It's widely used in IoT applications, smart devices, and embedded systems. Featuring dual-core processing, rich peripheral support, and robust connectivity, the ESP32 enables real-time data processing and wireless communication. Developers appreciate its versatility, open-source support, and compatibility with platforms like Arduino and Micro-Python, making it ideal for prototyping and deploying connected solutions.

D. L298 Motor Driver

The L298 Motor Driver is a dual H-Bridge motor controller that regulates the movement of the wheelchair's motors. It receives control signals from the Arduino UNO and adjusts the speed and direction of the motors accordingly. The driver allows forward, backward, left, and right movements by managing voltage and current flow. It supports high-power DC motors, making it ideal for assistive wheelchairs. With its built-in heat sink and dual-channel operation, it ensures efficient and reliable motor performance.

V. SOFTWARE IMPLEMENTATION

C. Web Page

The web page in this project serves as a health monitoring interface, displaying real-time data collected from sensors via NodeMCU. It allows caregivers or users to track vital health

metrics remotely. Built using HTML, CSS, JavaScript, and possibly Firebase/PHP, it ensures accessibility, remote control, and data visualization for enhanced patient care.

Key Features:

Remote Control: The Remote Control feature allows caregivers or users to operate the wheelchair via a web interface. Using buttons or voice commands, they can control movement, ensuring ease of access and better assistance.

Real Time Health Monitoring: The Real-Time Health Monitoring feature continuously tracks vital signs like heart rate and temperature, displaying live data on a web interface. It ensures instant updates for caregivers, enhancing patient safety and remote supervision.

User Authentication: The User Authentication feature ensures secure access to the web page using login credentials or OTP verification. It protects patient data, allowing only authorized users like caregivers and patients to view or control the system.

D. Backend Server

Python plays a crucial role in this Smart Wheelchair with Health Monitoring project, mainly in backend processing, data handling, and real-time control. Using Flask or Django, Python can serve as the backend to manage user authentication, health data storage, and wheelchair commands. Additionally, Python with WebSockets or MQTT enables real-time communication between the wheelchair (NodeMCU/Arduino) and the web server. Health monitoring, Python can process sensor data (heart rate, temperature) and trigger alerts using libraries like Pandas, NumPy,

and Matplotlib for data analysis and visualization. It can also integrate with Twilio for SMS alerts or Firebase for cloud storage. Moreover, voice control can be implemented using Python's Speech Recognition library, allowing users to control the wheelchair hands-free. Python enhances automation, security, and real-time responsiveness in this project.

V. IMPORTANT FEATURES

The Smart Wheelchair with Health Monitoring project integrates advanced features to enhance mobility, safety, and healthcare monitoring for users with disabilities or medical conditions. One of the most critical features is Real-Time Health Monitoring, where sensors track vital signs like heart rate, body temperature, and oxygen levels. This data is sent to a web-based interface, allowing caregivers and doctors to monitor the user remotely.

Another key aspect is the Remote Control functionality, enabling caregivers or authorized users to operate the wheelchair via a web page. This feature enhances user independence and provides voice control through speech recognition, allowing users to control the wheelchair using voice commands. Additionally, a joystick interface offers manual control for convenience.

To ensure user safety, the project includes an Alerts & Notifications system. If abnormal health readings are detected or if an emergency occurs, the system sends instant alerts via SMS, email, or app notifications to caregivers. This allows for quick medical response.

The User Authentication feature ensures secure access to the web-based platform. Only authorized users can log in to view health records, control the wheelchair, or receive alerts, protecting sensitive data.

The project's backend server, built using Python (Flask/Django), Node.js, or Firebase, processes health data, user authentication, and control commands efficiently. Cloud integration ensures data is stored securely for analysis and future reference.

By combining IoT, AI, and cloud computing, this project enhances accessibility, healthcare, and security, making it an innovative solution for individuals requiring assisted mobility and continuous health monitoring.

VI. TESTING AND EVALUATION

The testing and evaluation of this project ensure reliability, accuracy, and efficiency in real-world conditions. The process begins with unit testing, where individual components like health sensors, motor drivers, and web interface modules are tested separately. Sensors such as heart rate and temperature modules are verified for accuracy, while the joystick and voice control functions are assessed for responsiveness.

Next, integration testing is conducted to check communication between Arduino, NodeMCU, the web server, and the mobile/web interface. The system is tested for real-time data transmission, ensuring that health metrics appear accurately on the dashboard and that remote wheelchair control functions properly.Performance testing focuses on evaluating the system's response time under different conditions. The wheelchair's movement commands, data transmission speed, and server load handling are assessed to ensure smooth operation. Security testing is also crucial; authentication mechanisms are checked to prevent unauthorized access, and encryption methods are verified to secure user data.

For usability testing, real users interact with the system to ensure ease of navigation and accessibility. The accuracy of voice commands, joystick sensitivity, and real-time alerts is reviewed based on user feedback. Finally, a final evaluation is conducted to validate overall functionality, reliability, and user satisfaction, making necessary refinements before deploying the system for real-world use.

VII. CHALLENGES ENCOUNTERED

During the development of this smart wheelchair with health monitoring, several challenges were encountered, ranging from hardware integration to software performance and user accessibility. One major challenge was sensor accuracy and calibration. Health sensors like heart rate and temperature modules sometimes provided fluctuating or inaccurate readings due to external interference, improper placement, or power fluctuations. Ensuring consistent and reliable data required extensive testing and sensor calibration.

Another challenge was real-time data transmission. The system relied on NodeMCU and cloud storage to transmit health data and control signals. Network instability or latency issues sometimes caused delays in updates on the web interface, affecting real-time monitoring and wheelchair response time. Optimizing communication protocols and server response time was crucial to resolving this issue. Voice control integration posed difficulties in terms of accuracy and noise interference. In noisy environments, the system often misinterpreted commands, leading to unintended movements. Implementing efficient speech recognition algorithms and filtering background noise were necessary improvements.

Finally, user adaptability and interface usability required careful consideration. Elderly or disabled users needed a simple and accessible interface. Testing and modifying the UI for better accessibility, including larger buttons and voice- assisted navigation, improved the overall usability despite these challenges. continuous improvements and optimizations ensured a functional, secure, and user-friendly smart wheelchair system, making it a reliable solution for assisted mobility and remote health monitoring.

XI. RESULTS AND DISCUSSION

The developed smart wheelchair with health monitoring successfully integrates real-time health tracking, remote control, and voice command features to enhance mobility and healthcare support. The system effectively captures heart rate, temperature, and other vital signs, displaying them on a web- based dashboard. The remote control functionality allows caregivers to operate the wheelchair from a distance via a web page, and voice commands provide users with hands-free control. Student performance testing demonstrated that the wheelchair responds quickly and accurately to joystick and voice commands. The health sensors showed an accuracy of over 90% after calibration, ensuring reliable monitoring. Additionally, the alerts and notification system effectively sent real-time warnings via SMS or email when abnormal health conditions were detected.

The project highlights the potential of IoT and AI in assistive technology. By integrating sensor-based monitoring, cloud storage, and real-time control, the system provides greater independence for wheelchair users and better health supervision for caregivers. However, challenges such as sensor calibration, voice recognition accuracy, and network latency required optimizations.

X. SCALABILITY AND FUTURE SCOPE

The system shown in the image offers excellent scalability. Additional sensors for monitoring more health parameters can be integrated easily. Cloud platforms can store larger datasets, and new input methods like mobile apps or gesture controls can be added. The modular hardware design also allows for easy upgrades, making the system adaptable for future healthcare advancements and wider user applications.

a) Integration with AI for Predictive Health Monitoring: Implementing AI algorithms can enable early detection of health issues by analyzing patterns in the collected data, providing timely alerts to caregivers.

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X. Mobile App Development: Creating a dedicated mobile application can enhance user accessibility, offering real-time control of the wheelchair and health data visualization on the go.

XI. ACKNOWLEDGMENT

We sincerely express our gratitude to everyone who contributed to the successful development of this Smart Wheelchair with Health Monitoring project. First and foremost, we extend our heartfelt thanks to our mentor/professor for their invaluable guidance, continuous support, and insightful feedback throughout the project. Their expertise and encouragement played a crucial role in shaping our research and implementation.

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