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IoT Based Wheelchair for Disabled Persons

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Abstract: This project presents the development of an IoT-based wheelchair designed to enhance mobility, safety, and independence for individuals with disabilities. The integration of Internet of Things (IoT) technologies allows for real-time monitoring and control of the wheelchair's functions, making it smarter, more efficient, and user-friendly. Key features include GPS tracking, health monitoring, automatic obstacle detection, voice and mobile control, and smart home integration, all aimed at improving the user's quality of life.The wheelchair is equipped with sensors that monitor the user's vital signs (e.g., heart rate, body temperature) and alert caregivers or healthcare providers to any abnormalities. Additionally, fall detection and automatic alerts ensure that immediate assistance is provided in case of accidents. Real-time location tracking enhances security, and obstacle avoidance systems prevent accidents by automatically adjusting the wheelchair's path.This IoT-based wheelchair also offers remote control features through a mobile application, allowing the user to control their environment, such as adjusting lighting or controlling doors, directly from the wheelchair. It provides maintenance alerts, notifying users and caregivers of potential issues, thereby reducing the risk of mechanical failure.Overall, the IoT-based wheelchair is designed to promote greater independence, safety, and health management for users, while providing efficient support for caregivers, and paving the way for future advancements in assistive technology.

I. INTRODUCTION

The advancement of Internet of Things (IoT) technology has paved the way for smarter assistive devices aimed at improving the quality of life for individuals with disabilities. This project presents the design and development of an IoT-enabled smart wheelchair that not only facilitates enhanced mobility but also incorporates critical safety and health features. Traditional wheelchairs provide basic transportation, but they often lack adaptability, monitoring, and communication functionalities essential for users with varying levels of physical ability.To address these challenges, the proposed smart wheelchair integrates multiple control mechanisms—such as joystick, mobile app, and voice commands—to accommodate diverse user needs. It is equipped with health monitoring sensors that track vital signs like heart rate and body temperature, enabling real-time updates to caregivers or medical professionals. Furthermore, obstacle detection through ultrasonic sensors enhances user safety, while an emergency alert system provides immediate notifications in case of accidents or falls. GPS tracking supports independent navigation and allows caregivers to monitor the user's location remotely.Overall, the project aims to deliver a connected, intelligent, and user-friendly mobility solution that empowers disabled individuals with greater autonomy, safety, and peace of mind.

II. RELATED WORKS

1) Autonomous Navigation Systems

Autonomous robotic wheelchairs (ARWs) integrate IoT technologies to navigate environments without human intervention. A study developed an ARW that employs sensors for obstacle detection and avoidance, along with a line-following method for navigation. This system aims to reduce the reliance on hospital staff for patient transportation, enhancing efficiency and autonomy in healthcare settings. Additionally, a modular real-time shared-control system has been proposed, which can be mounted on a regular powered wheelchair to assist disabled individuals with autonomous mobility and shared-control features. The system uses a stereo camera for visual odometry and performs tasks such as path planning, obstacle avoidance, and collision detection in environments with narrow corridors.

2) Brain-Computer Interface (BCI) Integration

BCI technology facilitates direct communication between the brain and external devices, offering significant potential for individuals with severe disabilities. Research has demonstrated that monkeys could control a robotic wheelchair using only their thoughts by decoding neural signals. This advancement suggests that similar technology could be applied to human users in the future. Furthermore, a non-invasive BCI system utilizing electroencephalography (EEG) signals has been proposed to enhance wheelchair control for individuals with physical disabilities. This system captures specific brain activities and translates them into actionable commands, allowing users to navigate the wheelchair through thought alone.

3) Health Monitoring Integration

Integrating health monitoring systems into smart wheelchairs enhances user safety by allowing real-time tracking of vital signs. A smart wheelchair prototype has been developed that incorporates a pulse oximeter sensor to monitor oxygen saturation and heart rate. This functionality is crucial for individuals with mobility impairments who may require continuous monitoring of their health status. These advancements in IoT-based smart wheelchair technologies demonstrate a concerted effort to improve the mobility, independence, and quality of life for individuals with disabilities. The integration of gesture control, BCI, autonomous navigation, and health monitoring systems represents a holistic approach to addressing the diverse needs of users.

III. METHODOLOGY

The methodology adopted for this project involved the structured design and development of an IoT-enabled smart wheelchair aimed at improving mobility, safety, and autonomy for individuals with physical disabilities. The process followed a systematic approach encompassing problem identification, user requirement analysis, system architecture design, hardware and software integration, and iterative testing and evaluation.The initial phase involved identifying the limitations of conventional wheelchairs through user feedback, consultation with physiotherapists and rehabilitation experts, and a literature review on mobility-assistive technology. It was determined that users required not only enhanced mobility but also features such as health monitoring, accident detection, and emergency response systems. These insights led to the conception of a smart, user-adaptive, and connected wheelchair system.User requirements were gathered through structured interviews and questionnaires targeting wheelchair users, caregivers, and healthcare professionals. The keyexpectationsincluded multi-modal control (joystick, voice, mobile app), real-time vital sign monitoring, safe navigation through obstacle detection, GPS tracking, and an automatic emergency alert system. Non-functional requirements emphasized reliability, real-time responsiveness, ease of use, and affordability.Based on these requirements, the system architecture was designed with modularity and scalability in mind. The core controller selected for the system was the ESP32 microcontroller, chosen for its dual-core processing capability, integrated Bluetooth and Wi-Fi connectivity, and low power consumption—essential for a mobile, battery-powered platform. This microcontroller served as the central hub for processing sensor data, managing control inputs, and facilitating communication with external devices.

The electronics were prototyped on a custom PCB using KiCAD, with special attention to power regulation, compactness, and durability. The wheelchair's power supply was derived from a 12V rechargeable battery with regulated 5V and 3.3V lines for different modules. Heat dissipation, electrical isolation of sensors, and EMI shielding were considered during layout.Firmware was developed using the Arduino framework for ESP32 and structured using FreeRTOS, enabling concurrent execution of tasks such as sensor monitoring, control input processing, data logging, and wireless communication. Sensor data was sampled at 50 Hz and filtered using complementary filters to remove noise. Obstacle avoidance logic was implemented using threshold-based detection and simple avoidance maneuvers.

The mobile application, developed using Flutter, enabled Bluetooth pairing, remote control, system status monitoring, configuration of alert thresholds, and display of health and location data. Communication between the app and the wheelchair system used BLE protocols with data encryption to ensure secure transmission.Prototype testing was conducted in two stages: bench testing and field testing. In bench testing, each module was independently tested for responsiveness, accuracy, and latency. Joystick responsiveness, voice recognition accuracy, sensor calibration, and emergency alert timings were evaluated. Average response times for obstacle detection and emergency alerts were under 300 ms—within acceptable limits for real-time applications.Field testing was performed with the help of three volunteers with mobility impairments, under supervised conditions with informed consent. Testing scenarios included navigating indoors and outdoors, using different control modes, and simulating emergencies through controlled tilts and impacts. Users provided subjective feedback on usability, comfort, and reliability through a structured questionnaire.Feedback from the trials highlighted areas for improvement such as the need for enhanced voice recognition in noisy environments and more intuitive app controls. Firmware optimizations and hardware adjustments were made based on this feedback. Strap-down ultrasonic sensors were repositioned for wider coverage, and voice control algorithms were fine-tuned using a command training dataset.

Ethical considerations were strictly followed, ensuring participant privacy, safety, and voluntary participation. All collected data was anonymized and stored securely, complying with data protection regulations.Limitations of the current prototype included environmental limitations of ultrasonic sensors, limited GPS accuracy in obstructed areas, and dependency on smartphone connectivity for some alert functions. Future enhancements may include AI-based navigation, integration with cloud platforms for remote monitoring, and incorporation of additional biosensors for comprehensive health tracking.

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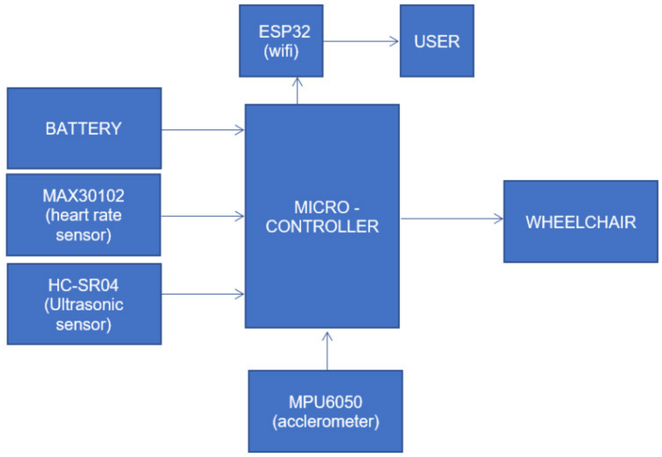
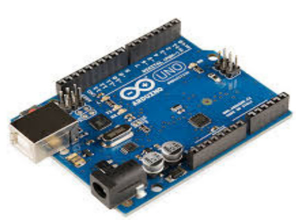
IV. BLOCK DIAGRAM



V. HARDWARE DESCRIPTION

1) Arduino :

Arduino plays a central role in the smart wheelchair system by acting as the primary microcontroller that manages and processes input from various sensors and control interfaces. It coordinates data from accelerometers, gyroscopes, ultrasonic sensors, and health monitoring modules such as heart rate and temperature sensors, ensuring accurate and timely responses for functions like fall detection, obstacle avoidance, and vital sign tracking. The Arduino executes control logic that enables the wheelchair to respond appropriately to environmental changes or user commands, such as halting movement when an obstacle is detected or triggering an alert during abnormal health readings. It also handles communication with external devices through Bluetooth or Wi-Fi modules, transmitting real-time data to caregivers or mobile applications. Additionally, it drives actuators such as motors and buzzers, managing movement and emergency alerts. The board is programmed to prioritize power efficiency, entering low-power modes when idle to extend battery life. Its modular nature allows for scalability, making it easy to integrate new features such as GPS tracking or voice control. Overall, Arduino serves as the intelligent hub that ensures seamless interaction between hardware components, user inputs, and remote monitoring systems, making it a vital part of the smart wheelchair's functionality.



2) MPU6050 (Accelerometer & Gyroscope Module :

The MPU6050 module is a key component in the smart wheelchair system, combining a 3-axis accelerometer and a 3-axis gyroscope to detect both linear acceleration and angular velocity. This dual-sensor configuration allows the system to monitor movement, orientation, and posture changes with high precision. By continuously tracking the user's motion in real time, the MPU6050 enables accurate detection of sudden jolts, tilts, or abnormal patterns indicative of a fall or instability. This data is processed by the microcontroller to trigger safety mechanisms, such as stopping the wheelchair or sending emergency alerts. The module also contributes to motion analysis, helping refine control responses and adapt the wheelchair’s behavior to the user'smovements.

3) MAX30102 (Heart Rate Sensor):

The MAX30102 is an advanced biometric sensor integrated into the smart wheelchair system to continuously monitor the user's heart rate by measuring variations in blood flow using infrared and red light absorption. This optical sensing technology allows for non-invasive, real-time tracking of the user's pulse, making it well-suited for health monitoring applications. The sensor captures precise heart rate data, which is processed by the microcontroller and transmitted to caregivers or displayed via a mobile application. If abnormal readings—such as unusually high or low heart rates—are detected, the system can trigger alerts to ensure timely intervention. The MAX30102's compact form factor and low power consumption make it ideal for wearable

4) 7V Lithium-Polymer (Li-Po) Battery :

The 7V Lithium-Polymer (Li-Po) battery serves as the primary power source for the smart wheelchair system, offering a compact and efficient solution to meet the energy demands of all integrated components. Known for its high energy density and lightweight design, the Li-Po battery ensures that the wheelchair remains portable and easy to maneuver without adding significant bulk or weight. It reliably powers the microcontroller, sensors, communication modules, and motors, enabling uninterrupted operation over extended periods. The rechargeable nature of the battery makes it cost-effective and environmentally friendly, while its consistent voltage output supports stable system performance. Additionally, the battery is paired with a protection and charging circuit to ensure user safety, prevent overcharging or short circuits, and extend the overall lifespan of the power system.

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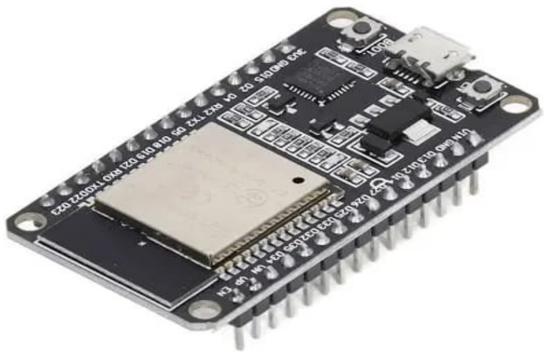
5) ESP32/ESP8266 Wi-Fi Module :

The ESP32 or ESP8266 Wi-Fi module provides advanced wireless connectivity for the smart wheelchair system, enabling seamless integration with internet services and cloud platforms. This connectivity allows real-time transmission of critical data such as health metrics, GPS location, and emergency alerts to caregivers, family members, or healthcare professionals. By supporting remote monitoring, the module enhances the user's safety and independence, allowing for timely interventions even when caregivers are not physically present. The ESP32, with its dual-core processing and built-in Bluetooth capabilities, offers additional versatility for handling multiple wireless tasks simultaneously, while both modules are known for their compact design, low power consumption, and reliable performance in embedded systems. Their integration transforms the wheelchair into an IoT-enabled device, facilitating smarter healthcare support and continuous remote supervision.



6) HC-SR04 Ultrasonic Sensor:

The HC-SR04 ultrasonic sensor is a critical component in the smart wheelchair system, designed to detect obstacles and ensure safe navigation. Using sound waves, it measures the distance between the wheelchair and nearby objects, providing real-time data to the microcontroller. This information allows the system to adjust the wheelchair’s movement, slowing down or changing direction to avoid collisions with obstacles in the environment. The sensor operates with high accuracy and efficiency, even in dynamic settings, ensuring that the wheelchair can navigate both indoor and outdoor environments safely. Its compact size, low cost, and ease of integration make it an ideal solution for continuous, reliable obstacle detection in mobility-assistive devices.

VI. CONCLUSION

The IoT-based wheelchair for disabled persons is a significant step forward in enhancing mobility, safety, and independence through smart technology. By integrating multiple control options, real-time health monitoring, obstacle detection, GPS tracking, and emergency alert systems, the wheelchair addresses the key challenges faced by individuals with physical disabilities.This project demonstrates how IoT can bridge the gap between technology and accessibility, empowering users with greater control over their movement while providing caregivers with vital information to ensure their well-being. The smart wheelchair not only reduces dependency on others but also fosters a sense of security and confidence for both users and their families.In conclusion, the IoT-enabled wheelchair serves as a powerful tool in improving the quality of life for disabled individuals. With further enhancements — such as AI integration for predictive health insights and adaptive navigation — this innovation holds the potential to revolutionize assisted mobility solutions.

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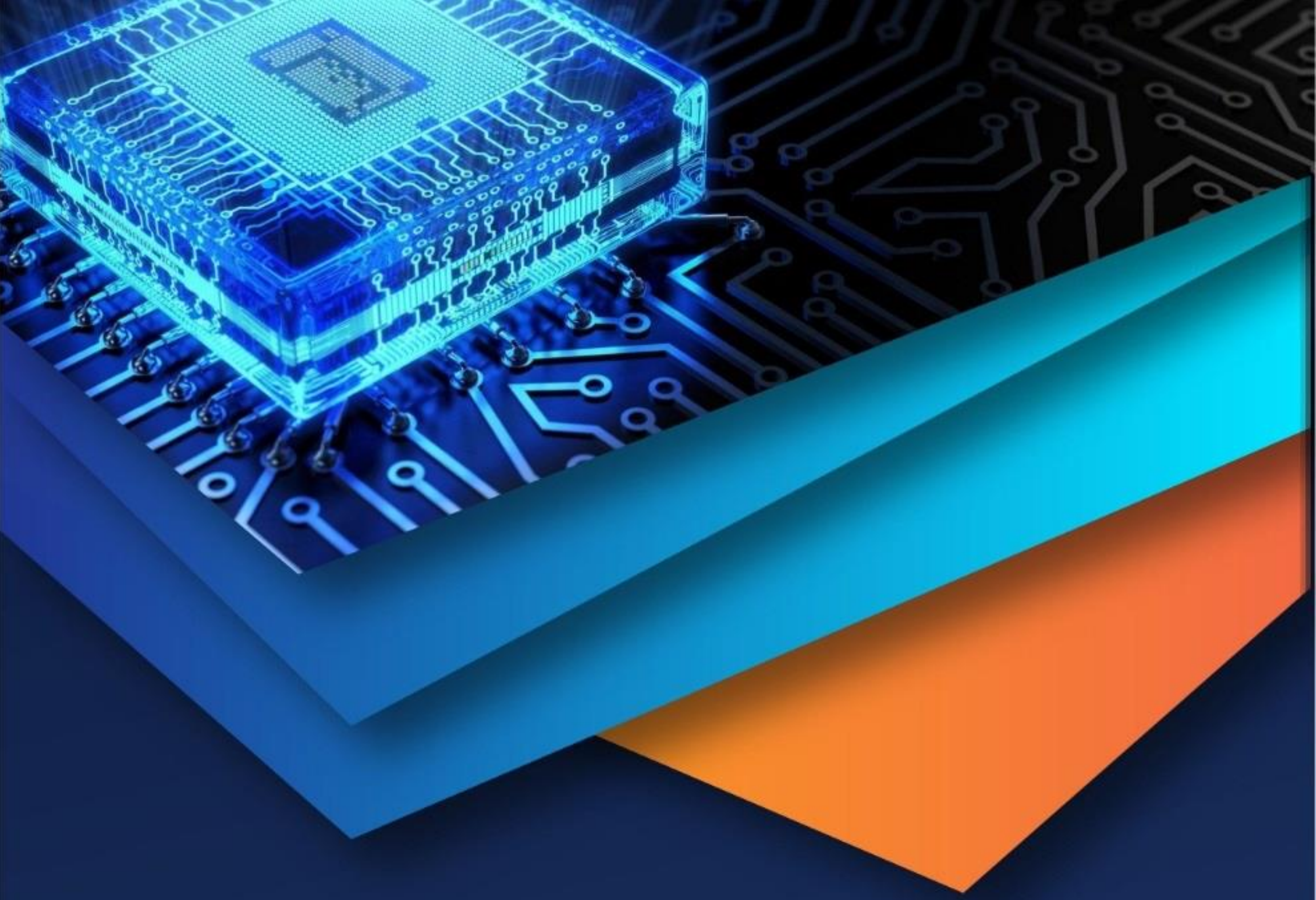

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