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SMART WHEELCHAIR WITH INTEGRATED HEALTH MONITORING SYSTEM

[1]Dr. Sowmya , [2]Namrata Palaki, [3]Subhendu Sagar, [4]Samir Yousuff Khan, [5]Mohammed Tauheed Pasha

[1] Professor , [2] UG Student , [3] UG Student, [4] UG Student, [5] UG Student
[1 2 3 4 5]Department of Computer Science and Engineering,
[1 2 3 4 5]City Engineering College, Bangalore, India

Abstract : Smart wheelchairs are transformative mobility aid devices that reduce physical exertion by making it easier to navigate. The devices use user input to reduce the effort required to move, allowing people with disabilities to travel with ease. They are also equipped with obstacle sensors that help to avoid accidents. In addition to public interest, they are becoming popular in nursing homes where elderly patients utilize them. Technological enhancements focus on making the devices more customizable and adaptable by integrating AI technology. They also exhibit voice features and facial surveillance that are used to protect the user. These tools are meant to be completely inclusive by ensuring that everyone feels comfortable and empowered while using them. Technology has made mobility aid a lot more user-friendly and comfortable for the user and the caregiver.

***Index Terms* - Smart Wheelchairs, Mobility Aid Devices, Accessibility, AI Integration, Elderly Care, User Empowerment**

I. INTRODUCTION

Smart wheelchairs with integrated health monitoring systems represent a significant advancement in assistive technology. These systems combine robotics, computer vision, and sensor technologies to provide users with enhanced mobility and health tracking capabilities. Research has shown that smart wheelchairs can utilize computer vision for landmark detection and head-and eye-tracking for control (Simpson, 2005). Additionally, the integration of hands-free control technology allows for automated guidance during navigation, particularly beneficial for individuals with severe physical disabilities (Nguyen et al., 2013).

Health monitoring in smart wheelchairs is crucial, as demonstrated by the development of Android applications that utilize smartphone sensors to record and process physical activities of wheelchair users (Batayneh & Aburmaileh, 2020). Furthermore, the Smart Chair Assistive Wheelchair Navigation System has paved the way for shared control systems, where human-machine interaction enables automatic adaptation to user behaviors (Levine et al., 1999).

The evolution of smart wheelchairs has seen the integration of sensors and computational capabilities, transforming traditional electric wheelchairs into intelligent systems capable of real-time monitoring and adjustments (Freddi et al., 2021). These advancements have led to the development of smart wheelchair prototypes that serve as valuable tools in the healthcare sector, promoting user independence and well-being (D et al., 2020).

II. EASE OF USE

Act as a smart technology consultant with expertise in assistive devices and health monitoring systems. I am interested in understanding how a smart wheelchair with integrated health monitoring can provide ease of use to its users. Explain the benefits and how the integration of these systems enhances the user experience. Focus on the practical aspects of daily use, such as maneuverability, comfort, and the health monitoring features' accuracy and responsiveness. Ensure that the explanation is straightforward and avoids technical jargon so it can be easily understood by someone without a technical background. If there are any potential drawbacks or limitations of such a system, please include those as well. Provide examples of real-life scenarios where the smart wheelchair's features would be particularly beneficial.

2.1 Related work

The related work on smart wheelchairs with integrated health monitoring highlights advancements in mobility assistance and health tracking. Research focuses on intelligent control systems for adaptive mobility and sensor technologies for real-time health monitoring, including vital signs and environmental factors. Data processing techniques, such as machine learning, provide actionable insights. User-centered design emphasizes intuitive interfaces aligned with individual needs. Challenges like data security, system reliability, and user acceptance persist, indicating the need for ongoing exploration and development in this field.

2.2 Existing System

The current systems for patient care primarily involve manual monitoring by healthcare professionals, supplemented by medical devices for specific parameter readings. Telemedicine aids remote monitoring, while some facilities employ basic robots for tasks like supply transport. However, these systems lack comprehensive, continuous monitoring and robust autonomous assistance needed for round the clock patient care.

There's a gap in sophisticated robotic solutions that address diverse patient needs across healthcare settings, necessitating innovation for more efficient, adaptable, and responsive patient care robotics.

2.3 Theoretical framework

The theoretical framework for smart wheelchairs with integrated health monitoring systems draws from human-computer interaction (HCI), assistive technology, sensor technology, adaptive control systems, and user-centered design principles. HCI principles guide the design of user-friendly interfaces, ensuring accessibility for users with varying abilities. Assistive technology concepts underscore the role of the smart wheelchair in enhancing users' independence and quality of life by overcoming mobility limitations and providing essential health monitoring capabilities. Sensor technologies, including wearable biosensors and IoT devices, capture real-time health data, while data processing techniques, such as machine learning and AI algorithms, analyze this data to offer actionable insights.

Adaptive control systems enable the wheelchair to navigate environments safely and efficiently, adapting to changes in terrain and obstacles. User-centered design principles prioritize user feedback to create intuitive interfaces and customizable features tailored to individual user needs. This comprehensive framework provides insights into the functionality and potential impact of smart wheelchairs with integrated health monitoring systems on users' mobility and well-being.

III. RESEARCH METHODOLOGY

The development of a human-friendly system for individuals with disabilities entails a systematic approach involving several key phases. Beginning with requirement analysis, end users' needs and challenges are thoroughly understood through interviews and observations. The system design phase follows, focusing on conceptualizing a cohesive architecture integrating components like voice-controlled wheelchair movement and health monitoring sensors. Hardware and software integration ensures seamless communication between selected components. Specific functionalities, such as voice-controlled wheelchair movement and integration of health monitoring systems, undergo intricate programming and algorithm development. Rigorous testing and validation are conducted at each stage to ensure functionality, accuracy, and user-friendliness. Upon successful testing, the system is deployed, accompanied by comprehensive user training and support to ensure efficient utilization. This iterative process aims to effectively meet user goals and requirements, ultimately enhancing mobility, health monitoring, and independence for individuals with disabilities. Leveraging advanced technologies like ESP, Arduino, and Raspberry Pi 4, the integrated system exemplifies practical and sophisticated control mechanisms, setting a precedent for future technology-driven solutions in improving daily living.

3.1 System Overview

Our entire system is applied on a wheelchair which is manually controlled by the user. Our wheelchair looks like any normal wheelchair but with enhanced features and pros. The wheelchair is equipped with DPDT switches. DPDT switch can work in two ways like a normal switch at our home. With 4 DPDT switches the user can easily move the chair in any direction he/she wants. The reason we didn’t go with a joystick is because of the cost.

We want to keep the price as low as possible so that everyone can afford it. The wires from the DPDT switch box directly goes to the two DC motors attached at the bottom. The motors get its power from a 12V power supply from batteries which can be recharged and reused again.

3.2 Manual Controls and Bluetooth Connections

Everyone wants to become independent, especially the ones who must spend their entire life in wheelchairs. Our wheelchair is designed to enable individuals to move freely indoors and outdoors by their own. It is equipped with motors with two directional switches and can also be controlled by phone. Fig.2 shows the Manual Control and Fig.3 shows the Bluetooth Connection.

3.2.1 Manual Controls

We've integrated Double Pole Double Throw (DPDT) switches into our wheelchair, each featuring two inputs and four outputs. These switches utilize polarity reversal, enabling simultaneous handling of two energized circuits. With terminals labeled A, B, C, D, E, and F, we've connected AF and BE as depicted in the figure 1.

Terminals C and D are linked to the positive and negative battery terminals, while A and B are connected to the motor, acting as outputs ***Figure 1*** . By attaching two DPDT switches to the wheelchair, patients can easily control its operation.

The key advantage of utilizing DPDT switches is their ability to turn the wheelchair both ON and OFF simultaneously with just one flick of the switch.

3.2.2 Bluetooth Connections

The HC-05 is a module that helps devices talk to each other using Bluetooth. It's commonly used to connect things like microcontrollers or gadgets with Bluetooth capabilities. There are already lots of phone apps available in app stores that make using the HC-05 easier ***Figure 2 .***

In our wheelchair, we've also included a Bluetooth module called HC-05. This module lets the wheelchair connect to a smartphone. In the picture labeled "Bluetooth connection," you can see how the Bluetooth module is connected to an Arduino UNO, which acts like the brain of the wheelchair. The Arduino controls all the other parts connected to it.

Since the Arduino can't give enough power to the motor, we added a motor driver. This gives the motor the power it needs to work properly. The wheelchair runs on batteries that can be recharged and used again.

Using Bluetooth, the patient can move the wheelchair in any direction they want, like forwards, backwards, right, left, and diagonally. Having a motor system inside the wheelchair makes moving around the house much easier.

3.3 Inbuilt Health Monitoring System

The "Inbuilt Health Monitoring Facility" is a vital aspect of our Smart Wheelchair project. It addresses the need for continuous health monitoring, especially when caregivers cannot be present round-the-clock. Our system integrates a Heartbeat Sensor, specifically the 'SEN-11574', attached to the patient's hand in the wheelchair. This sensor swiftly captures pulse values at 30-second intervals, ensuring real-time monitoring. These pulse values are transmitted directly to our database via NODEMCU, recording each reading with timestamps.

While smart wheelchairs are available in foreign countries, the integration of an Inbuilt Health Monitoring Facility is a rare feature.

3.4 Safety Measures

Several safety measures have been taken to protect the users. One out of them is alerting via SMS. Signals detected are then processed and analyzed before sent via SMS to alert medical experts or family members. It is beneficial in terms of cost, no complicated settings, save time and even very helpful for patient whom lives alone. Also, a website has been made where the users health details will be stored and protected via password set by them.

3.4.1 Pulse Rate

Heart beat Rate: When the heart beats, a pressure wave moves out along the arteries at a few meters per seconds (appreciably faster than the blood flows). This pressure wave can be felt at the wrist, but it also causes an increase in the blood volume in the tissues, which can be detected by a Pulse Sensor ***Figure 3*** . As the ***Table 1*** shows the average heartbeat rate range versus the age of person.

3.4.2 About The Equipment

A Heartbeat sensor is a device used to measure heart rate in real-time or record it for later analysis, providing valuable insights into heart function. This sensor detects blood flow through the finger and generates a digital output representing the heartbeat when a finger is placed on it. The digital output can be directly connected to a microcontroller to measure the Beats per Minute (BPM) rate. The Pulse Sensor is a user-friendly heart-rate sensor designed for Arduino, featuring an open-source monitoring app for real-time pulse graphing.

The Arduino Uno is a microcontroller board with digital input/output pins, analog inputs, and a USB connection, making it easy to connect to a computer or power source. It's an open-source platform for writing software and controlling hardware.

Additionally, the Arduino GSM Shield enables connectivity to the internet, voice calls, and SMS messaging. It utilizes a radio modem M10 by Quested and can be controlled using AT commands.

3.4.3 System Block Diagram

The above block diagram gives an overview of the project. The chair is mainly connected to ESP, Raspberry Pi, and Arduino Uno boards. The components connected to the Arduino Uno board are mostly for controlling the movement of the wheelchair. The Raspberry Pi is connected to a camera for face detection to prevent intrusion or theft, while the voice assistant acts as an assistant to communicate with the user. The components connected to the ESP are for health monitoring and for communication purposes. **Figure 4**

3.4.4 Movement Control

The wheelchair's movement is dictated by user instructions through three primary control methods, providing versatility and accommodating individual preferences. Users can effortlessly navigate the wheelchair according to their specific requirements, optimizing comfort and accessibility. Whether through manual controls, wireless Bluetooth connectivity, or voice commands, the wheelchair ensures ease of operation and enhances user autonomy. This multifaceted approach to control ensures that users can effectively and efficiently maneuver the wheelchair in various environments, promoting independence and improving overall mobility assistance. ***Figure 5***

3.4.5 Health Monitoring

Regular health updates are collected and transmitted to the designated caregiver responsible for the user's well-being.
These updates provide crucial information about the user's health status, ensuring timely monitoring and intervention, when necessary, thereby facilitating effective care and support for the user. ***Figure 6***

3.4.6 Future Aspects and Challenges

As we know it consists the hardware project hence will be having the both future aspects and the challenges as mentioned below:

3.4.6.1 Challenges

Smart wheelchairs present a promising arena for ongoing technological exploration. They serve as valuable platforms for sensor research, particularly in machine vision. Additionally, they offer opportunities to delve into human-robot interaction, adaptive or shared control, and innovative input methods like voice control, EOG, and eye-tracking. However, in our country, there has been limited effort in smart wheelchair development, with few researchers involving people with disabilities in evaluation activities. Furthermore, comprehensive, controlled evaluations of smart wheelchairs in real-world settings are lacking, primarily due to the prohibitive hardware costs involved in constructing sufficient units. Conducting user trials presents challenges, as immediate improvements in navigation skills may not be evident, and long-term studies are necessary to understand the true impact of smart wheelchair usage.

3.4.6.2 Future Aspects

The future of smart wheelchair research holds several intriguing possibilities. One important aspect is understanding the role of smart wheelchairs as mobility aids, training tools, or evaluation instruments. Studies suggest that users accustomed to their wheelchairs may have little tolerance for new features' failures, emphasizing the importance of full autonomy. To address these trends, future research directions should focus on the following priorities:

3.4.6.3 Human-Smart Wheelchair Interaction Model

Developing an efficient interaction model between users and smart wheelchairs is essential. Leveraging learning techniques, such as boosting learning, can aid in creating robust interaction models. These models should integrate sensor feedback from devices like Emotive sensors, environment sensors (e.g., virtual reality sensors, laser scanners, cameras, GPS), and robotic arms. Shared control schemes could facilitate effective collaboration between users and smart wheelchairs, adapting assistance to user performance and environmental changes.

3.4.6.4. Autonomous Navigation

Future smart wheelchairs should offer autonomous or semi-autonomous navigation options, catering to users' preferences. Users should be able to select operating modes based on their comfort level. These wheelchairs should navigate preprogrammed routes with minimal physical or cognitive effort, indoors and outdoors. Individualized profiles can track user preferences, optimizing input methods, wheeling speed, turning speed, and verbal feedback.

3.4.6.5 Smart Wheelchair with Smart Home

Integration of smart wheelchairs with smart homes can enhance user experience and control over household appliances. Outdoor models could feature retractable roofs for weather protection and additional safety measures. Advanced imaging technologies, including optical stereoscopic and spherical vision imagery, combined with machine vision algorithms, can enhance navigation and obstacle avoidance. Localization data from IMU, GPS, and Bluetooth beacons can guide smart wheelchairs to their destinations. Future smart wheelchairs should adhere to liability regulations similar to plug-in electric vehicles, requiring user certification or licensing following standardized wheelchair skills tests.

IV. RESULTS AND DISCUSSION

4.1 Results of Experiment

In this section, we evaluate the system's performance in real operational environments. The first experiment assessed the system's responsiveness to user commands using two switches. The user navigated the wheelchair prototype in a cluttered lab environment using full manual control and semi-autonomous control. With the use of switches, the user successfully reached checkpoints and completed maneuvering tasks without collision. Additionally, Bluetooth connectivity between the chair and phone was established. Semi-autonomous mode required less user effort, as interaction was only needed to change travel direction. Testing with phone control yielded satisfactory results, as depicted in ***Figure 7*** illustrating the connection between ARDUINO, Motor, and cellphone.

To test our safety measures thoroughly, we deliberately simulated a scenario mimicking that of a heart patient. This simulation aimed to evaluate the effectiveness of the GSM module's heartbeat monitoring alert system, which sends notifications via SMS in case of irregularities. ***Figure 8*** The simulation involved monitoring the simulated patient's heartbeat closely to ensure that the system responds promptly and accurately to any deviations from the normal range.

Moving forward, ***Figure 9*** showcases the culmination of our efforts – the final model of the wheelchair. This model incorporates all the necessary components, meticulously assembled to ensure seamless functionality. Each component has been integrated into the wheelchair's design in a systematic manner, resulting in a comprehensive and reliable system ready to serve its intended purpose.

Figures and Tables

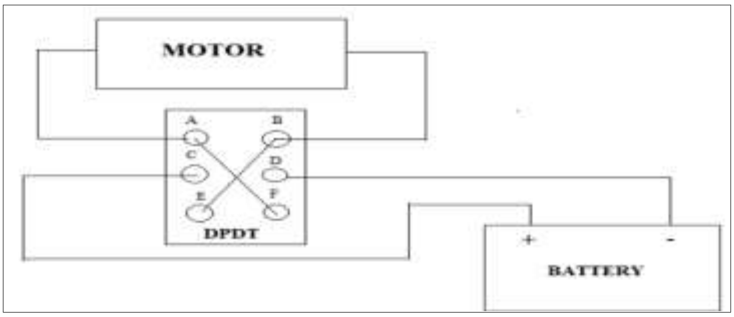

Figure 1

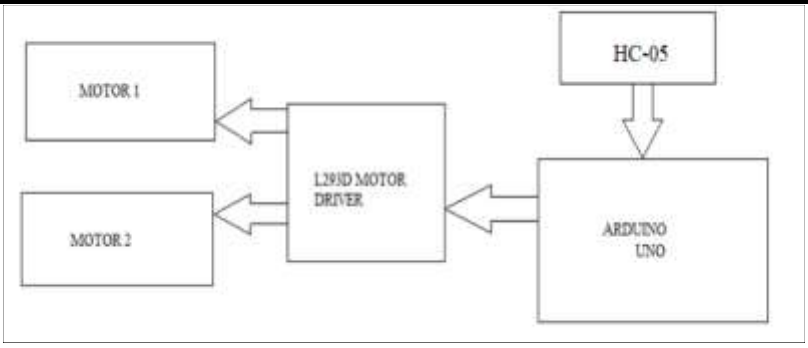

Figure 2

Figure 3

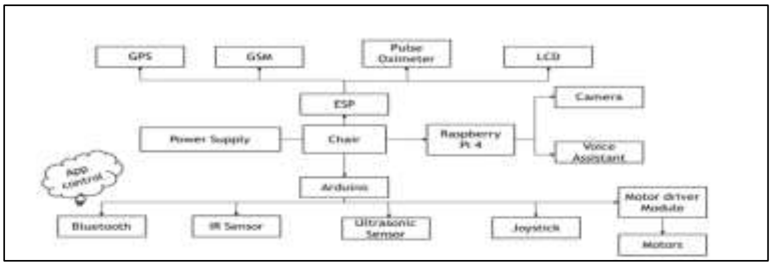

Figure 4

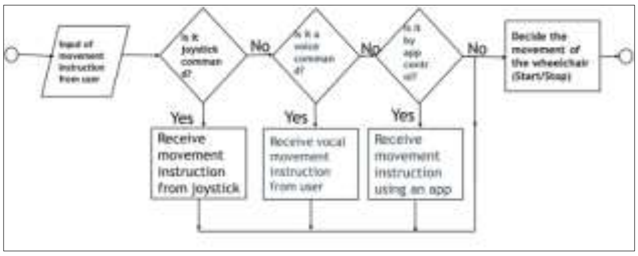

Figure 5

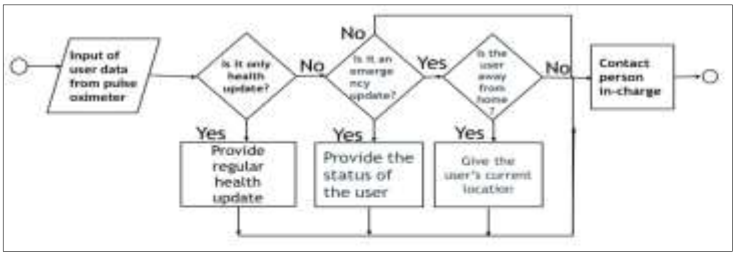

Figure 6

Figure 7

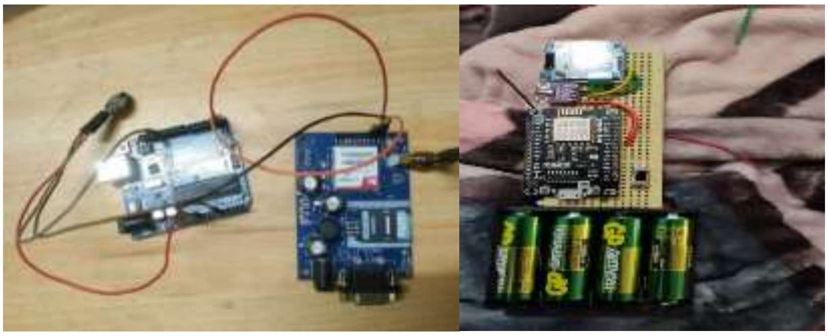

Figure 8

Figure 9

Table 1 Table of Pulse Rate

AGE	RANGE	AVERAGE RATE
<1 year	80-180	130
1-3 years	80-160	120
4-8 years	70-120	125
9-11 years	60-110	85
12-16 years	60-110	85
>16 years	60-100	80

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