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Smart Wheelchair for Locomotive Patients

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ABSTRACT

Designing equipment for individuals with special needs is challenging due to their unique clinical picture. This variability makes it difficult to develop new technologies that can meet everyone's specific needs effectively. Thus, the design of assistive devices for individuals with special needs requires careful consideration of each person's unique challenges and requirements, making it a complex and nuanced process. This project aims to help them maneuver without social assistance, designed for people who lost mobility due to brain injury or limb loss but retain speech. It enhances a powered wheelchair with advanced sensors to detect surroundings, critical for those with locomotive disorders. The intuitive display offers multiple modes, including Speech, Gesture, and Joystick, and the Arduino Mega processes user specifications to rotate the motors accordingly. The wheelchair includes a Battery Indicator and Ultrasonic sensors for obstacle detection, providing an extra layer of safety. This approach aims to develop reliable and efficient technology to significantly improve the mobility and independence of individuals with locomotive disabilities.

Keywords: Battery indicator, Gesture mode, Joystick control, Smart Wheelchair, Speech interface,

INTRODUCTION

The prevalence of physical disabilities is increasing rapidly, influenced by factors like aging, lifestyle changes, and occupational hazards. The World Health Organization predicts a significant rise in disability rates in the future. Moreover, inadequate accessibility in public places, including stairs, narrow doorways, and restrooms, can compound the difficulties faced by individuals with disabilities [8]. Technology is providing new ways to enhance the lives of individuals with physical disabilities. Advanced electric wheelchairs with features like voice command are now available, making it easier for those with paralyzed hands or arms to operate them. Researchers are developing exoskeletons that enable people with spinal cord injuries to stand and walk again. The concept of a smart wheelchair is also revolutionizing assistive technology, offering greater independence for those with mobility issues.

The wheelchair is designed to be operated without any social assistance, making it an ideal solution for people who require a high degree of autonomy. The system is particularly well-suited to individuals who have lost mobility due to brain injury or the loss of limbs, but who retain the ability to speak. The wheelchair's sensors detect its surroundings and provide real-time data to the system's control unit, which is an Arduino Mega microcontroller. The control unit processes this information and translates it into motor commands, allowing the wheelchair to navigate through complex environments. One of the most innovative features of this wheelchair is its user interface. The system provides a variety of modes of operation, including a Speech interface that interprets verbal commands, a Gesture mode that recognizes hand movements, and a Joystick for manual control. The interface is designed to be easy to use, with large buttons and clear graphics that make it accessible to users of all abilities. To ensure the safety of the user, the wheelchair is equipped with an Ultrasonic sensor that detects any obstacles in its path. In addition, a battery indicator is used to signal low battery levels, helping users to avoid being stranded without power.

PROBLEM STATEMENT

Recent statistics show that India's population has reached 1.38 billion, with a 2.08% prevalence rate of locomotor disability affecting both genders. The majority of this population (60%) belongs to lower-class households, with nearly half being illiterate. Cerebrovascular accidents and cerebral palsy were the leading causes of locomotor impairments (25% and 23% respectively). Those with locomotor disabilities found mobility to be the most challenging domain (80%), followed by self-care (57%) and interpersonal skills (63%) [3]. Current wheelchair designs require physical effort to control, limiting independence. To address this, new wheelchair designs are necessary to enhance mobility, safety, comfort, and social interaction for people with locomotor disabilities.

Objective

The objective of developing a user-friendly system for people with locomotive disabilities is to address the challenges faced by wheelchair users, such as limited mobility, safety concerns, and lack of independence. By developing a system that is easy to use and accommodates different modes of operation, individuals with locomotive disabilities can have greater control over their mobility and enhance their quality of life.

The three modes of operation include voice, gesture, and manual control, which allow users to operate the wheelchair using different methods depending on their physical abilities and preferences. Voice recognition technology enables users to control the wheelchair using verbal commands, while gesture control involves using hand or head movements to navigate the wheelchair. Manual control is also provided as an option for users who prefer a more traditional method of controlling the wheelchair.

By providing multiple modes of operation, individuals with different levels of physical ability can use the system to enhance their mobility and independence. This objective aligns with the goal of promoting inclusivity and accessibility for individuals with disabilities, and has the potential to transform the way in which wheelchair users interact with their environment.

LITERATURE REVIEW

Anuradha Jayakody, Asiri Nawarathna, Indika Wijesinghe, Sumeera Liyanage, Janith Dissanayake[1] proposed a smart wheelchair to facilitate disabled individuals. The wheelchair has a motor system, voice recognition, microcontroller, and microprocessor, and offers manual and autonomous modes of operation. A speech recognition system with a controller and microphone sends voice commands from the user to the software modules, which use the Google STT engine to convert speech to text. A. Tayab Noman, M. S. Khan, M. Emdadul Islam, and H. Rashid [2] proposed a Gesture Controlled Smart Wheelchair that utilizes a microcontroller. This wheelchair makes use of Arduino programming, and an IP camera for remote monitoring and emergency assistance. Naveen Kumar K., T. Swetha M. E., B. S. Sai Kumar, and K. Rahul [3] developed a smart wheelchair with two modes, voice and hand gesture, for quadriplegia, hand amputees, elderly people, and paralyzed patients. The motor is operated by Embedded C software in the voice-controlled mode, which uses an Android application and accelerometer. The second mode, hand gesture mode, utilizes flex sensors attached to hand gloves. Mohammed Abdul Kader el at. [4] proposed a semi-autonomous wheelchair for quadriplegic patients based on head motion control using a 3-axis accelerometer sensor. The wheelchair includes two DC motors for propulsion, two sonar sensors to detect obstructions, and a GSM modem for sending position information to family members in case of accidents.Sajid, Mubdi-Ul Alam, Md Firoz Mahmud, Imteaz Rahaman, Saquib Shahriar and Mim Naz Rahman[5] developed a smart wheelchair for individuals with disabilities, incorporating multiple sensors such as a gyro sensor, accelerometer, sonar sensor, and tilt sensor.

The wheelchair is controlled through gesture control using a gyro sensor connected to an Arduino Nano. Amiel Hartman and Vidya K. Nandikolla [6] proposed a low-speed autonomous smart wheelchair with smart feature electronics that work with controllers and joysticks for people with a variety of limitations. The wheelchair has a vision system for spotting terrain impediments and data integration into the user interface for visual feedback, aimed at enhancing real-time data. Samuel Oliver and Asiya Khan[7] designed a customizable open-source joystick control system for wheelchair users with dexterity disabilities. The system includes a body-mounted accelerometer for motion detection and gesture control, enhancing accessibility, universality, and resilience for all users. Atif Naeem, Waqas Safdar, and Abdul Qadar [8] proposed a Voice Controlled Intelligent Wheelchair using Raspberry Pi, with DC motors, an Arduino microcontroller circuit, and ultrasonic sensors to detect obstructions in the path of the wheelchair's movement. Joseph, Cynthia, S. Aswin, and J. Sanjeev Prasad [9]proposed a voice and gesture-controlled wheelchair which mainly has two modes i.e., voice and gesture. Arduino microcontroller and voice recognition have been used to support the movement of the wheelchair. Ultrasonic sensors are used to detect obstacles. Evangelin Glory N, Vijayalakshmi P, Satheesh Kumar G[10]proposed a Speech and Gesture Enabled Wheelchair System that uses a speech recognition system trained with Hidden Markov models and a deep-learning based speech recognition system for both English and Tamil. A user-defined hand gesture recognition system is built using accelerometer-gyroscope-based MPU 6050 with ESP32 Bluetooth enabled device, and the wheelchair control is enabled by a robotic arm to control joystick functionalities through speech or gesture.

METHODOLOGY

This wheelchair features an easy-to-use display for selecting different modes of operation:

- A Speech interface for interpreting commands with the help of a microphone
- A Gesture mode using an accelerometer sensor for controlling the motion
- Joystick for manual control

The system is built to function in a number of modes that let people direct the wheelchair's movements in accordance with their needs. These modes are integrated with and linked to an Arduino Mega, which serves as the wheelchair's primary controller. The Raspberry Pi 4 communicates commands to the Arduino Mega via a motor driver, which enables the robot to move in the correct direction. Ultrasonic sensors are also used to identify objects that are close to the robot and prevent collisions. The Raspberry Pi 4GB serves as the central controller for the robot, managing all of its operations. To power the motors, a rechargeable 24-volt battery is used.

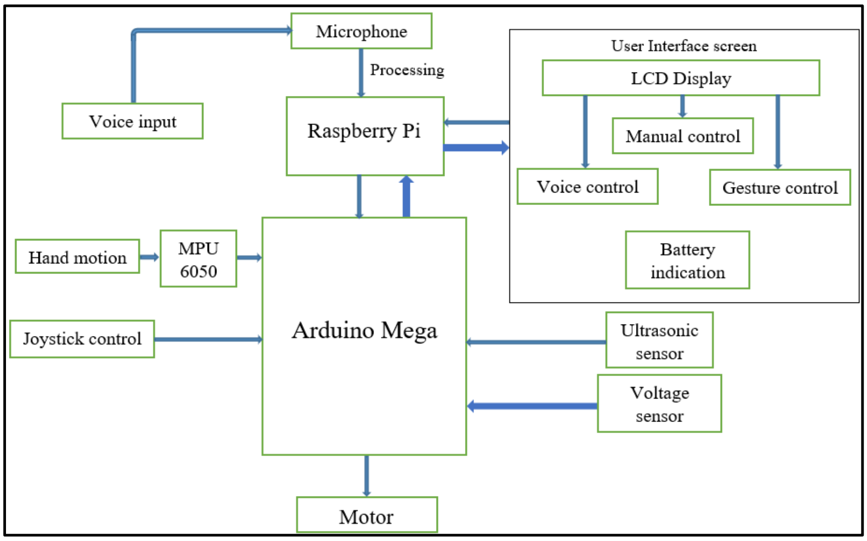

Figure 1: Block Diagram

The smart wheelchair seamlessly integrates all three modes of operation – voice mode, gesture mode, and joystick mode - into a cohesive system that enables users to control their mobility with ease and flexibility.

Hardware Architecture Of Individual Modes

The sub controller of the smart wheelchair is implemented with Arduino controller. It is mainly used to receive serial data from the main controller i.e., the LCD display. The received data is analyzed by the Arduino. Arduino issues signal to the motor driver to drive the wheelchair.

(i) Voice Mode

A microphone is attached to the wheelchair is used to capture the voice commands. The microphone is used to capture the voice input from the user as commands. When the command "forward" or "back" is given, wheelchair goes forward or back. Commands, "turn left "and "turn right" commands make the wheelchair turn left or right. Command "stop" makes the wheelchair stop and apply brakes.

(ii) Gesture Mode

User's hand gestures are detected through an attached sensor, which identifies the position of the user's palm and determines their intention. The main controller evaluates the gestures and sends corresponding action commands to the sub-controller via a serial communication link. An accelerometer measures an object's acceleration or velocity changes, which is useful in a wheelchair to detect sudden stops, starts, or turns. MPU6050 tracks chair movement based on user's hand movements, aiding quadriplegic mobility.

(iii) Manual Mode

An analog joystick is a two-dimensional input device that controls the wheelchair's direction/speed. Joystick mode signals Arduino to execute functions. Joystick connects to Arduino for control mode functions. The joystick's position can be customized on the chair's armrest or controller based on the user's preference/abilities. It is calibrated to move in user-specified directions. Joystick signals control motor driving circuit for desired movement.

Integration Of Ultrasonic Sensors

Two Ultrasonic sensors are placed around the wheelchair body to stop the motor's movement in case the patient on the chair comes across an obstacle or a staircase. The ultrasonic sensors used in this system are a type of distance sensor that operates by emitting high frequency sound waves and measuring the time it takes for the waves to bounce back after hitting an object. These sensors are capable of detecting obstacles even in low-light conditions or situations where visual sensors may not be effective. The Microcontroller Unit System (MCU) is the brain of the system and is responsible for processing the data received from the sensors. The MCU analyses the distance data and sends signals to the motor driving circuit to either slow down or stop the motors based on the predefined threshold. In addition to obstacle detection, the ultrasonic sensors can also detect the presence of stairs, which is an important safety feature for wheelchair users. If the sensors detect a staircase, the MCU can stop the motors to prevent the wheelchair from falling down the stairs and potentially causing harm to the patient. The wheelchair then changes directions in the mode it was working previously and continues moving. Overall, this system provides an important safety feature for wheelchair users, allowing them to navigate their environment with greater ease and security.

Battery Indicator

A voltage detection sensor module is being used to monitor the battery level. This module is able to measure the voltage of the battery and provide an output value that can be processed by a Raspberry Pi. To use the module, an initial voltage value is set in the code, which represents the voltage level of a fully charged battery. For example, if the battery being monitored has a maximum voltage of 24V, this value would be used as the initial voltage value. When the voltage detection sensor module is first connected to the battery, it will output the same voltage value as the initial voltage value specified in the code. This value is then processed using a formula shown below to convert the voltage value into a percentage value that represents the current battery level.

$$\text{int output} = \frac{(\text{in\_voltage} - \text{battery\_min})}{(\text{battery\_max} - \text{battery\_min})} X\ 100 \qquad (1)$$

The resulting percentage value is then sent to the Raspberry Pi, where it is displayed on an LCD screen. This allows the user to easily monitor the battery level and see how much charge is remaining. Additionally, if the battery level drops below a certain threshold, it can be programmed to send an alert message to the user to indicate that the battery needs to be charged. This helps ensure that the battery is always charged and ready for use.

Integration Of All Modes

The speech interface, gesture mode, and joystick mode are all seamlessly combined into one system by the smart wheelchair, allowing users to easily and adapt ably control their movement. The user may easily adapt to their environment and preferences by switching between these modes using the intuitive display. For instance, the user can switch to gesture mode to operate the wheelchair with hand motions if they are in a noisy area and are unable to use the speech interface. The user can switch to the speech interface to issue voice commands if their hands are otherwise occupied. The integration of these modes also enables the smart wheelchair to provide users with greater safety and convenience. For instance, regardless of the user's current mode, if the wheelchair uses ultrasonic sensors to identify an obstruction in its route, it will halt the motors. Moreover, the user interface shows the battery level and alert messages when the battery needs to be recharged, protecting the user and avoiding unplanned shutdowns.

Result And Discussion

The smart wheelchair is designed to prioritizes user’s comfort and control. Users can select the mode that best suits them based on their skills and preferences from the three controlling options available to them: voice, gesture, and joystick. In contrast to the gesture mode, which allows the user to operate the wheelchair by making precise hand motions, the voice mode enables the user to give voice commands to the wheelchair. For users who prefer conventional wheelchair controls, the joystick mode is ideal. The main user interface, displays all of the wheelchair's essential controls and settings, to choose the desired mode before switching between them. The primary user interface links the smart wheelchair's three control modes—voice, gesture, and joystick—together. Once the mode is selected, the wheelchair will be configured to receive commands from that mode and operate.

Figure 2: Different Modes of Operation shown on the Display Screen

The wheelchair's battery life plays a key role in how effectively it functions, and the user interface shows the battery level as a % so that the user may monitor how much life is still left in the battery.

Figure 3: Wheelchair Used

The wheelchair won't suddenly stop while in use if the battery level drops too low because the warning prevents sudden stops. A critical aspect of the smart wheelchair is obstacle detection. Ultrasonic sensors on the wheelchair can detect objects in its path. The microcontroller unit (MCU) will turn off the wheelchair's motors if it detects an obstruction, protecting the user by preventing a collision.

CORE FEATURES OF THE WHEELCHAIR

Customized gesture implementations

There are some patients who cannot move their wrist but can move their arm, and there are others who cannot move their arm but can move their shoulders. In these circumstances, the end user can set the gesture sensor wherever it is most appropriate.

Miniature and sensitive Joystick

Bulky joysticks make the operation difficult for patients with limited finger sensation. Hence, miniature, and sensitive joysticks are used.

Adjustable Controls

The controls are feasible for both left and right-handed users.

Emergency Stop Button

An emergency stop switch is a safety device used to turn off the wheelchair in a crisis when it cannot be turned off normally.

User Friendly and Flexible Interface

A user-friendly display that makes it simple to choose between different operating modes and providing quick access to common features or commands.

CONCLUSION

The development of a smart wheelchair with different modes of operation, including voice, gesture, and manual control, along with ultrasonic sensors to detect obstacles, is a significant step towards improving the mobility and independence of people with physical disabilities. However, there are still several challenges that need to be addressed, such as balancing cost and accuracy, creating smart wheelchairs that cater to different types of disabilities, monitoring patient conditions, and researching smart wheelchairs for independent use by mentally challenged individuals. Despite these challenges, the potential for technological advancements in the field of robotics and sensors makes the future of smart wheelchairs promising, and they have great potential for widespread commercial success in the years to come.

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