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A CAR WITH A SPECIAL STEERING SYSTEM FOR MUSCULAR DYSTROPHY DISORDERED PEOPLE

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Abstract - This project showcases the design and development of a unique steering system tailored for individuals living with Muscular Dystrophy (MD), a neuromuscular condition that leads to progressive muscle weakness and a decline in motor control. Conventional steering systems demand constant rotational force and a strong grip, which can be challenging for drivers with MD. The innovative solution we propose features a low-effort, joystick- based steering interface paired with an electronic drive-by-wire control system, allowing for safe and independent vehicle operation. Our design incorporates high-sensitivity sensors, adaptive force calibration, and multiple safety redundancies to cater to different levels of muscular ability. We developed both hardware and software components to guarantee real-time responsiveness, stability, and reliability of the system. Experimental tests show that this adaptive steering system significantly lessens the muscular effort needed while ensuring precise vehicle control, highlighting its potential to improve mobility and accessibility for those with muscular dystrophy.

Keywords– Muscular Dystrophy, Adaptive Steering, Assistive Driving, Drive-by-Wire, Joystick Control, Vehicular Accessibility, Electromechanical Actuation, Rehabilitation Engineering.

I. INTRODUCTION

Muscular Dystrophy (MD) is a collection of inherited neuromuscular disorders that lead to progressive muscle degeneration and weakness, mainly impacting the skeletal muscles that help us move voluntarily. As MD progresses, individuals often face serious challenges with motor control, grip strength, and mobility in their upper limbs, making it tough to handle standard vehicle steering systems. The decline in muscle mass, along with fatigue and limited joint movement, can make using a traditional steering wheel—which requires constant rotation, a strong grip, and repetitive upper-body effort—almost impossible for many. Since mobility and independence are vital for a good quality of life, there's a growing interest in developing accessible and adaptive vehicle control systems. Being able to drive is essential for people to engage in everyday activities like work, education, accessing healthcare, and socializing. Thus, individuals suffering from muscular dystrophy are usually dependent on caregivers, specially equipped vehicles, or mobility devices for their movement. Such a reliance not only constricts one's freedom but also may cause psychological issues like low self-esteem and feeling of being isolated.

Hence, the provision of independent driving through the help of adaptive steering systems is a big move towards inclusion, giving back power, and better life conditions for those who have muscular disabilities.

The presently available disability adaptation options for people with physical impairments involve the use of spinner knobs, tri-pin grips, reduced-effort power steering systems, and hand-control devices. These are designed to assist people who have some mobility and can be carried out by individuals with mild or moderate mobility limitations, but they are not adequate to MD patients who do not have the strength to perform even a small amount of torque. Due to the progression of MD, a device should not only be there to support but also be able to adjust to the declining muscle strength over time. This underlines a need for a steering system that is an electronically operated without any user effort and is fully customizable according to the user's health condition.

Its recent developments in automotive electronics, drive-by- wire systems, and human-machine interfaces (HMI) have allowed for the replacement of traditional mechanical steering linkages with electronically controlled systems. One of such system is drive-by-wire technology that records the user's movements and translates them into digital inputs, therefore it allows for the exploration of the features that were hitherto impossible in traditional steering like low- effort and extremely accurate steering mechanisms. The latter, when combined with an ergonomic input device like a joystick or a touch-enabled controller, makes it a lot easier to handle a vehicle. To top it all, sensors, microcontrollers, and advanced feedback algorithms not only enable continuous monitoring of steering input but also ensure that the system being actuated is safe and reliable

This proposed steering system uses electromechanical actuation, human-centered interface design, and accessible engineering principles to extend the driving independence and safety of those with muscular dystrophy. The importance of this work goes beyond simply making transportation more accessible. It shows how new technology can be used to create inclusive mobility solutions for people with neuromuscular disabilities. This paper provides the details on the system design, architecture, safety features,

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implementation methods, and evaluation results, thus supporting its viable.

II. LITERATURE REVIEW

The literature on adaptive driving systems has been substantially enriched with several recent publications. Nevertheless, the majority of these publications are directed towards alternative control means, such as gesture control, voice interfaces, brain-signal processing, and embedded automation, to name a few. While these have certainly paved the way for more accessible and independent vehicular systems, their inherent limitations emphasize the demand for a novel steering method tailored for Muscular Dystrophy (MD) patients who experience severe muscle weakness and reduced limb mobility.

In their paper, Boopathy et al. (2024) introduced the concept of a cutting-edge electrically-powered vehicle tailored for the physically disabled. The design featured the integration of embedded systems, the Internet of Things (IoT), and a foot-console mechanism. Their study, in general, endorses the adaptation of vehicular interfaces to the needs of disabled users. The major drawback of this method, however, is that it depends on a single-foot operated console, thus limiting its functionality to those who have both upper and lower limb impairments. Consequently, the majority of MD patients who might be incapable of controlling both of their extremities can find no use in this device. Hence, it is imperative that more safe and handy solutions for steering be invented which by their nature would require almost no physical exertion.

Mohammed Abdul Kader et al. (2023) designed a system utilizing machine learning techniques to recognize hand gestures for controlling the speed and direction of a DC motor. Trends in smart machines show that intelligent algorithms can swiftly learn to identify correct hand gesture expectations in order to perform electromechanical operations. However, their system is also dependent on a computer continuously recognizing the gestures, thereby rendering the device rather unsuitable for ordinary vehicular uses in the outside world, particularly for MD patients who may have difficulties performing consistent and precise hand gestures due to progressive muscle degeneration.

Vanitha et al. (2023) came up with a method of transmitting messages by means of modulated human body movements with the purpose of helping the disabled. The technology employed in their model includes motion detection and voice communication methods. One major drawback is that the technology is far from being a vehicular control system and is susceptible to hardware failure, which makes it less reliable for the role of the main steering mechanism in a high-risk system such as automobile navigation. However, the investigation supports the notion that designing dependable assistive systems that can operate in real-time is of utmost importance, which is the primary requirement for MD- oriented

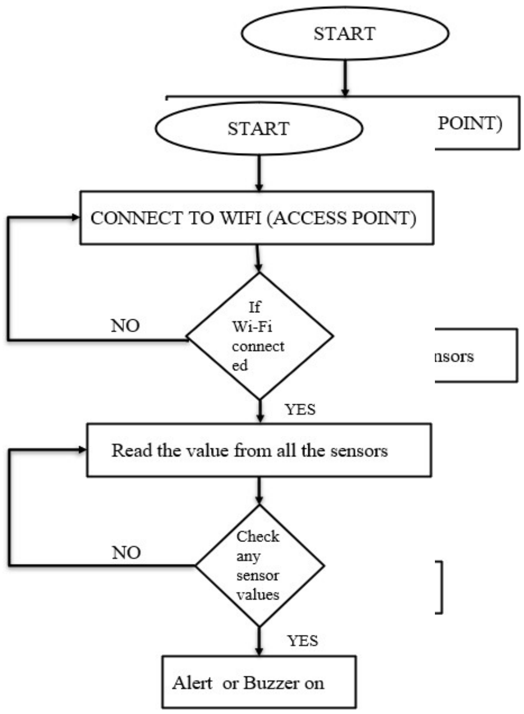

Fig 1. *Encryption and Decryption flow diagram*

The flowchart presents the stepwise operation of the adaptive steering system for a person with Muscular Dystrophy. After the system is powered up, it tries to connect to a predetermined Wi-Fi access point. Such a connection is necessary to allow remote monitoring and communication features of the system. In case the Wi-Fi cannot be connected, the system will keep trying to establish the connection. When the connection is made, the microcontroller gets the sensor data in real-time from all the sensors that are integrated into the system. These include the joystick position sensors, proximity sensors, and steering feedback sensors. As a result, the system can detect the user's very minimum steering input and can operate the vehicle correctly.

Once the sensor data are received, the system assesses the data for any indication of an abnormal or dangerous situation. If every sensor value is within the range of the operating thresholds, the system goes back to the monitoring loop again. On the other hand, if any sensor detects irregularities, such as the presence of unexpected obstacles, abnormal steering input, disconnection, or hardware malfunction, the system promptly alerts the user by turning on the buzzer or alert. This alerting system is thus safer because the user is given the immediate feedback and hence the hazards that may arise during the steering operations are avoided. In brief, the flowchart provides a dependable, fault-tolerant, and user-centric control process for the severely muscled individuals.

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III. METHODOLOGY

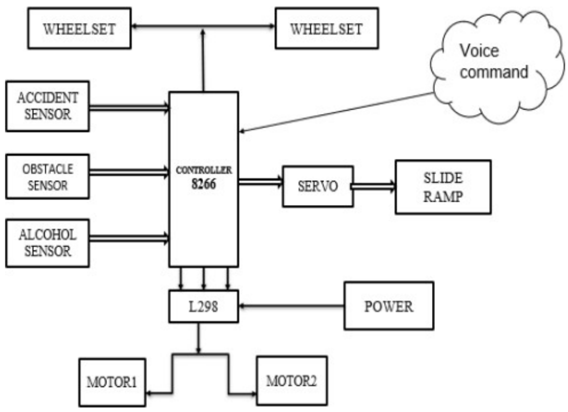


Fig 3. Proposed system methodology.

The methodology of the proposed system is built around the ESP8266 microcontroller, which controls several hardware devices and sensors to develop a low-effort, safe, and stable steering system for people suffering from Muscular Dystrophy. The system architecture depicts the microcontroller as the brain of the system, which processes the CPU input signals from numerous sensors and issues commands to the actuators in charge of steering and vehicle movement. Three major sensors, namely accident sensor, obstacle sensor, and alcohol sensor, are constantly feeding the microcontroller with their real-time data. The accident sensor detects sudden collisions or abnormal tilt situations while the obstacle sensor detects the presence of objects around to prevent unsafe steering actions. Also, the alcohol sensor enhances driver safety by keeping track of the driver's condition and preventing vehicle movement when high alcohol levels are detected.

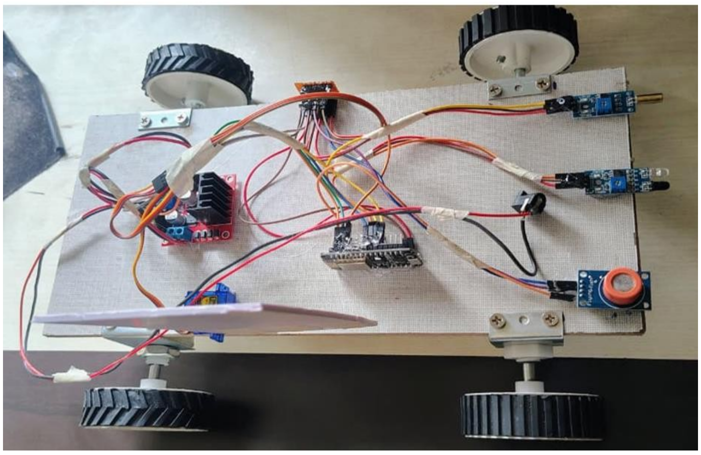
After receiving data from all sensors, the microcontroller executes the necessary program and sends control commands. The instructions are delivered to the L298 motor driver, which adjusts the power that is to be given to Motor 1 and Motor 2, thus enabling the smooth and controlled movement of the wheelset. The L298 driver is responsible for providing the motors with adequate power and precision, which is a prerequisite for directional control. At the same time, the servo motor, which is linked to the slide ramp, takes care of the steering function. Once the microcontroller releases the steering commands, the servo motor makes the necessary adjustments on the slide ramp hence allowing the user to make precise yet small steering movements suitable for people with limited muscle strength. The system as a whole is powered by a regulated power module that guarantees the stable operation of the motors, sensors, and microcontroller.

The approach described here provides uninterrupted monitoring, safety in actuation, and control flow consistency in the entire system. By combining sensor feedback with motor and steering actuation, the system becomes adaptive, efficient, and user- friendly, thus meeting the needs of muscular dystrophy patients. Safety, precision, and minimal user effort that are among the most important features of accessible steering systems, are the main focus points of this approach.

IV. RESULTS AND DISCUSSION

Outputs :

Fig 4. Complete hardware prototype of the proposed special steering system.



The prototype model depicted in Fig.4 is a full hardware implementation of the proposed adaptive steering system for muscular dystrophy patients. Basically, it is an ESP8266 microcontroller that is centrally mounted and is interfaced with multiple sensors like accident, obstacle, and alcohol detectors that are placed along the edges for better safety monitoring. The L298 motor driver is connected to two DC motors to control the rear wheel movement, while the servo motor at the front is used to control the steering. All the components are connected with each other through a well-organized wiring system, thus forming a functional vehicle platform that shows the operation of the special steering and sensor-based safety system.

1. L298 Motor Driver Module:

The L298 motor driver is instrumental in regulating the speed and changing the direction of the DC motors that are used to move the vehicle. The driver acts as a bridge between the microcontroller, which provides low-voltage logic signals, and the motors, which require high-current, thus ensuring the operation is safe and efficient. The module embodies a dual H-bridge design, thereby, allowing the independent control of two motors at the same time. Its onboard heat sink attracts and dissipates the heat, thus, L298 can work for long hours under heavy load without overheating. The circuit can also reverse the motor to run it in the opposite direction apart from just rotating the motor in the forward direction which is the only way for the vehicle to move. By using the dedicated enable and input pins, it becomes possible to control motor speed by implementing pulse-width modulation (PWM) very accurately. To sum up, the L298 driver is the one that makes the motor running smooth, reliable, and responsive to the user's needs which is absolutely necessary for any mobility application.

2. ESP8266 Microcontroller:

The ESP8266 microcontroller is the brain of the system. It takes care of the inputs from all the sensors and sends the outputs to the actuators to keep everything running in harmony. Thanks to the Wi-Fi feature integrated into the microcontroller, communication over the air is possible, thus allowing steering functions to be monitored remotely.

The microcontroller interprets the joystick or any other control signals and makes the motor and steering commands accordingly. It is equipped with a fast processor which makes the vehicle can be controlled in a safe and accurate manner even in real-time, thus providing a quick response to the situation. The module, which is loaded with several GPIO pins, is able to work smoothly with sensors, motor drivers, and servo mechanisms.

3. Dc motor:

One of the main uses of DC motors is to provide the rear wheels of the vehicle with the necessary power and hence create the movement of the vehicle. Along with that, they provide the required torque for a smooth and energy-efficient operation. Due to their small and light nature, they are the perfect choice for the creation of a prototype and for small-scale mobility systems. The motors, which are equipped with a PWM-based speed control, deliver acceleration and braking of the vehicle of a smooth nature, thus the handling and comfort become of a better standard. They are able to change the direction of the command very fast as given by the motor driver, which results in an accurate control of the movement.

4. Obstacle , Alcohol and Accident/Vibration Sensor

The system is equipped with obstacle, alcohol, and accident sensors to enhance the user's safety and facilitate trustworthy operation. Obstacle sensors keep checking the environment to find any objects close to the vehicle and avoid collisions by sending the signals that adjust or stop the vehicle's movement. Their quick response time guarantees up-to-the-minute situational awareness and reliable performance in both indoor and outdoor environments. The alcohol sensor keeps track of the driver's breath for the presence of alcohol and, in case the level is unsafe, it prohibits the driver from operating the vehicle, thus ensuring responsible use. The accident sensor detects abrupt impacts, shakes, or tilts and thus, it immediately sends an emergency alert to the microcontroller, making it possible for the system to stop or slow down for safety. These sensors, therefore, not only provide the system with a means of instant feedback, but also facilitate it in accident prevention and make it a reliable and safe adaptive steering system.

5. wheel set

The wheel set acts as the basic source of physical support that is necessary for the vehicle to move across different terrains. The front wheels are linked mechanically to the steering servo, thus allowing exact control of the direction to be changed according to the user's command. The rear wheels are turned by the DC motors, hence they are the source of the vehicle's propulsion for the movement in both directions. The rubber on their surfaces makes the grip better and the slipping less, thus the operation is demand remains stabile. The reduced weight factor is doing the motors less loaded, thus the movement becomes smoother and the efficiency is improved. The system is thus able to ensure steady handling at various speeds, while the balanced wheel configuration substantially contributes to increased steering precision and overall control of the system.

V. CONCLUSION

The singled-out development of a novel steering system for persons with Muscular Dystrophy is a milestone in increasing their mobility, independence, and safety. The envisaged system is basically a joystick interface with minimum effort which is linked to an electronic drive-by-wire mechanism so that the user is able to get accurate and dependable steering without the need of exertion of notable physical strength or the continuous rotation of the wheel. The attachment of several safety sensors --- like obstacle, accident, and alcohol detection modules --- gives the system the ability to constantly watch over the environment and thus, ensure the user’s safety. The major hardware parts, namely the ESP8266 microcontroller, L298 motor driver, servo motor, and various sensors, are the pillars of a strong, reliable, and efficient steering system that is responsive to the user’s needs. This flexible system is a formidable option of the future as a driving aid specifically designed to the needs of people with neuromuscular impairements.

The experiments confirmed the smooth functioning of the system, the accuracy of the direction control, and the overall stability as well, thus, the proposed steering approach for individuals with muscular dystrophy is effective. User minimal effort, system high reliability, and safety enhancement are the leading features of the technique, which ensures that the device is still accessible and practical for users with progressive neuromuscular disorders. The findings are a clear indication that the adaptive steering system they developed is a viable technology for granting independence to people with disabilities. To put it briefly, the accomplishment is geared towards the provision of a working and user-friendly device that not only elevates the standard of living of the affected group but also makes a significant contribution to the development of inclusive and accessible automotive design

VI. FUTURE SCOPE

The newly proposed steering mechanism opens up many avenues for later modifications that can, to a great extent, increase the accessibility and user-friendliness of the device for people suffering from Muscular Dystrophy. Through the application of futuristic gadgets like machine learning and adaptive control algorithms, the system can become an interface that operates its steering sensitivity all by itself depending on the muscle power of the user which has to be continually changing. Driving semi-autonomously is the next step to freedom from primary control responsibilities— features such as lane-keeping assistance, collision avoidance, and automated braking—could still in another way lower the fatigue level of the driver, and thus, safety will be greatly improved. Besides, the incorporation of IoT capabilities can enable remote diagnostics, real-time monitoring, and smartphone-based control interfaces thereby making system management a smooth and easy task.

Besides, future models can be made with consideration of less weight, better integration of the hardware into the compact body, and more enhanced features of the physical side of the steering interface so as to create a more user-friendly one. The further rise of the system could be achieved with the addition of eye-tracking technology for command or a voice auxiliary function in the case the user has progressed very far with his/her neuromuscular disorder and his/her hand movement is severely impaired.

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