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Voice-Controlled Wheelchair for Children in Underserved Regions

Jeniffer Guardia[1]; Karla Gutierrez[2]; Mariah Villalon[3]; Jesse Herrera[4]
Faculty Mentor: Mohammed Benalla, Ph.D[1]
[1]Vaughn College of Aeronautics and Technology, NY, USA,
jeniffer.guardia@vaughn.edu, karla.gutierrez@vaughn.edu, mariah.villalon@vaughn.edu, jesse.herrera@vaughn.edu,

***Abstract*– This project aims to create a cost-effective, voice-controlled smart wheelchair that will increase independence and improve the quality of life for children who experience mobility challenges in underserved regions in Latin America. The goal of creating a smart wheelchair with intelligent voice control incorporated is to provide an innovative, efficient, and user-friendly mobility solution with key features such as safety, obstacle avoidance, and customization that will ensure a secure experience, ultimately improving ease of navigation and reducing physical strain for users. First, the incorporated sensors check for obstacle clearance before allowing users to speak the integrated commands. After no obstacles have been detected, the voice recognition module will execute the programmed commands. The smart, voice-controlled wheelchair integrates a lightweight PVC and mild steel chassis and a lead-acid battery that powers the motors based on voice commands to ensure cost-effectiveness and user safety for a seamless operation. This project will directly impact how children with quadriplegia —complete loss of function in all four limbs—can improve their way of living and shall expand the patient's mobility to move with ease around different environments by providing freedom to move for more than 10 hours uninterrupted at standard operating time.**

Keywords—technological assistance, smart wheelchair, voice control, quadriplegia, mobility solutions, children, accessibility.

I. INTRODUCTION

The project's objective is to develop a cost-effective voice-controlled wheelchair system that enhances mobility, and independence designed specifically for children and individuals with physical disabilities that meet the size and weight constrains of the chair. Traditional wheelchairs require manual operation, which can be difficult for those with limited upper body strength or dexterity. The project explores the integration of voice control technology to provide a more accessible solution to wheelchair navigation, focusing on directly benefiting paralysed and handicap children. The wheelchair responds to five one-word voice commands—"straight," "back," "right," "left," and "stop"—processed by the Elechouse V3 voice recognition module which utilize sophisticated programmed algorithms to interpret and respond to the spoken commands. At the core of the system is a microcontroller-based unit system, powered by two 12V motors and controlled via the Cytron MDD10A motor driver. The system learns the user's unique speech patterns through repeated commands training, ensuring accurate and patient recognition of their speech pattern. Once processed, the commands are converted into electrical signals that drive the wheelchair's motors via the motor ver allowing precise movement control [1]. To enhance user safety, ultrasonic sensors are integrated for obstacle detection, ensuring real-time communication and collision prevention. Overall, combining voice recognition, real time user-friendly interface and cost-efficient design, this project presents an innovative, affordable and inclusive solution to improve quality of life for children with disabilities.

II. NEED STATEMENT

Traditional wheelchairs often require physical effort, making them impractical for individuals with limited upper body mobility. Moreover, the reliance on traditional wheelchairs increases the need for caregiver assistance and adds to the overall expense making it less accessible. A low-cost, voice-controlled wheelchair addresses these challenges by providing hands-free navigation, safety features, and affordability eliminating the need of paying for caregivers and possible injuries due to excessive effort. A cost-effective design using low-cost materials makes the voice-controlled wheelchair more practical and accessible to families who may struggle with the high costs of current mobility devices, particularly for those in low-income communities in Latin-America.

A voice-controlled wheelchair is essential for enhancing mobility but also to foster and support children's development. There is a need for smart technologies advancements that supports children's development by providing interactive experiences and fostering cognitive skill growth. Ultimately, the accomplishment of this project will promote technological advancements to bridge the gap between technology and accessibility in assistive mobility devices and empower individuals with disabilities to navigate their environments safely and independently.

III. BACKGROUND RESEARCH

There are currently no completely integrated voice-controlled wheelchairs on the market, despite improvements in assisted mobility technology. Although there are many mobility solutions available, they don't address the unique requirements of people with severe mobility limitations, especially kids who can't use conventional joystick-controlled devices. The Vocalize Bluetooth Mobile Phone Voice Control System, as shown in Fig. 1, is an effective add-on for traditional wheelchairs that improves communication but doesn't provide actual independence nor helps with mobility. It helps family members or caretakers to communicate via voice-activated calls and texts rather than giving users direct control over their wheelchair, which adds workload rather than lessens their strain. [2]

Fig. 1 Bluetooth Mobile Phone Voice Control System for wheelchairs

Munevo DRIVE as shown below in Fig. 2, is another cutting-edge device that uses smart glasses to monitor head motions to drive electric wheelchairs. Even tough, it isn't voice-activated, it provides an alternate hands-free option that responds by head movements. However, those with neuromuscular diseases or severe spinal cord injuries—who lack head mobility—cannot use this approach. [3].

Fig. 2. Munevo DRIVE for wheelchairs

Ultimately, most power wheelchairs available on the market use joystick control as shown in Fig. 4, it represents a significant challenge for those who are unable to move their hands because of neurological injury or illnesses like cerebral palsy. If the joystick system fails or becomes unresponsive, users with limited motor function would be left completely immobile. Cost is still a major obstacle as well. Many people cannot afford most motorized wheelchairs on the market, which are over $1,000, particularly in low-income areas. The lack of an affordable, voice-controlled wheelchair leaves a gap in assistive technology, limiting independence and mobility for those who need it most.

Fig. 3 Joystick general market smart wheelchair

IV. Impacts

Millions of people with mobility impairments could have their lives completely changed by the creation of a voice-activated wheelchair, which would solve issues connected to personal independence as well as more general social, economic, and health issues. Over 75 million individuals globally need a wheelchair, yet only 5–15% have access to one because of budgetary and infrastructure constraints, according to the World Health Organization (WHO) [4].

A. Social Impact

A voice-controlled wheelchair will reduce reliance on physical exertion or assistance for its users, achieving the goal of the project which is to improve user's quality of life. In according to UNICEF, millions of individuals worldwide face mobility challenges, with over 8 million children under 14 in Latin America living with some form of disability [5], and many have experienced exclusion or discrimination in education, social life, or cultural settings. As a result, they face vulnerability and fewer opportunities for personal development, affronting discrimination, lack of awareness and inclusion. Furthermore, the project aims to support children during their development phase to avoid the social isolation caused by limited resources which impacts their physical and mental health [6]. It is widely seen that those living in poverty who cannot afford medical assistance, frequently experience direct impacts on their general growth and well-being but also on their community engagement and social development. Moreover, the project aims to advocate for social change by improving countries' infrastructures for individuals with disabilities. The voice-controlled wheelchair seeks to work along the advancements in different countries rather than make the wheelchairs all-terrain. Instead of preparing users for poorly developed rural areas and sidewalks, the focus is to encourage the development of accessible, inclusive environments that adequately meets the need of all individuals. As the voice-controlled wheelchair continues being developed, it can help change many lives and support initiatives focused on educating families and caregivers, as well as launching civic awareness initiatives that will promote inclusion and respect for disabled people.

B. Economic impact

A voice-controlled wheelchair can have significant economic impacts as creating a low-cost solution in a region where millions lack access to assistive devices. This innovative has the potential to increase the demand for local manufacturing and the creation of job opportunities, driving economic growth in underserved areas. This will open a path to introduce new companies focused on selling and distributing voiced-controlled wheelchairs. This project can provide a practical alternative to expensive electric wheelchairs, ensuring accessibility for low-income communities and its great market value would traduce into a sustainable product. Furthermore, launching reasonably priced mobility solutions might enable people with disabilities to seek education and work, ultimately boosting the local economy. Overall, Wheelchair use can increase the income of households with disability. Clients responded that there have been several aspects which need further support, including skills improvement, employment generation for people with disabilities, and adequate public transportation facilities [7].

C. Environmental impact

The advantages of developing the speech recognition wheelchair extend beyond improving mobility accessibility. Using accessible materials in production not only saves money but also promotes sustainability. This fosters a more inclusive environment where business and commercial sectors shall have obstacles free infrastructures, accessible ramps and adapted routes tailored for people with mobility impairments.

The more consumers support companies that act sustainably, the more likely other companies are to take the same path. By practicing sustainability, medical supply companies make it easier for wheelers to live environmentally-friendly lives [8]. The voice-controlled wheelchair does not have negative influence on the environment contrasted to other products or industrial techniques that cause pollution, resource depletion, and increasing waste. It is meant to be sustainable. The materials used in its production are chosen for their longevity and environmental friendliness, and its energy-efficient design minimizing power consumption. The wheelchair's lengthy lifespan encourages reduced waste over time, making it a responsible choice for both users and the environment.

V. Requirements And Constraints

A. Market Requirements

1) *Affordability*: the wheelchair should offer cost-effective solutions compared to the wheelchairs that exist in the market.
2) *Accessibility & Inclusivity*: the system should include an integrated voice recognition system Designed for individuals with severe mobility impairments, including those unable to use joysticks or manual controls.
3) *Adaptability*: the wheelchair system should be user-friendly and require minimal training to operate the simple commands e.g., "forward," "back," "stop".
4) *Environmental Responsibility*: the design shall include eco-friendly materials to support sustainable manufacturing while reducing power consumption.

B. Engineering Requirements

This engineering design assures that the wheelchair as shown in Fig. 5, is economical, useful, and safe by including speech recognition, obstacle detection, and cost-effective power management, making it an accessible mobility solution for people with severe movement disability.

1) *Weight and Dimensions:* The wheelchair must support a maximum weight of 490.5 N to accommodate the user safely. The dimensions are based on the standard wheelchair size, ensuring accessibility and compliance with mobility aid regulations. The frame is constructed using lightweight mild steel durable material to balance stability and maneuverability.
2) *Motion Control*: The primary requirement is selecting high-torque motors to support the wheelchair's weight and provide smooth, controlled movement. Two 12V DC geared motors with a maximum torque of 60 kg-cm, a no-load current of 0.5 A, and a nominal speed of 30 rpm (up to 100 rpm) were chosen. These motors ensure precise movement, sufficient power, and energy efficiency.
3) *Microcontroller*: A high-performance microcontroller is required for real-time processing of voice commands and motor control. The STM32F4 was selected for its 512KB flash memory, 192KB SRAM, and 168 MHz clock speed, making it capable of handling voice recognition, sensor integration, and motor control simultaneously.
4) *Power Supply*: The wheelchair operates on a 24V lithium-ion battery with a 60Ah capacity, ensuring extended usage per charge. Additionally, a Pulse Width Modulation (PWM) motor driver was selected to optimize power consumption and improve motor efficiency. A battery management system (BMS) is included to protect against overcharging and overheating.
5) *Voice Recognition System*: The Elechouse V3 Voice Recognition Module was chosen for its high accuracy and adaptability to user speech patterns. This module interfaces with the microcontroller through a Universal Asynchronous Receiver-Transmitter UART communication, enabling efficient processing of voice commands for movement control.
6) *Safety and Obstacle Avoidance*: To prevent collisions, the wheelchair is equipped with High Conductance (HC) ultrasonic sensors (HC-SR04) placed at the front and rear. These sensors detect obstacles within a range of 2cm to 400cm, ensuring safe navigation. Additionally, an emergency stop mechanism is integrated to halt movement in case of potential hazards.
7) *Manufacturability and Cost Efficiency*: The design prioritizes cost-effective materials and manufacturing methods, including mild steel for the seat components to obtain a lightweight durable product. The use of widely available electronic components ensures scalability and ease of repair.

VI. Estimated Cost

The estimated cost for the Voice-controlled smart wheelchair is shown below in TABLE I. Summarizing, voice control wheelchair ranges between $200-$300 for the protype. This range considers the components and materials listed in TABLE I with the cost breakdown.

TABLE I

BUDGET

Component	Qty.	Subtotal USD
Arduino Mega (Uno)	3	62.97
Cytron 10ADD motor driver	1	26.90
22 AWG wire kit	1	12.99
Cakula 12v gearbox 40000RPM motor	1	29.98
Elechouse V3 Module	1	29.98
Ultrasonic Sensor	2	3.99
Lead-acid Battery	2	39.98
PVC Pipes	3	18.87
Caster Wheels	2	25.98
Tires	2	25.98
Total		277.62

VII. ENGINEERING STANDARDS

A. Design

1) All computer-aided design (CAD) done in SolidWorks adhere to the American Society of Mechanical Engineers Standard (ASME) criteria, since it uses both metric and decimal-inch units to define drawing sizes and formats.

B. Programming

1) The Arduino mega utilized International Organization for Standardization (ISO) C++ language and was employed during the programming of the voice control smart wheelchair.

C. Power Management

1) Battery selection and management, ensuring safe operation, charging, and discharge cycles for uninterruptible power supply (UPS) systems adhere to the Institute of Electrical and Electronic Engineers (IEE) 1184-2006.
2) Electrical power regulation adheres to IEE 295-1969, ensuring safe and stable power distribution through transforming all electronic components.
3) For enhanced safety in lithium-ion batteries, for the International Electrotechnical Commission (IEC) 62133 standards were incorporated to protect against overheating, short-circuiting and leakage.

D. Biomedical and Medical Compliance

1) The Code of Federal Regulations (CFR) Title 21 (890.3850) standard was followed to meet the Food and Drug Administration (FDA) requirements for powered wheelchairs, ensuring medical-grade safety, user compatibility, and regulatory approval.
2) The Power Operations Manual System (POMS) HI 00610.200 medical standard was applied to document and validate the medical necessity and safety of the wheelchair for individuals with mobility impairments.
3) Quality management during production and lifecycle adhere to ISO 13485, ensuring consistent compliance with medical device regulations.

E. Safety

1) The wheelchair navigation and obstacle avoidance systems were designed following ASME B56.8, ensuring safe operation in high-traffic areas and preventing collisions.
2) Electrostatic discharge (ESD) protection was implemented according to American National Standards Institute (ANSI)/ESD S20.20-2021, safeguarding sensitive electronic components from potential damage due to electrostatic discharge.
3) Emergency response features, such as voiced activated stop commands and breaking mechanisms, were designed in compliance with the FDA and ASME safety regulations to prevent accidents and ensure user protection.
4) Cybersecurity practices aligned with the National Institute of Standards and Technology (NIST) Cybersecurity Framework to ensure data integrity and protect user information from potential threats.

VIII. DESIGN CONCEPT

A. Mechanical Design

The voice-controlled wheelchair has a frame composed of manufactured pieces and off-the-shelf components. It is a four-wheel drive system with two high-torque 12V Direct Current (DC) motors that provide smooth motion. The frame is made of mild steel, creating a solid and durable framework capable of supporting a load of 50 kilograms (490.5 Newton's) while maintaining user safety and comfort.

The wheelchair has two primary drive wheels and two caster wheels, allowing for better flexibility. The front wheels allow for directional adjustments, while the rear wheels are powered by DC motors. The frame design provides stability, minimizing rolling and allowing for effective weight distribution.

To properly select the motors for the wheelchair drive system, we calculated the required torque and speed using the formula from equation (1) for the speed. The torque required for movement can be calculated as shown in equation (1).

$$\tau = F \cdot r \quad (1)$$

Where τ represents torque, F represents the total force exerted, r is the wheel radius.

The total force applied by the wheelchair is determined by calculating both the force of friction and the force of acceleration as shown in equation (2).

$$F_{total} = F_{friction} + F_{acceleration} \quad (2)$$

To appropriately select the framework, we determine the maximum weight carriage for the framework considering the factor of safety adopted is about 50kg. The maximum weight carriage was determine using equation (3).

$$F = m \cdot g \quad (3)$$

$$F = 50\ kg\ \cdot 9.81\ m/s^2 = 490.5\ N$$

The friction force is determine using (2). Given that the coefficient of friction between the wheel and the floor is approximately 0.6.

$$F_{friction} = F \cdot \mu_{floor} \tag{4}$$
$$F_{friction} = 0.6 \cdot 490.5\ N = 588.6\ N$$

Assuming an acceleration of 0.15 m/s^2. The acceleration force is calculated using equation (5).

$$F = m \cdot a \tag{5}$$
$$F = 100 * 0.15 = 15\ N$$

Thus, the total forced exerted by the wheelchair is calculated using equation (2).

$$F_{total} = 588.6\ N + 15\ N = 294.3\ N$$

Assuming a wheel radius of 0.127 meters. The torque required per motor is calculated on equation (6).

$$\tau = F_{total} \cdot r \tag{6}$$
$$\tau = 294.3\ N \cdot 0.127\ m = 37.37\ N \cdot m$$

Since the wheel is powered by two motors, the torque per motor is calculated on equation (7) .

$$T_{motor} = 18.68\ N \cdot m \times \frac{1kg}{9.81\ N} \times \frac{100cm}{1m} = 190.4kg \cdot cm \tag{7}$$

A stress study was performed to guarantee that the wheelchair frame could withstand the predicted load. The chosen mild steel material has a yield strength of 247 MPa, and a factor of safety of 4 was used on equation (8) to ensure reliability.

$$\sigma_{allow} = \frac{S_y}{N} \tag{8}$$
$$\sigma_{allow} = \frac{247\ MPa}{4} = 61.75\ MPa$$

Where σ represents the stress allowed on the system, S_y the yield strength and N the factor of safety.

To determine the induced stress of the wheelchair based on seating cross-sectional area is given on equation (9).

$$\sigma = \frac{load}{area} \tag{9}$$
$$\sigma = \frac{490.5\ N}{175} = 2.80\ kPa$$

The speed of the wheelchair is determined by using equation (10).

$$Speed = Periphery\ of\ front\ wheel \cdot Motor\ speed \tag{10}$$

The periphery is calculated on (11) using a wheel radius of 0.127 meters.

$$Periphery = 2\pi r \tag{11}$$
$$Periphery = 2\pi \cdot 0127 = 0.798\ m$$

Assuming the motor speed is 100 RPM, the wheelchair speed is calculated on (13).

$$Speed = 0.798\ m \cdot 100RPM = 1.33m/s \tag{12}$$

The wheelchair's design adheres to standard dimensional guidelines to ensure easy access and compatibility with a variety of environments, including hallways, elevators, and public transportation. Its compact frame allows for easy navigation in tight spaces, and the seat height and width are ergonomically designed to provide comfort and support to users of various body types. The dimension and sizes of a typical wheelchair are shown in Fig. 4 .

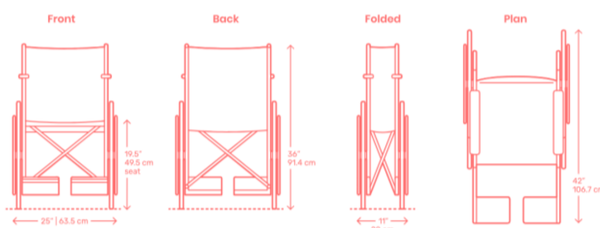

Fig. 4 Wheelchair dimension

The wheelchair's mechanical system incorporates a lightweight PVC chassis with mild steel additional support to ensure both flexibility and structural strength. The lead-acid battery powers the drive motors, which are connected to the rear wheels to enable forward, backward, and turning motions based on voice commands. Caster wheels are positioned to enhance stability and support smooth directional changes. The obstacle detection sensors are linked to the automatic braking system, which activates to halt the wheelchair when an obstacle is detected. This mechanism guarantees safe navigation by combining mechanical and electronic components. The entire structure is designed for optimal weight distribution, reducing tipping risks and enhancing user comfort.

The final design created on using SolidWorks is provided in Fig. 5 and represents the latest design of our smart voice-controlled wheelchair.

Fig. 5 Wheelchair CAD Design.

B. Electrical Design

An Arduino Mega 2560 microcontroller is used to control the system. The schematic described is shown in Fig. 6 below.

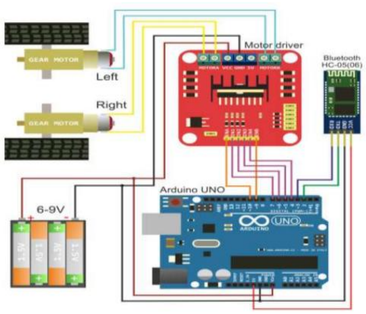

Fig. 6 Schematic Diagram

From this, the electrical design is dived into:

1) Power: The system is powered by a lead-acid battery, which provides sufficient energy to drive the wheelchair motors and support electronic components.

A Cytron MDD10A motor driver is used for motor control, ensuring stable operation. The battery voltage capacity is carefully selected to meet power demands.

2) Drive Train System: The system includes two 12V DC motors for movement, each controlled using a Cytron motor driver. These H-Bridge motor drivers provide precise control over the wheelchair's motion using PWM signals from the Arduino.

Each motor driver has two PWM and two enable pins for precise speed control. The torque of the control is given by equation (13).

$$\tau = \frac{Power \cdot 60}{2\pi N} \quad (13)$$

Since torque is proportional current, high-torque motors are required, drawing a higher current during operation.

The gyroscope sensor is integrated into the system to monitor movement and assist in stability and course correction.

3) Obstacle Avoidance System: For safety, the wheelchair includes an ultrasonic sensor (HC-SR04) to detect obstacles and prevent collisions. The sensors used sound waves to measure the distance between the wheelchair and nearby objects, ensuring real-time adjustments to prevent accidents.

4) Microcontroller: The Arduino Mega 2560 is the core controller of the wheelchair. It includes various communication interfaces such as PWM, Internal Integrated Circuit (I2C), Serial Peripheral Interface (SPI), UART, Analog, Digital Input/Output (I/O).

5) Voice Recognition System: The Elechouse Voice V3 module is used to recognize voice commands given by the user. The module communicates with the Arduino Mega using UART (TX, RX pins). The recognized commands are translated into movement instructions such as straight, back, left, right and stop.

To enhance response accuracy, the system is programmed to filter background noise and recognize predefined commands effectively.

6) Power Constraint and Runtime Calculation: The power budget for the system is carefully analyzed. The stall and rated current consumption for each major component is listed in TABLE II below.

TABLE II
POWER BUDGET

Component	Qty	Stall Current	Total	Rated Current	Total
Motor	2	5.5 A	11 A	0.75	3.75
Arduino Mega	3	~500 mA	1.5 A	1.5 A	1.5 A
Voice Module	1	0.04 A	0.04 A	0.02 A	0.02 A
Ultrasonic Sensor	2	0.015 A	0.03 A	0.03 A	0.03 A
Total	12.57 A			5.3 A	

From this data, the operating time of the wheelchair can be calculated on equation (14), the battery's capacity and current draw.

$$Operating\ time = \frac{battery\ capacity\ (Ah)}{nominal\ current\ draw\ (A)} \quad (14)$$

$$Nominal\ operating\ time = \frac{60\ Ah}{5.3\ A} \approx 11.32\ h \quad (12.1)$$

This means the wheelchair can operate for approximately 11.3 hours under normal conditions.

However, if the motors reach stall conditions, power consumption increase significantly.

$$Minimun\ operating\ time = \frac{60\ Ah}{12.57\ A} = 4.77\ A \quad (12.2)$$

This means the wheelchair can only operate for about 4.77 hours under extreme load conditions. However, since motors rarely operate at stall current, the actual runtime is expected to be much longer.

C. Programming

The Arduino IDE is used to program the voice-controlled wheelchair, which uses ISO C++ for fast hardware interface. The Arduino Mega 2560 microcontroller was chosen for its large number of I/O ports, PWM functionality, and serial communication interfaces, which enable seamless integration with the voice recognition module, motor drivers, and ultrasonic sensors. The flowchart diagram is shown in Fig. 7.

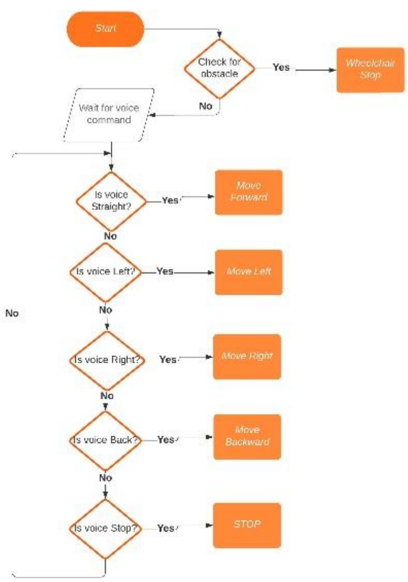

Fig. 7. Flowchart Diagram

IX. COMPLEX PROBLEM SOLVING

Building the smart voice-controlled wheelchair required solving numerous complex engineering challenges in the mechanical, electrical, and software areas of expertise. One of the most difficult challenges was creating a lightweight strong structural framework suitable for children. While PVC provided weight advantages, ensuring stability and durability demanded strategic reinforcement with mild steel in high-stress areas. To balance strength and weight, we performed a load capacity analysis, optimizing the design for carrying up to 50 kg while maintaining ease of use.

Another major challenge was combining voice recognition and real-time motor control. The system needed to interpret voice commands correctly, process them through the microcontroller, and execute smooth motor responses. This required calibrating the microphone for various voice tones and implementing correction methods to avoid unintended movements.

Furthermore, obstacle detection and automatic braking required precise sensor placement and programming. To ensure that sensors detected obstacles at appropriate distances and did not cause unnecessary stops, sensor sensitive and response algorithms had to be fine-tuned. We also had to ensure power efficiency, as the lead-acid battery needed to support all electronic components while still providing a reasonable operational runtime.

Various complex engineering challenges were addressed through iterative design improvements and testing, leading to a system that achieves structural stability, responsive control, and user safety. Key design constraints were overcome by optimizing the lightweight framework, enhancing voice recognition accuracy, and ensuring reliable obstacle detection, resulting in a wheelchair that is both functional and accessible for children with mobility needs.

X. FUNCTIONALITY TEST AND EVALUATION

Multiple evaluations were conducted to ensure proper functionality. The analysis procedures were separated into:

A. Drive Train and Load Test

The drive system of the voice-controlled smart wheelchair was tested to ensure consistent mobility in a variety of conditions. The wheelchair, which is powered by two 12V gear motors, went through mobility testing with simulated user weights of up to 41 kg. The tests confirmed that the wheelchair could support the load while maintaining stability and smooth navigation over a variety of terrains. The front caster wheels provided extra support, ensuring balance and simplicity of directional movement throughout the test.

B. Voice-Control and Obstacle Avoidance Test

The wheelchair's voice control mechanism was thoroughly tested with the Elechouse Voice Recognition V3 module. The system correctly responded to predefined commands like "Straight," "backward," "left," "right," and "stop." The tests assessed the system's ability to recognize commands accurately in various ambient noise levels, ensuring consistent performance in real-world scenarios.

In Fig. 8 the setup of the voice control system is shown, demonstrating how it will be incorporated with the doll in its designated position. This visual representation highlights the placement and interaction of the voice control components, providing a better understanding of how the system will work once fully assembled.

Fig. 8 Wheelchair with the voice recognition module test.

C. Stability and Motion Correction Test

The MPU6050 gyroscope was used to evaluate the wheelchair's stability, ensuring smooth and balanced movement. The system successfully detected deviations from the intended motion and adjusted the motor speeds to keep the balance. This test confirmed that the wheelchair could navigate uneven terrain while maintaining user safety.

D. Battery Performance and Load Evaluation

Battery performance tests were carried out to determine operating time and charging efficiency. The wheelchair, powered by a 12V 60Ah lead-acid battery, had an operational runtime of approximately 11.32 hours under normal load conditions and 4.77 hours at maximum load (stall current).

XI. RESULTS

The smart, voice-controlled wheelchair demonstrated smooth operation and functionality in all key features. The mobility system, which was powered by a lead-acid battery, allowed for responsive movement, including forward, backward, and turning motions, while the lightweight PVC chassis and mild steel reinforcements provided maneuverability and stability. The obstacle detection sensors and automatic braking system were effective in stopping the wheelchair when obstacles were detected, significantly increasing user safety. The design optimized weight distribution to prevent tipping and ensure stability even on sharp turns and uneven surfaces. The ergonomic seating provided comfort, while the structural integrity of the materials ensured durability and long-term usability. The lead-acid battery provided several hours of power to the system, allowing the wheelchair to be used as intended. As seen in Fig. 9Fig. , the wheelchair is shown on its final result after running some tests.

Fig. 9 Final Result Isometric View

XII. CONCLUSION

The voice-controlled wheelchair project effectively combines innovative assistive technology to improve mobility and freedom for those with severe motor disabilities. Users may navigate their environment using voice recognition technology, which eliminates most of the need for human effort or caregiver support. The system includes ultrasonic sensors for obstacle detection, which ensures safe and precise mobility. A high efficiency 24V rechargeable lead acid battery powers the wheelchair, allowing for longer operation times, while a PWM motor driver optimizes energy use. This initiative intends to close the accessibility gap by providing a low-cost alternative to pricey electric wheelchairs, making mobility solutions more accessible, especially in low-income regions. The utilization of recycled materials promotes sustainability and lowers production costs. Finally, this voice-controlled wheelchair helps people with impairments by increasing autonomy, quality of life, and social inclusion. It is a practical and innovative step toward making affordable, safe, and intelligent transportation solutions available to people who require them the most.

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REFERENCES

[1] Haggerty, James, "Sninoff 1977," NASA, Technology Utilization Program Report, Jan. 1977. Accessed: Jan. 31, 2024. [Online]. Available: https://ntrs.nasa.gov/api/citations/20070019874/downloads/20070019874.pdf

[2] "Vocalize Bluetooth Mobile Phone Voice Control for Power Wheelchair use – Inclusive Inc." Accessed: Jan. 14, 2025. [Online]. Available: https://inclusiveinc.org/products/vocalize-bluetooth-cell-phone-voice-control-system-for-power-wheelchair

[3] "Innovative head control for wheelchairs | munevo DRIVE." Accessed: Jan. 14, 2025. [Online]. Available: https://us.munevo.com/

[4] "Assistive technology." Accessed: Jan. 14, 2025. [Online]. Available: https://www.who.int/news-room/fact-sheets/detail/assistive-technology

[5] "Investing in education | UNICEF." Accessed: Jan. 14, 2025. [Online]. Available: https://www.unicef.org/lac/en/investing-education

[6] I. L. de L. Almeida, J. F. Rego, A. C. G. Teixeira, and M. R. Moreira, "Social isolation and its impact on child and adolescent development: a systematic review," *Rev. Paul. Pediatr.*, vol. 40, p. e2020385, doi: 10.1590/1984-0462/2022/40/2020385.

[7] A. B. Pratiwi, H. Setiyaningsih, R. Mahardya, F. Hafidz, and D. A. Puspandari, "The economic impacts of wheelchair use: Evidence from Central Java, Indonesia," *J. Community Empower. Health*, vol. 2, no. 2, Art. no. 2, Dec. 2019, doi: 10.22146/jcoemph.47592.

[8] "The Environmental Impact of Wheel Life," New Mobility. Accessed: Jan. 31, 2025. [Online]. Available: https://newmobility.com/disability-environmental-impact/