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VocalVision: Smart Wheelchair Maintenance with Pressure Sensors and Machine Learning

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Abstract

The Vocal Vision system introduces an innovative approach to enhancing electric wheelchair maintenance and control. It utilizes a network of sensors embedded within the wheelchair's wheels to gather real-time data on tire pressure, temperature, tread wear, and alignment. This data is wirelessly transmitted to a central control unit. Advanced algorithms, incorporating machine learning and predictive analytics, analyze the data to detect irregularities and predict maintenance needs. Users can control direction, speed, and perform complex maneuvers with precision using voice commands and eye gestures. The wheelchair integrates OpenCV for eye gesture recognition and Google Speech Recognition API for voice commands, enabling intuitive control methods. This proposed method introduces a new assistive technology for individuals with disabilities, leveraging cutting-edge technologies.

Keywords: Pressure Sensor, Machine Learning, Predictive Analytics, Sustainability, Cost-Efficiency.

1. Introduction

Imagine a world where mobility knows no bounds, where individuals with limited physical capabilities can navigate their surroundings with unprecedented ease and independence. This vision is now a reality with our revolutionary Eye and Voice Controlled

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Wheelchair. Designed with cutting-edge technology and a deep understanding of accessibility needs, this wheelchair empowers users like never before. Through the simple power of their voice commands and the subtle movements of their eyes, individuals can effortlessly navigate their environment with precision and grace.

With its intuitive interface, users can seamlessly control direction, speed, and even perform complex maneuvers with unparalleled accuracy. Whether indoors or outdoors, in crowded spaces or open terrain, this wheelchair offers unparalleled freedom and flexibility. Our paper introduces an innovative eye and voice-controlled wheelchair system designed to revolutionize mobility assistance for individuals with physical disabilities. By seamlessly integrating eye-tracking and voice recognition technologies, our system offers users unparalleled control and independence. Through intuitive gaze-directed navigation and natural language commands, users can effortlessly maneuver the wheelchair with precision and ease, empowering them to navigate their surroundings with newfound freedom and confidence. This paper presents the design, implementation, and potential impact of our cutting-edge assistive technology, paving the way for enhanced mobility solutions in the field of accessibility.

1.1 Objectives

To develop an intuitive wheelchair interface integrating advanced eye-tracking and voice recognition technologies for individuals with disabilities.

To enhance precision in wheelchair control through improved eye-tracking accuracy, robust voice command interpretation, and adaptive learning mechanisms, to maximize user independence, safety, and satisfaction.

2. Literature Review

The existing methods for developing wheelchairs for individuals with disabilities have utilized EEG-based brain control, sensors, machine learning, deep learning, and other technologies. The proposed work builds upon insights gathered from these existing systems. A brief overview of the existing studies is as follows.

Dev et al. [1] proposed an EEG-based brain-controlled wheelchair using a Brain-Computer Interface (BCI) with the NeuroSky MindWave EEG Headset. This was basically developed for the quadriplegic patients to help them move on their own. Dahmani et al. [2] put forth a system to help people with motor disabilities move easily and independently using an eye-controlled electric wheelchair, offering affordable tools for organizations supporting wheelchair users. Raiyan et al. [3] proposed an automated Arduino-based wheel chair with voice control. The proposed method was simple and cheaper to use with common electronic devices, making it highly beneficial for developing and underdeveloped countries. Azam et al. [4] put forth a voice-controlled wheelchair for physically disabled people, using a voice recognition system to control all its movements. Luo et al. [5] developed a system that utilized eye movement to determine the direction of the gaze and control the wheel chair. Gupta et al. [6] designed an eye-controlled wheelchair to enable people with disabilities to operate the wheelchair independently by using their eye movements and face landmark recognition technology, eliminating the need for assistance. HemaMalini et al. [7] proposed a smart wheel chair for the disabled incorporating the Raspberry Pi, OpenCV, and speech recognition technology. Pham et al. [8] propose a gaze-based interface that allows users to control wheelchairs naturally using eye gaze without translating it into specific commands. This system includes a navigation detection model to discern user intentions, enhancing semi-autonomous wheelchair navigation.

Karande et al. [9] analyze the challenges faced by physically challenged individuals with traditional wheelchairs and the high cost of powered alternatives. To address these issues, a prototype based on neural networks and the backpropagation algorithm is proposed. This model utilizes voice recognition for control and is trained to respond to commands like forward, backward, left, right, and stop. Commands are converted to text and wirelessly transmitted via Bluetooth to Arduino UNOs and DC motors for wheelchair movement. The goal is to create an affordable, user-friendly smart wheelchair that enhances comfort and independence for physically challenged users. Chauhan et al. [10] developed a new model using artificial intelligence. It uses a Raspberry Pi to control the device, infrared and ultrasonic sensors for reliable obstacle detection, a USB microphone for voice commands, and upgrades the hardware from previous models while keeping costs low. Devi et al. [11] designed a hybrid brain-computer interface for wheelchairs that uses voice recognition sensors to assist physically challenged individuals, reducing the need for high concentration and effort.

3. Proposed Work

The VocalVision system is a new way to enhance the maintenance and performance of electric wheelchairs. It uses sensors in the wheels to monitor tire pressure, temperature, tread wear, and alignment. This system gathers real-time data and wirelessly transmits it to a central unit. OpenCV and the Google Speech Recognition API are used to control the wheelchair's movement.

3.1 Components Used

The working principle of the wheelchair revolves around the integration of advanced technologies to provide seamless mobility assistance for individuals with disabilities. The system comprises several essential components:

- The Sensors embedded within the wheelchair monitor the tire pressure, temperature, tread wear, and alignment.
- Advanced voice recognition software enables users to issue commands verbally, such as starting, stopping, or changing direction, providing an additional mode of control for individuals with mobility.
- A central control unit (ESP32-microcontroller), processes input signals from the sensors, eye-tracking technology (web cam and OpenCV) and the voice recognition system (Google Speech Recognition API), coordinating the wheelchair's movements in real-time.
- The Wireless communication protocols (Bluetooth or Wi-Fi) facilitate seamless communication between the wheelchair's control unit and the user interface, enabling remote control and data transmission.
- Servo motors, motor drivers, and an LED display are also used to ensure the proper movement of the wheel chair.
- The safe movement of the system is ensured by sensors and an emergency stop button, which activates whenever an obstacle is detected.
- **Hardware Components**

The Table.1 below shows the software components used in the work

Table 1. Hardware Components Used

S. No	Components	Purpose	
1.	Sensors	Tire Pressure (TPMS-01)	Tire pressure sensors provide real-time monitoring and alerts for enhanced safety and performance of the wheel chair.
		Temperature (DS18B20)	Temperature sensors ensure optimal comfort and prevent overheating of components.
		Tread Wear (Resistive Tread Wear Sensors 100ohm - 1000-ohm, dimension (1 cm x 1cm))	Tread wear sensors enhance safety by monitoring tire condition for timely maintenance and improved tracking.
		Ultrasonic sensors (HC-SR04)	Used to detect the obstacles.
2.	Esp32	The ESP32 process input signals and manage wheelchair movements. Facilitates the wireless connectivity for remote control and data transmission, enhancing accessibility and functionality of the wheelchair.	
3.	Embedded Webcam (Logitech C270)	The embedded webcam enables real-time eye ball movement for enhanced navigation and helps for easy movement of the wheel chair.	

4.	Servo Motors	Servo motors facilitate precise and responsive control of movement mechanisms, enhancing mobility and user independence.
5.	Motor Driver	Motor drivers regulate and amplify electrical signals to drive motors, enabling smooth and efficient movement control.(DC Motors (Brushed)). The DC motor drive is a type of amplifier or power modulator that integrate between the controller and a DC motor.
6.	LED Display	LED displays the direction in which the chair actually moves like Forward/backward and Left/Right.

- **Software's Used**

The Table.2 shows the software components used in the proposed work

Table 2. Software's Used

S.No	Libraries Used	Purpose
1.	OpenCV	Utilized for real-time image processing by detecting the eye ball movement of the user.
2.	MEDIAPIPE	Recognizes the movement of the user's eyeball for the further navigation.
3.	NUMPY	Enables efficient array operations and data manipulation for computational tasks. This means to be computed the boundaries for detecting the movement.
4.	UTILS	It is to perform Data Handling (to perform the interpretation of the comment accessed through the database) and for Logging(to debug the errors and analyze the performance).
5.	MATH	In case of capturing eyeball motion, it performs the smoothing and normalization of the coordinates of

		the eye gaze and in voice recognition it is utilized for signal processing to interpret commands.
6.	TIME	It is to perform to delay control to keep the actions smooth and for Event Scheduling for events based on specific timings.
7.	SERIAL	Facilitates communication between the wheelchair's control system and external devices(with the laptop with embedded webcam for the detection).
8	Google Speech recognition API	To recognize the voice commands and control the movement of the wheelchair.

3.2 Workflow

The Figure 1 illustrates the flowchart of the proposed

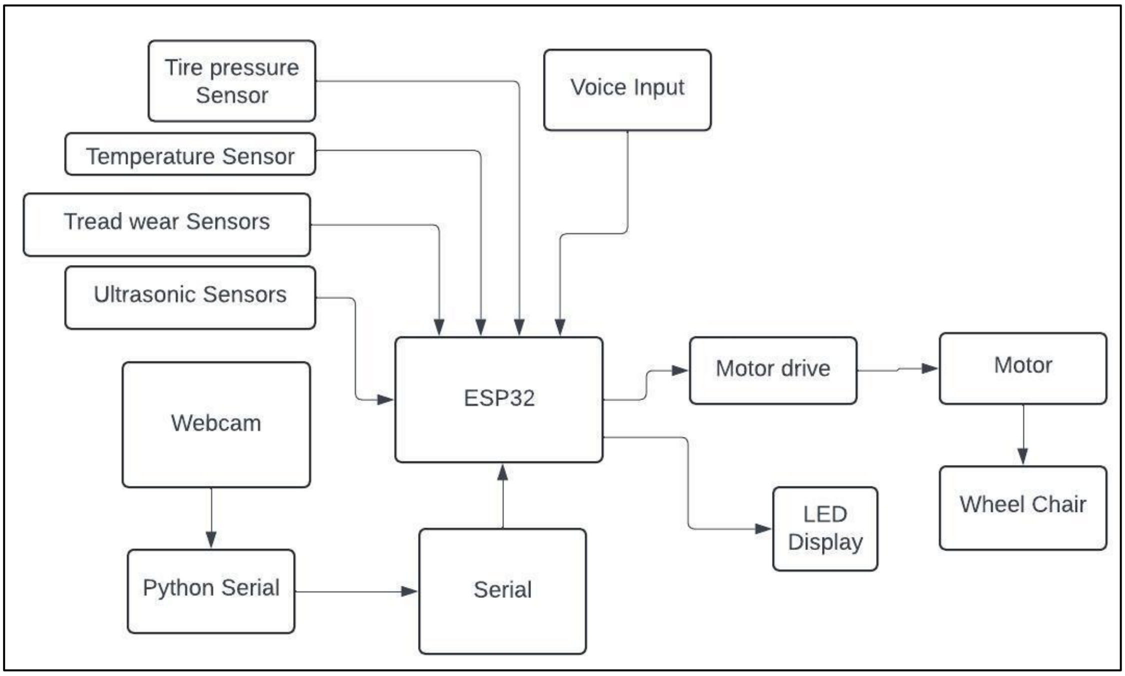

Figure 1. Flow Chart

3.3 Working Principle

- The Webcam captures the eye ball movement that is used to navigate the wheelchair by moving forward/backward or to turn left/right.
- the USB microphone connected to the ESP32 microcontroller captures the voice commands. The voice commands are processed using Google Speech Recognition API and sent to control unit.
- Python code running on the ESP32 processes both eye and voice commands. It communicates with the motor driver through a serial communication protocol, which involves transmitting data bit by bit over a single communication channel.
- Motor Driver controls the electric motors that propel the wheelchair. It receives commands from the ESP32 microcontroller and regulates the power going to the motors.
- The ESP32 acts as the central processing unit of the system. It receives eye movement data from the webcam, processes it using OpenCV for navigation commands, and sends control signals to the motor driver. The ESP32 is chosen for its affordability, low power consumption, and integrated Wi-Fi and Bluetooth capabilities, facilitating communication with the internet and enabling remote control of the wheelchair.
- The motors propel the wheelchair based on commands received from the motor driver, facilitating movement in various directions. The Figure 2 shows the circuit diagram of the proposed.

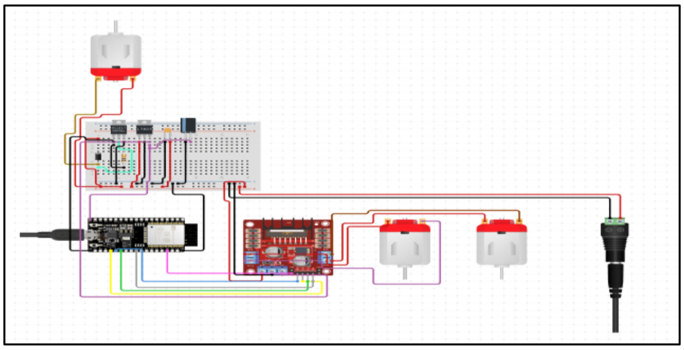

Figure 2. Circuit Diagram

4. Results and Discussions

The Figure 3 depicts the hardware protype of the proposed work.

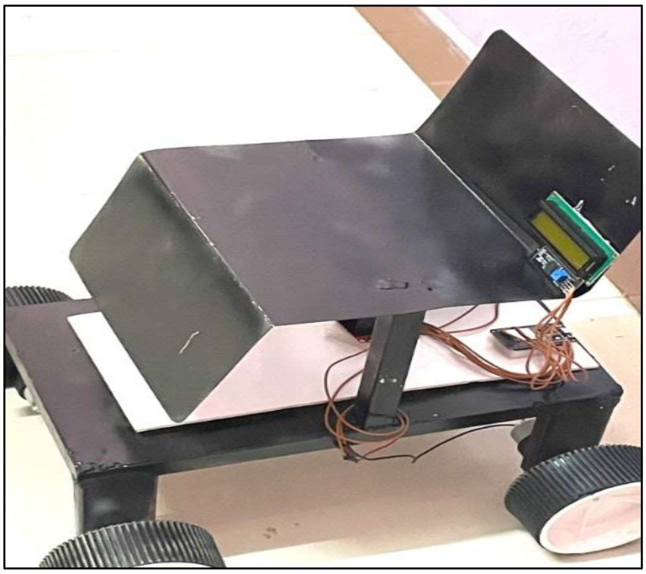

Figure 3. Final Outcome

The proposed wheel chair uses advanced eye-tracking technology, letting users control its movement by looking in the direction they want to go. Voice recognition software allows users to give commands and navigate verbally, adding convenience. It also includes an emergency stop button for manually halting the chair in case of obstacles. The Figure 4 shows the voice command interpretation displayed in the LED display.

4.1 Voice Command Processing

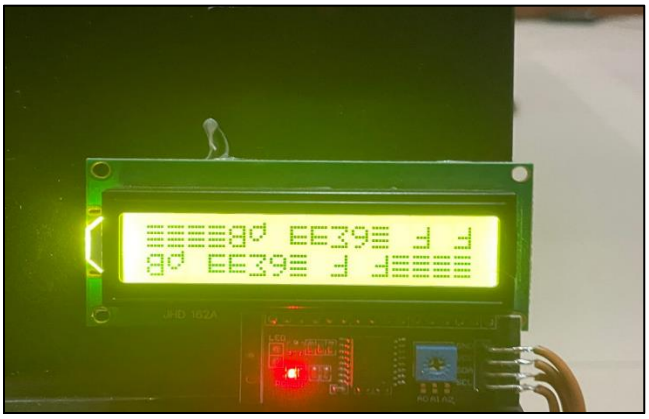

Figure 4. Display of Voice Command

Upon receiving a voice command, the LED screen instantly displays the recognized instruction, ensuring that the user's input is accurately interpreted and understood. Here the commands (Forward, Backward, Right, Left) will be displayed in inverted format. The LED screen provides visual feedback to confirm the executed command, enhancing clarity and reinforcing the user's confidence in the wheelchair's responsiveness to their voice prompts. Users can personalize the LED screen's display interface, choosing font size, color schemes, and layout preferences to optimize visibility and accommodate individual visual needs. The LED screen also serves as a dashboard for monitoring critical wheelchair parameters such as battery level, system diagnostics, and connectivity status, providing users with real-time awareness and control over their mobility device.

4.2 Eye Ball Motion Tracking

The wheelchair is equipped with a high-resolution embedded webcam strategically positioned to capture the user's eye movements with precision. OpenCV, a powerful open-source computer vision library, is utilized to process the webcam feed in real-time, enabling accurate detection and tracking of the user's eye ball motion. OpenCV algorithms analyze the webcam images to detect the user's pupils, determining their position and movements within the camera frame. By continuously tracking the positions of the user's pupils over time, the wheelchair's system can estimate the user's gaze direction, allowing for intuitive control of the wheelchair.

4.3 Future Work

The data monitored by the tire pressure sensors, temperature sensors, and tread wear sensors is analysed using a machine learning model and forwarded to the control unit to take necessary actions, enhancing the safety of the wheelchair

5. Conclusion

The development of an eye and voice-controlled wheelchair system represents a significant leap forward in assistive technology, offering users a novel and intuitive means of navigating their surroundings. By seamlessly integrating eye-tracking and voice recognition technologies, we have created a versatile system that empowers individuals with disability to move with greater independence and efficiency. The customizable interface ensures that the system can be tailored to suit the unique needs and preferences of each user, promoting inclusivity and enhancing overall user experience.

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