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Eye-Controlled Mobility: Advancing Wheelchair Technology with Blinks

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Abstract

Despite the vast size of the wheelchair market, which encompasses over 600 million individuals worldwide with disabilities or aging requiring a wheelchair, many of these individuals face limitations in body movements, rendering traditional wheelchairs impractical. Powered wheelchairs have emerged as an alternative for those with moderate physical disabilities or long-term illnesses, offering various control methods like head control, joystick control, and sip-puff control. Nevertheless, there remains a significant population that cannot utilize these conventional control methods. To address this issue, a proposed model seeks to enhance the lives of disabled individuals by providing a more efficient and simplified solution, promoting self-sufficiency, confidence, and happiness. The proposed model Wheelchair Automation using Eyeblink is a ground-breaking project that aims to empower individuals with limited mobility by enabling them to control a wheelchair using eyeblink signals. This research focuses on the utilization of shape predictor 68 and face landmarks algorithms to detect eyeblinks and facilitate wheelchair movement. This paper explores the technical aspects, challenges, and potential benefits of using shape predictor 68 and face landmarks algorithms in Wheelchair Automation using the Eyeblink system.

Keywords: *Eye-Controlled Wheelchair, Land Face Mark, Automatic Wheelchair, Eye Gaze.*

1. INTRODUCTION

People with disabilities often face segregation and limited opportunities within their communities when their specific needs are not met [17]. Providing wheelchairs not only enhances their mobility but also opens new perspectives and opportunities, empowering them to engage with the world [5]. To address this, key steps include developing national policies, expanding training in design, and ensuring the production and supply of wheelchairs [17]. Every individual's freedom of movement is highly valued, especially for those who have lost voluntary muscle control due to accidents or diseases affecting the nervous system. Electric wheelchairs controlled by joysticks are available, but many individuals with restricted hand movements cannot use them effectively [9]. In India, out of a population of 1.38 billion, 26.8 million individuals are disabled, accounting for 1.58% of the total population. Of these, 18.7 million reside in rural areas, while 8.1 million live in urban areas. By focusing on developing electric wheelchairs controlled by eyeblinks, it is possible to make the lives of individuals with disabilities in India simpler and more inclusive, addressing the needs of both rural and urban populations [5].

The Wheelchair Automation using Eyeblink system on Raspberry Pi is an innovative assistive technology project that aims to provide individuals with limited mobility a means to control a wheelchair using eyeblink signals. This ground-breaking approach leverages real-time image capture, image processing algorithms, and intelligent control mechanisms to enable users to navigate a wheelchair with ease and independence. The system utilizes a camera

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attached to the wheelchair to capture high-resolution images of the user's eyes and eyeblinks. These images are then processed on a Raspberry Pi, a compact and versatile single-board computer that serves as the system's central processing unit. The Raspberry Pi executes sophisticated algorithms and translates the eyeblink signals into precise commands for wheelchair movement. The system implements shape predictor 68 and face landmarks algorithms to detect eyeblinks accurately. These algorithms analyze the captured images and identify key facial landmarks, including the position and shape of the user's eyes. The system can detect eyeblinks and distinguish them from other facial movements by continuously monitoring these landmarks [1].

The commands generated by the eyeblink detection algorithm are transmitted to the wheelchair's movement mechanisms through the General-Purpose Input / Output (GPIO) pins of the Raspberry Pi. The system controls the DC motors connected to the wheelchair's wheels, allowing for smooth and coordinated movement in various directions, including forward, backward, right, and left. To enhance user inter- action and communication, an LCD screen is integrated into the wheelchair. The screen displays the available movement options, enabling users to visually confirm their desired direction before blinking their eyes to make a selection. This visual feedback ensures clear communication between the system and the user.

Safety is a critical aspect of the Wheelchair Automation using Eyeblink system. To address this, an ultraviolet (UV) sensor is incorporated into the wheelchair for obstacle detection. The UV sensor helps identify potential obstacles in the wheelchair's path, enabling the system to make informed decisions regarding movement and avoid collisions, thereby ensuring the safety of the user [1].

Overall, the Wheelchair Automation using the Eyeblink system on Raspberry Pi offers a ground-breaking solution for individuals with limited mobility, providing them with

2. MATERIALS AND METHODS

The "Eye-Controlled Mobility: Advancing Wheelchair Technology with Blinks" project aims to provide individuals with limited mobility a means to control a wheelchair using eyeblink detection. This innovative system leverages real-time image capture of eye blinks through a camera attached to the wheelchair, enabling precise control over its movements. Let's delve into the technical details of this system.

a) Hardware Components:

1) Wheelchair: The wheelchair is equipped with four wheels, each connected to a separate DC motor. This con- figuration allows for accurate and independent control of the wheelchair's movement in different directions.
2) Camera: A camera is attached to the wheelchair, capturing high-resolution images of eye blinks in real time. These images serve as input data for the eyeblink detection algorithm.
3) Raspberry Pi: The Raspberry Pi serves as the central processing unit of the system. It is responsible for receiving and processing the captured eye blink images, determining the specific option selected by the user, and sending corresponding commands to control the wheelchair's movement.
4) Relay Motor: A relay motor facilitates wireless communication between the Raspberry Pi and other components, enabling the transmission of commands.

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5) ZigBee Communication Module: A ZigBee module isutilized for wireless reception and transmission of commands. It ensures seamless communication between the Raspberry Pi and other components of the system.

6) L298N Motor Driver: The L298N motor driver is employed to regulate the power supply to the DC motors. This component plays a crucial role in ensuring smooth and coordinated movement of the wheelchair.

7) LCD Screen: An LCD screen is attached to thewheelchair, displaying the available options for the user. This visual interface enables clear communication and allows users to make selections conveniently.

8) Ultraviolet (UV) Sensor: To enhance safety, the system incorporates an ultraviolet sensor for obstacle detection. This sensor helps identify potential obstacles in the wheelchair's path, enabling the system to make informed decisions regarding movement and avoid collisions.

2.1 Software and Algorithms

1) Eyeblink Detection Algorithm:

The eyeblink detectionalgorithm implemented on the Raspberry Pi processes thecaptured eye blink images. It analyzes the images, identifies eye blinks, and determines the selected option based on predefined patterns or gestures associated with each direction (forward, backward, right, or left). The algorithm uses image processing and machine learning techniques to accuratelydetect intentional eye blinks.

2) Command Generation: Once the eyeblink is detected and

The selected option is determined, the Raspberry Pi generates the appropriate commands for controlling the wheelchair's movement. These commands are based on the recognized eyeblink pattern and are sent to the relevant GPIO (General Purpose Input/Output) pins [7].

2.2 System Operation

1) User Interaction: The user interacts with the system by blinking their eyes to select the desired direction of movement.The LCD screen attached to the wheelchair displays the available options, providing visual feedback and facilitating clear communication between the system and the user.

2) Eye Blink Image Capture: The camera captures real-time images of the user's eye blinks. These images are continuouslyfed into the Raspberry Pi for processing.

3) Eyeblink Detection and Option Selection: The eyeblink detection algorithm analyzes the captured images, identifies intentional eye blinks, and determines the specific option selected by the user. This information is used to generate the corresponding movement commands.

4) Command Transmission and Wheelchair Control: The generated commands are transmitted from the Raspberry Pito the appropriate GPIO pins, which control the wheelchair's DC motors. The motors receive the commands and initiate the desired movement, such as moving forward, backward, turningright, or turning left.

5) Safety Measures: The UV sensor integrated into the system helps detect potential obstacles in the wheelchair'spath. This information allows the system to make informed decisions to avoid collisions and ensure the safety of the user.

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By combining hardware components like the wheelchair, camera, Raspberry Pi, relay motor, ZigBee module, L298N motor driver, LCD screen, and UV sensor with the implementation of the eyeblink detection algorithm, the" Wheelchair Automation using Eyeblink" project provides individuals with limited mobility a reliable and intuitive method to control their wheelchair using eye blinks, enhancing their independence and mobility.

3. PROPOSED MODEL

A comprehensive integration of hardware components, software algorithms, and user inter- action mechanisms to enable individuals with limited mobilityto control their wheelchair using eye blinks. Here is a detailed and enhanced description of the solution.

Fig 1: Face Landmark

Fig 2: Eye Detection

a) Data Acquisition:

Position the camera module in a suitable position to cap- ture the user's eye region effectively. Ensure proper lighting conditions for optimal image quality. The camera captures a stream of images continuously, which will be used for eyeblinkdetection. Develop a program on the Raspberry Pi to accessthe camera module and acquire the image data. [8]

b) Eye Detection and Face Landmarks:

Implement the Face Landmarks algorithm to detect andtrack the user's eyes in the acquired images. This algorithm uses deep learning techniques to identify key facial landmarks, including the eyes. By leveraging pre-trained models, the algorithm can accurately locate the eye regions in the images. [5]

c) Eye blink Detection:

Once the eyes are detected, the next step is to detect eyeblinks. Utilize the Shape Predictor 68 algorithm, which uses machine learning techniques, to predict the positions of 68 facial landmarks, including the eye landmarks. Thisalgorithm analyzes the detected eye regions and identifieseyeblinks based on changes in the positions of the landmarks over time. Thresholds or statistical analysis can be applied to determine if a blink has occurred. [21]

d) Blink Pattern Analysis:

Develop a pattern analysis module that analyzes the detectedeyeblinks to determine the specific direction of movement intended by the user. Define predefined patterns or gestures associated with each direction (e.g., forward, backward, right, left). This module compares the detected blink patterns with the predefined patterns and selects the appropriate movement command. [19]

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e) Command Generation and Transmission

Once the eyeblink is detected and the selected option is determined, the Raspberry Pi generates the corresponding commands for controlling the wheelchair's movement. These commands are based on the recognized eyeblink pattern and are sent to the relevant GPIO (General Purpose Input/Output) pins. [15] The GPIO pins interface with the DC motors connected to the wheelchair's wheels, transmitting the generated commands to initiate the desired movement. The motors respond accordingly, enabling the wheelchair to move forward, backward, turn right, or turn left. [9]

f) Wheelchair Control:

Translate the selected movement command into signals thatcontrol the wheelchair's DC motors. Configure the GPIO pins of the Raspberry Pi to output the necessary signals. Connect the GPIO pins to the motor control mechanisms to activate the motors responsible for wheelchair movement in the desired direction. Ensure proper coordination and synchronization of the motor control signals. [18]

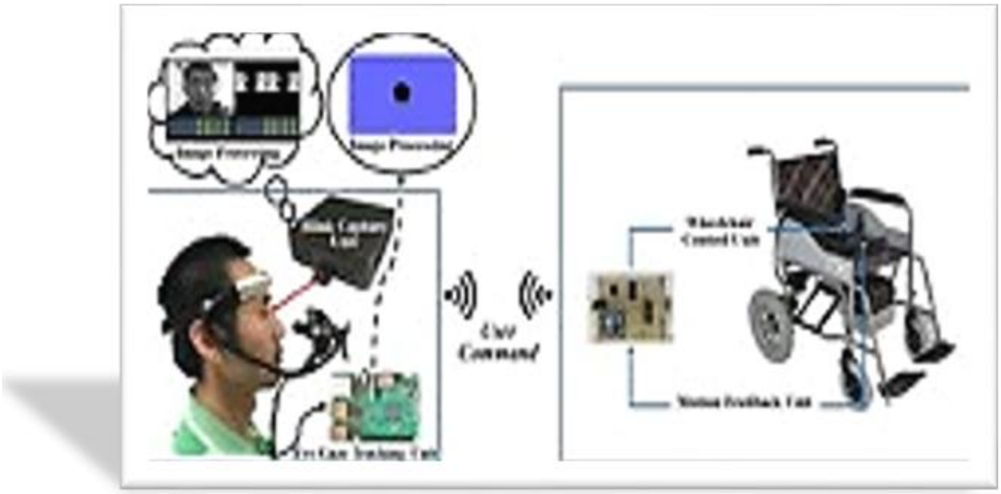

Fig: 3 System architecture of Wheelchair controlled eyeblink system

g) User Interaction:

The LCD screen attached to the wheelchair plays a crucial role in facilitating user interaction. It displays the available movement options in a clear and easily understandable format. The user can select their desired direction of movement by blinking their eyes, providing a simple and intuitive means of control. [12] The LCD screen continuously updates to reflect the current selected option, ensuring real-time feedback forthe user. This visual interface enhances communication and engagement, allowing users to make their movement choices comfortably and confidently. [14]

h) Safety Measures:

The inclusion of an ultraviolet (UV) sensor adds an additional layer of safety to the system. The UV sensor is utilized for obstacle detection, identifying potential obstacles in the wheelchair's path. By processing the UV sensor dataand incorporating collision avoidance algorithms, the system can make informed decisions regarding movement. When an obstacle is detected, the system can adapt its movement plans to avoid collisions. It may adjust the wheelchair's direction, slow down, or come to a complete stop, prioritizing user safety and

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preventing accidents. [20]. the research empowers individuals with limited mobilityto control their wheelchair with precision and ease. The combination of hardware components, the advanced eyeblink detection algorithm, intuitive user interaction mechanisms, and safety measures ensure a reliable and efficient system that enhances the mobility and independence of its users. [6]

3.1 System design and implementation

In order to remove background noise, the eye image from the Shape detection 68 has been subjected to an image binarization procedure. The pupil's center was then estimated in order to determine the subject's intended gaze direction. Ma-chine learning models were employed to identify eye blinks,as shown in Fig. 4, in order to increase accuracy and stability. Convolutional neural networks outperformed SVM in termsof accuracy when three machine learning techniques—pixel ratio, CNN, and SVM—were compared. To operate the electric wheelchair, a driver circuit board was created with a wireless connection serial interface. The subject used the followingcommands to operate the HCI system: blinking once with the left eye to shift the wheelchair to the left, once with the right eye to move it to the right, four times with the forward motion,and twice with the stop motion.

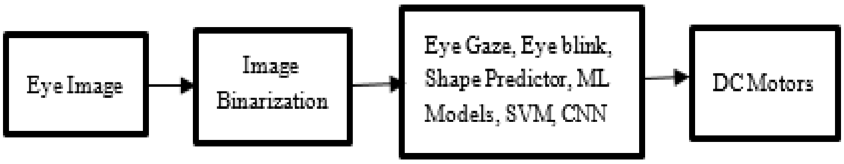

Fig 4: Eye Gaze and Eye Detection System

The authors in [2] designed a wheelchair model (Fig 2.) operated by Dc motors. A webcam was used to scan the facein order to detect facial landmarks using the One Millisecond Face Alignment using an Ensemble of Regression Trees approach created by Swedish Computer Vision researchers who implemented it in the Dlib toolkit. The left and right eye landmarks were extracted from the facial landmark points to find the gaze ratio. The eye direction collected from OpenCV was further processed by an Arduino board that transferred thesignals to the L298N integrated circuit board. The Dc motors got instructions from the circuit to regulate the wheelchair's movement in left, right, forward, and backward directions. [4]

Fig 5: Image processing module for eye gaze detection

The wheelchair's prototype sensed the user's eye movement and changed its motion accordingly. Motion tracking and eye identification are performed by the image-capturing module. As seen in Fig. 5, the images are binarized before being evaluated by a Matlab software. The PIC Microcontroller, which controls the direction of the Dc motors, receives the output signals via a serial port. [13]

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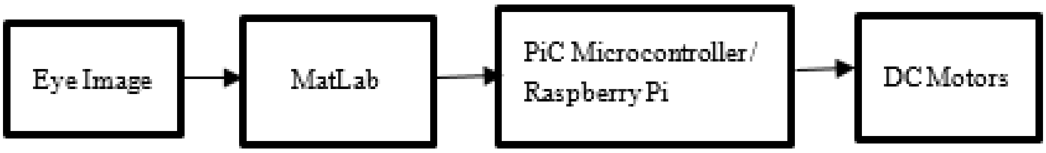

Fig 6: Image Analysis in MATLAB

Image processing methods are used on the Raspberry PI module's eye images, as shown in Fig. 6. When the chosen threshold value is reached by the image processing technique, the chair continues to move in the same direction. Similar to this, the minimum value moves backwards while the maximum value advances if the value is higher than the chosen threshold value. The Raspberry Pi, the webcam, and other parts are all directly connected to the Actual DAC (Data Acquisition) operating system. The wheelchair movement can be stopped by the ultrasonic sensor by identifying impediments and delivering indications to the control circuit. The Raspberry Pi system used in this project is affordably priced. [24]

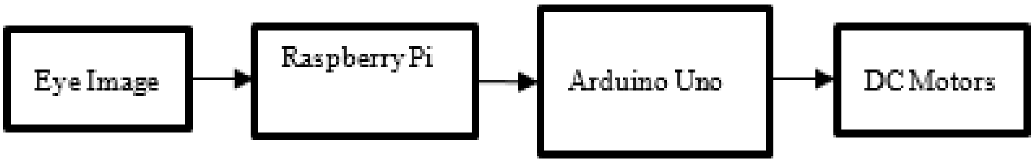

Fig 7: System Design Using Raspberry

When the pupil of the eye moves to the left, the wheelchair motor runs on the left side, and when the eye moves to the right, the right side of the motor must move [13]. If the eye is in the middle, the motor must also move forward. If problems are found, the system stops working. Eyes blink logic applies to starting and stopping wheelchair systems [14]. Figure belowshows a block diagram of a wheelchair system. The raspberry pi camera is installed in front of the user. The distance betweenthe eyes and the camera is fixed and must be in the rage of15 to 20 cm. [22]

The system is entirely autonomous, and each module operates separately from the others. Each component in this systemmust have its own power supply, and the Raspberry Pi, Pi camera, sensors, and motors all require normal power [11]. Figure below depicts how the system operates.

The system architecture integrates the components of image capture, processing, command generation, motor control, user interface, wireless communication, and obstacle detection to create a functional and efficient wheelchair automation systemusing eyeblink detection. [14]

3.1.1 Hardware Implementation

The hardware setup begins with selecting a suitable motorized wheelchair equipped with four wheels. Each wheelis connected to a dedicated DC motor, enabling independent control over the wheelchair's movement in different directions.

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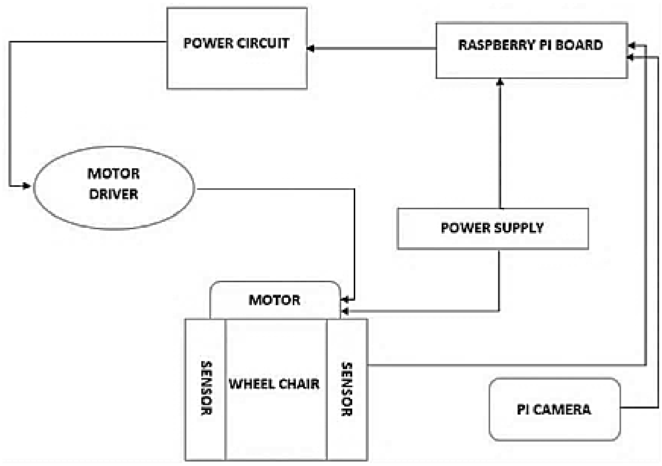

Fig 8: Flow Control of System

This configuration ensures precise maneuverability [8]. To cap ture eye blinks, a camera is attached to the wheelchair. The camera captures real-time, high-resolution images of the user's eyes, which serve as input data for the eyeblink detection algo rithm [23]. A Raspberry Pi is chosen as the central processing unit of the system. It receives the captured eye blink images and performs real-time image processing, option selection, and command generation. The Raspberry Pi provides the necessary computational power and flexibility for these tasks [21]. To facilitate wireless communication between the Raspberry Pi and other components, a relay motor is incorporated. This motor enables the transmission of commands, ensuring seamless connectivity [20]. A ZigBee communication module is utilized for wireless reception and transmission of commands. This module serves as a reliable communication interface between the Raspberry Pi and other system components, allowing for efficient command exchange. [14] The L298N motor driver is used to regulate the power supply to the DC motors connected to the wheelchair's wheels. It ensures smooth and coordinated movement by providing appropriate power control and management. [15] To provide visual feedback and enable user interaction, an LCD screen is attached to the wheelchair. The LCD screen displays the available movement options, allowing the user to easily select their desired direction of movement through eye blinks. Safety is enhanced by incorporating an ultraviolet (UV) sensor for obstacle detection. This sensor helps identify potential obstacles in the wheelchair's path, allowing the system to make informed decisions regarding movement and avoid collisions.

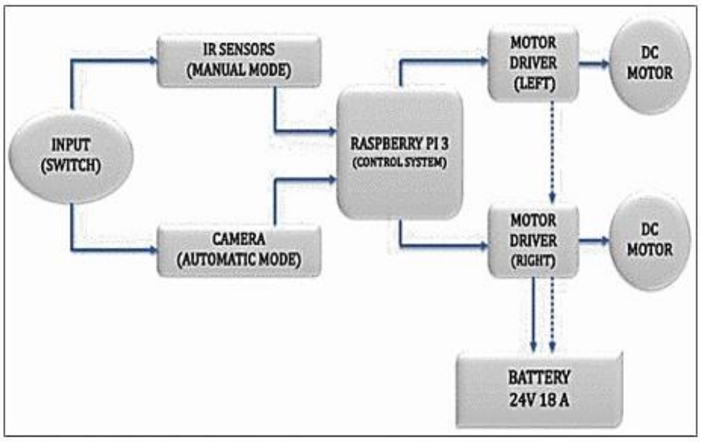

Fig 9: Flow Diagram

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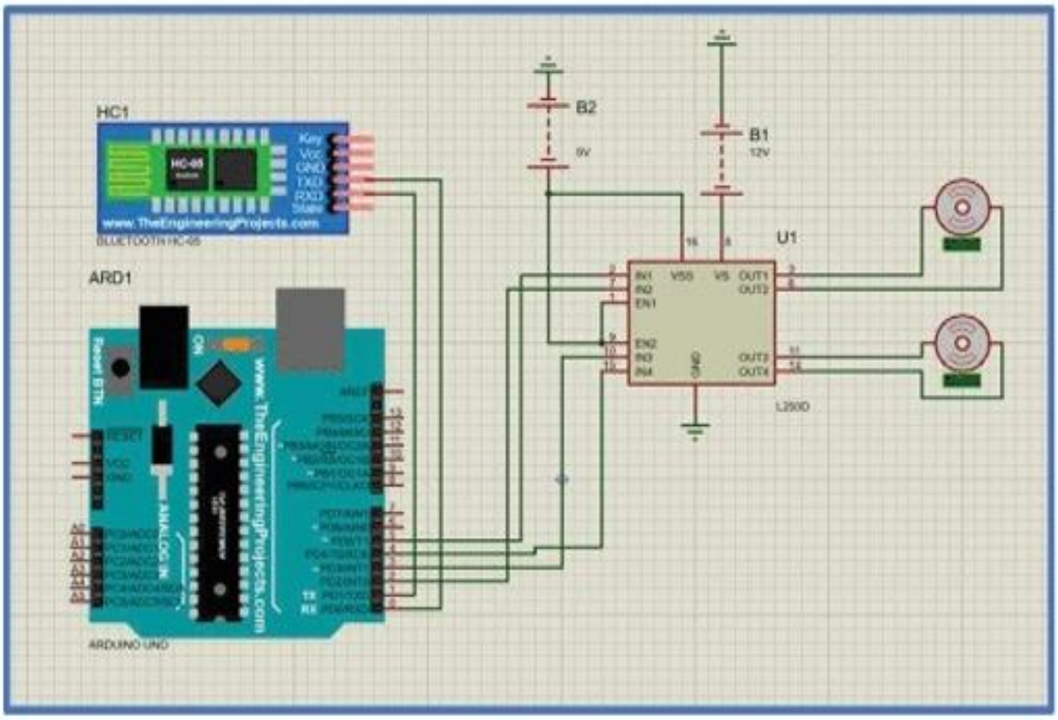

Fig 10: Circuit Diagram

3.1.2 Software Implementation

The software technologies used in the implementation:

i) Image Processing and Computer Vision Libraries: OpenCV: A popular open-source library for computervision tasks, including image capture, pre-processing, feature extraction, and pattern recognition. NumPy: A numericalcomputing library used for efficient manipulation of arraysand matrices, commonly used in image processing tasks. [13]

ii) Machine Learning Libraries: Scikit-learn: A machine learning library that provides a range of algorithms

iii) And tools for training and deploying machine learning models. Tensor Flow: Deep learning frameworks used for developing and training neural networks for advanced image analysis and recognition tasks.

iv) Communication and Wireless Protocols: ZigBee: A low-power wireless communication protocol commonly used for short-range wireless communication between devices. MQTT: A lightweight messaging protocol that enables efficient and reliable communication between devices.

v) Raspberry Pi Libraries and Frameworks: RPi.GPIO: A Python library for accessing and controlling GPIO pins on the Raspberry Pi. picamera: A Python library for controlling the Raspberry Pi camera module, capturing images, and adjusting camera settings. [16] These software technologies provide the necessary tools, algorithms, and communication capabilities to implement the image processing, eyeblink detection, communication, and control functionalities required for the wheelchair automation system.

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The software implementation involves the following key components:

i) Image Processing and Eyeblink Detection:

- Capture and preprocess real-time images from the cam- era.
- Analyze the eye region to detect intentional eye blinks.
- Set thresholds or use machine learning techniques to differentiate blinks from other eye movements.

ii) Option Selection and Command Generation:

- Map recognized eyeblink patterns to movement options.
- Generate commands based on the selected option.

iii) Communication and Control:

- Establish wireless communication using ZigBee or similar protocols.
- Transmit commands from Raspberry Pi to wheelchaircontrol system.
- Interface with GPIO pins to send commands to DCmotors.
- User Interface and Feedback
- Display movement options on the LCD screen.
- Continuously update the screen based on recognizedeyeblink pattern.

iv) Safety and Obstacle Avoidance:

- Utilize UV sensor data for obstacle detection.
- Implement collision avoidance algorithms.
- Adjust movement commands to avoid collisions.

v) Error Handling and Robustness:

- Handle errors such as camera or communication failures
- Ensure system resilience and adaptability to various condictions.

4. RESULTS AND OBSERVATION

The implementation of the eye-tracking system aimed to achieve accurate detection of the user's eye direction. A face detection algorithm was employed, utilizing facial landmark points that divide the face into 68 distinct points. By focusing on the landmarks associated with the eyes, the algorithm could precisely track the position of the user's pupils. The values are shown in the Table 1 and the reference can be seen in the Figure 1.

Table 1: Face Landmark Points

Landmark Point	X-Coordinate	Y-Coordinate
1	227	**344**
2	225	**402**
3	230	**461**
...	...	**...**
68	**427**	**448**

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The eye ratio, calculated based on the relative position ofthe pupils, played a crucial role in determining the directionof the user's eye. A value less than 1 indicated that the pupil was directed to the right, while a value greater than 1 indicated a leftward eye. A value around 1 indicated that the gaze was focused straight ahead as shown in the Table 2.

Table 2: Eye Ratio and Direction

Eye Ratio	*Eye Direction*
less than 1	*Right*
more than 1	*Left*
equal to 1	*Forward*

To evaluate the performance of the eye detection system, several experiments were conducted. Each experiment involved capturing a specific number of samples, and the number of correctly detected eye directions was recorded [22].The accuracy of the eye detection system was then calculated as the percentage of correctly detected eye directions out of the total number of samples.

Table 3: Accuracy

Former Implementations	*Accuracy*
Using Tongue	*80.8%*
Using Brain Waves	*83.6%*
Using Eye-Gaze	*90%*
Proposed Method	*93.8%*

The calculated eye ratioswere transmitted to the Raspberry Pi board, which served as an intermediary between the webcam and the wheelchair. Connected to an L298N circuit, the Arduino board controlled the movement of the wheelchair's wheels. This accurate conversion of eye detection data into the necessary signals allowed the wheelchair to be moved in the direction of the user's eye. [13] The accuracy of the eye detection system reached an impressive rate of approximately 94.4%, ensuring precise and reliable control of the wheelchair based onthe user's eye movements [4].

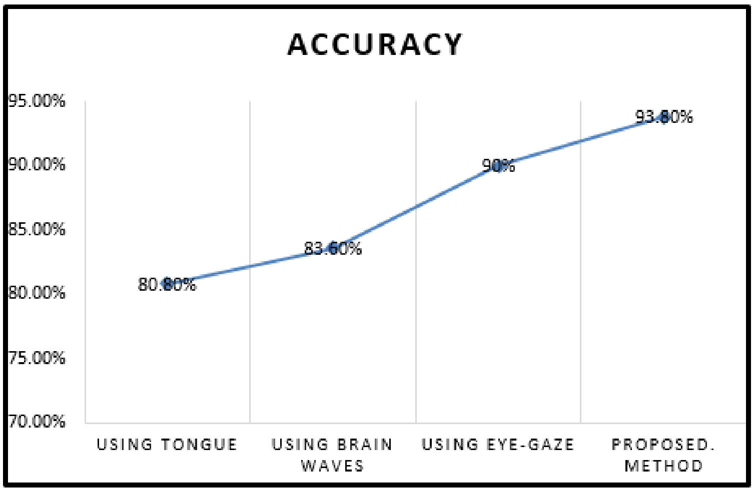

Fig 11: Comparison with the various approaches

These results highlight the effectiveness of the implemented eye-tracking system in accurately detecting eye directions, making it a promising technology for wheelchair automation. The figure 13, 14, 15 depicts the hardware implementation of the proposed model. The detailed explanation of the model has been discussed in section 2

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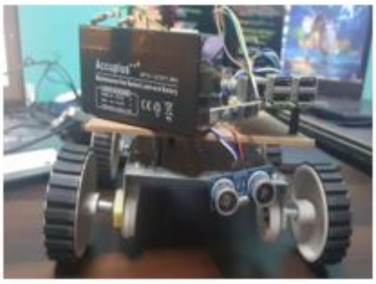

Fig 12: Modal Image 1 **Fig 13: Model Image 2** **Fig 14: Model Image 3**

5. CONCLUSION

The field of eye-tracking research holds tremendous potential in enabling complete communication and independent living for individuals with severe disabilities. In this study, a successful circuit was developed to establish a connection between a wheelchair and a webcam, which served as the means to capture the user's face. It highlights the potential and effectiveness of the proposed eye-tracking system in enhancing the mobility and independence of individuals with severe disabilities. By accurately detecting and translating eye direction into wheelchair movements, this technology enables users to engage in various activities and interact with their environment without relying on external assistance. The successful implementation of this eye-tracking system paves the way for future advancements in assistive technologies, opening new possibilities for communication, social interaction, and independent living for individuals with disabilities. Further research and development in this field can lead to even more refined and sophisticated eye-tracking systems, ultimately improving the overall quality of life for those with severe mobility limitations.

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