Manipal Journal of Science and Technology

Volume 9 | Issue 1 Article 3

6-30-2024

Advanced Eye Movement Tracking Using Computer Vision for Physically Disabled Patients

Anitha V R
BMS Institute of Technology and Management, Bengaluru, nithavr@bmsit.in

Nisha Ponnambalam
BMS Institute of Technology and Management, Bengaluru, nishaponnambalam1@gmail.com

Impana Bharadwaj
BMS Institute of Technology and Management, Bengaluru, impanabharadwaj14@gmail.com

Rajat Mundhra
BMS Institute of Technology and Management, Bengaluru, rajatmundhra2000@gmail.com

Research Article

Advanced Eye Movement Tracking Using Computer Vision for Physically Disabled Patients

Anitha V R*, Nisha Ponnambalam, Impana Bharadwaj, Rajat Mundhra

Email: anithavr@bmsit.in, nishaponnambalam1@gmail.com, impanabharadwaj14@gmail.com, rajatmundhra2000@gmail.com

Abstract

The paper introduces an efficient mobility assistance system to empower individuals with moderate to severe physical disabilities and chronic disorders such as Quadriplegia (Paralysis of four limbs) and Amyotrophic Lateral Sclerosis, utilizing advanced technology. The project focuses on developing an affordable eye-controlled wheelchair using Raspberry Pi, Pi camera, DC motors, proximity sensor, and computer vision technology. The core innovation involves integrating a Pi camera onto the wheelchair to obtain a live acquisition feed of the patient's eye. This captured eye movement serves as a control input to the Raspberry Pi board. Advanced computer vision algorithms analyze and translate the patient's gaze into precise direction commands for the DC motor drivers, facilitating wheelchair navigation. In addition, an integrated proximity sensor enhances patient safety by detecting obstacles and preventing collisions. The core objective of this project is to provide an affordable, accessible, and efficient solution for individuals with disabilities caused because of paraplegic and quadriplegic diseases, to improve their quality of life and independence.

Keywords: Computer vision, eye movement-controlled wheelchair, image processing, NumPy library, Python, Raspberry Pi.

I. Introduction

Mobility impairments can have a profound impact on an individual's ability to navigate their surroundings independently and can limit their freedom of movement. Quadriplegia, a disability that paralyzes all four limbs, affects a substantial global population of two million patients and underscores the need for innovative assistive solutions. While assistive technologies like voice control or hand gesture recognition exist [3-7], their efficiency is reduced by vocal and motor limitations in severe patients. Fortunately, advancements in technology have opened new possibilities for effective control systems, one of which is eye movement-based control which ensures a universally applicable solution spanning all spectrums of quadriplegia.

Eye movement-based control systems offer a promising solution for individuals with mobility impairments, as they allow the user to maneuver a wheelchair using only their eye movements. One such system is being proposed that leverages the capabilities of Raspberry Pi, a low-cost, credit card-sized computer, along with other essential components like DC motors, a Pi camera, and a DC motor driver. This innovative system aims to enable wheelchair navigation through the intuitive and precise control of eye movements.

The development of this eye movement-controlled wheelchair system involves many key steps. Firstly, the Pi camera captures the user's

Anitha V R[1]*, Nisha Ponnambalam[2], Impana Bharadwaj[3], Rajat Mundhra[4]

[1] Department of Electronics and Communication, BMS Institute of Technology and Management, Bengaluru, India

[2,3,4]Department of Electronics and Communication, BMS Institute of Technology and Management, Bengaluru, India

Manuscript received: 10-03-2024

Revision accepted: 30-03-2024

* Corresponding Author

How to cite this article: Anitha V R, Nisha Ponnambalam, Impana Bharadwaj, Rajat Mundhra, "Advanced Eye Movement Tracking Using Computer Vision for Physically Disabled Patients" *Manipal J. Sci. Tech.*, vol.9(1), 14-24, 2024.

eye movements, which are then processed in real-time using advanced image processing and computer vision techniques on the Raspberry Pi. These techniques analyze the captured eye movement data, allowing for precise tracking and interpretation. Finally, the processed data is utilized to control the DC motors responsible for wheelchair movement, translating the user's eye movements into desired actions.

By implementing this eye movement-controlled wheelchair system, the quality of life and independence of individuals with mobility impairments who are unable to utilize their limbs for control can be significantly improved [10]. The system offers a viable solution for those who require an alternative means of mobility. Moreover, by employing Raspberry Pi and other affordable components, this system strives to address the issue of accessibility and affordability, ensuring that individuals with mobility impairments can have access to this transformative technology.

The benefits of eye movement-based control systems extend far beyond the ability to maneuver a wheelchair. They empower individuals with mobility impairments to regain a sense of agency and autonomy, allowing them to actively participate in various aspects of life, such as education, employment, and social interactions. Moreover, these systems can enhance the overall physical and mental well-being of users by enabling them to engage in physical activities and explore their environment freely. In addition to its immediate advantages for individuals with mobility impairments, the eye movement-controlled wheelchair system holds great potential for further advancements and integration with other technologies [2]. For example, it could be combined with smart home automation systems to provide users with control over various appliances and devices through their eye movements. This would further enhance their independence and convenience in daily life.

The development of an eye movement-controlled wheelchair system using Raspberry Pi and other affordable components presents a remarkable opportunity to empower individuals with mobility impairments. By harnessing the power of advanced image processing, computer vision techniques, and precise motor control, this system can revolutionize the way individuals with limited limb mobility navigate their surroundings. By offering an accessible and affordable solution, it has the potential to improve the quality of life and independence of countless individuals, enabling them to actively participate in society and pursue their goals with newfound freedom.

II. Literature review

The application that extensively uses the concept of eye tracking include sectors in automotive industries, medical research, fatigue simulation, vehicle simulators, cognitive studies, computer vision, activity recognition, etc.

The significance of eye detection and tracking in commercial applications has increased over time. This significance of eye-tracking applications leads to more efficient and robust designs which is necessary in lots of today's modern devices.

An extensive review of literature has been done in the field of healthcare applications concerning the eye tracking system. Prior research has been done in this field and much new advancement is made every day. Some of the available interfaces are as follows:

1. ***Voice-based method*:**

It takes the user's voice as input and based on its recognition; directs the wheelchair to move. After voice analysis, the voice is converted to electronic data represented by digital signals. Perhaps the only downside of this voice-controlled system is that it is prone to noise and its signal-to-noise ratio is very low. Also, it is not helpful for people with speech disabilities.

2. ***EEG-based wheelchair*:**

The wheelchair moves based on brain signals and voltage differences. Technically, it is called Electroencephalogram or EEG. EEG signals in the form of voltages are sent to the microcontroller which then takes care of movement of the wheelchair [9]. This is a more precise technique compared to the rest of the interfaces as it does not require any body movement and there is no addition of noise.

***3. Joystick-controlled wheelchair*:**

In this, the patient is provided with a joystick with which the user can assume control of the wheelchair [8]. It is not very useful for people with full body paralysis as they will not be able to move their hands and hence lose their credibility when it comes to quadriplegia.

***4. Gesture-controlled wheelchair*:**

It controls the wheelchair movements using hand gestures [1]. It is a reliable method for an interface between humans and computers and can be used for wheelchair movement. Web cameras can be used to input gesture signals. Further, the AdaBoost algorithm is brought into use to detect the location of the centre of the hand. The output image has a resolution of 320*240 pixels which is divided into nine blocks. The algorithm checks as to which block the hand is located and moves the wheelchair accordingly.

III. Objectives

There are certain objectives of this project, which are stated below:

- **To develop an eye movement-controlled wheelchair using Raspberry Pi, DC motor, Pi camera, and DC motor driver:**

  This point outlines the objective of creating a wheelchair that can be controlled by the movement of the user's eyes. The Raspberry Pi, a small computer, will be used as the main control unit. The DC motor and DC motor driver will be responsible for the wheelchair's movement, while the Pi camera will capture the user's eye movements for control input.

- **To implement an efficient eye-tracking algorithm for accurately capturing eye movements:**

  To accurately interpret the user's eye movements, an efficient eye-tracking algorithm will be developed. This algorithm will analyze the video feed from the Pi camera and extract relevant information about the direction and intensity of the user's gaze. The goal is to ensure precise and reliable control of the wheelchair-based on the user's eye movements.

- **To design a user-friendly interface for controlling the wheelchair using eye movements:**

  Creating a user-friendly interface is essential to ensure that individuals with mobility impairments can easily operate the eye movement-controlled wheelchair. The interface will provide intuitive controls that map the user's eye movements to wheelchair commands. The design will focus on simplicity, clarity, and ease of use to facilitate smooth interaction between the user and the wheelchair.

- **To evaluate the performance and usability of the developed system through experiments and testing:**

  After developing the eye movement-controlled wheelchair and its accompanying interface, it is crucial to evaluate its performance and usability. This will involve conducting experiments and testing the system with individuals who have mobility impairments. The aim is to assess the system's accuracy, responsiveness, and overall user experience. Feedback from users will be gathered and analyzed to identify areas for improvement and validate the effectiveness of the developed solution.

- **To provide a cost-effective and accessible solution for individuals with mobility impairments:**

  The goal of this project is to create a wheelchair control system that is both cost-effective and accessible. By utilizing affordable components like the Raspberry Pi and incorporating open-source software, the aim is to reduce the overall cost of the system. Additionally, the focus on accessibility means that the solution should be usable by individuals with varying degrees of mobility impairments, ensuring that it can be easily adopted and integrated into their daily lives.

Our primary objective is to develop a highly accurate and responsive eye movement-based control system that specifically focuses on tracking the movements of the user's eyes. The core concept behind this innovative system is to create a wheelchair that is monitored by a camera constantly fixated on the person's eyes. By closely observing the eye movements, the system can make informed decisions regarding wheelchair movement, enabling it to navigate in the desired direction precisely and reliably.

To achieve this, a camera is strategically positioned to capture and analyze the person's eye movements in real time. The collected eye movement data is then processed using advanced algorithms and computer vision techniques. By accurately interpreting the direction and intensity of these eye movements, the system determines the user's intended movement commands for the wheelchair.

This eye-monitored wheelchair system represents a significant advancement in assistive technology, as it allows individuals with limited or no limb control to control their mobility effortlessly and intuitively. It offers a direct and natural interface that directly translates their eye movements into wheelchair commands, providing a level of independence and freedom that was previously inaccessible.

By focusing on the precise tracking and interpretation of eye movements, we aim to create a system that is highly responsive and can effectively cater to the unique needs and preferences of each user. This personalized approach ensures that the wheelchair accurately reflects the intentions of the individual, enhancing their overall sense of control and autonomy.

In summary, our goal is to develop an eye-monitored wheelchair system that capitalizes on the movements of the user's eyes. Through continuous monitoring and analysis of eye movements, this innovative system allows for intuitive and accurate control of the wheelchair, empowering individuals with limited limb control to navigate their environment with confidence and independence.

IV. Methodology

The principle of this system is eye movement tracking and blinking of the eyes based on computer vision technology. The first step involves mounting a Raspberry Pi camera on the wheelchair for eye tracking and connecting DC motors to the wheelchair for navigation. Next, image acquisition is done continuously to capture video frames from the Raspberry Pi camera. Following this, accurate eye detection is performed by using the OpenCV library (cv2) to detect and localize the eyes in each frame and the Dlib library's facial landmarks to precisely identify eye regions. Subsequently, Image Preprocessing using scikit-image is carried out by applying preprocessing techniques in scikit-image functions to enhance eye-tracking accuracy. After this, gaze estimation is implemented via a gaze estimation algorithm to determine the direction of the user's gaze based on eye positions. Dlib provides tools for estimating gaze direction using the positions of facial landmarks. Post this step, the critical step of Data Processing is performed which utilizes NumPy for efficient manipulation and processing of eye movement data. We also apply smoothing techniques to reduce noise in gaze estimation. Now, a mapping is created between the estimated gaze direction and wheelchair movement commands. For example, if the gaze is directed to the left, instruct the wheelchair to turn left. After the successful completion of mapping, DC motor drivers are interfaced with a wheelchair to control the movement of the wheelchair. The GPIO pins on the Raspberry Pi send commands to the motor drivers. Thus, following the above procedure, we have implemented a real-time feedback mechanism to maneuver the patient in their desired direction.

V. Block diagram

The system is fully independent, and all modules work independently of each other. In this system, the power supply of each component is mandatory, and standard power must be used for Raspberry Pi, Pi cameras, sensors, and motors.

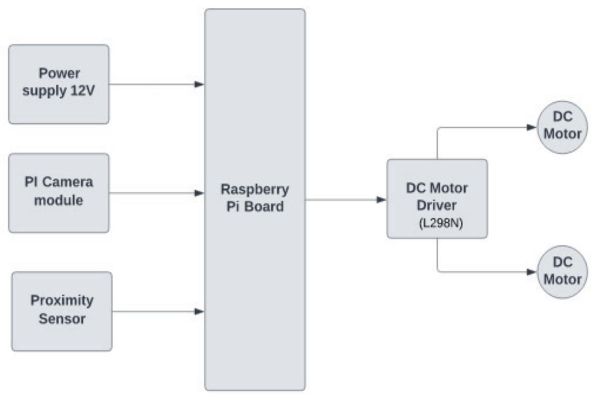

Fig 5.1. System architecture

Figure 5.1 shows the working of the system:

The Raspberry Pi Board is the heart of the system, which controls the entire work of the system. The Raspberry Pi card is a single-board computer that runs under the LINUX operating system.

The Raspberry Pi controls the motor driver circuit which activates the GPIO pin of the Raspberry Pi. The Raspberry Pi B model only processes frame by frame.

The Pi camera module is a lightweight portable camera that supports Raspberry Pi. It interacts with Raspberry Pi via the MIPI camera serial protocol. Usually used in project supervision. The camera takes the picture. Various operations are performed on this image to get the output signal. The Raspberry Pi then analyzes the output signal and sends the control signal to the motor drive circuit based on the eyes' position. It responds to motor movements in a clockwise or counterclockwise direction or stops. Two separate motors are mounted on each wheel. When the sensor detects a barrier near the wheelchair, it gives a Raspberry Pi signal and sends a command to the motor driving circuit to stop the motor.

DC motor

Two 12 V DC motors show wheelchair movements in front, back, left, and right. The L298N motor driver is used to interact with the Raspberry Pi board. L298N is a dual H Bridge driver that supports speed and direction control of two DC motors simultaneously. This module can drive DC motors with voltages in the range of 5 to 35 V with peak currents of 2A.

VI. Implementation and experimental setup

A. Experimental setup

Here is an experimental setup for an eye-controlled wheelchair using Raspberry Pi, a Pi camera, and DC motors:

The Proximity Sensor is based on infrared (IR) technology and uses active sensing mechanisms to detect the presence or absence of objects in their vicinity. The proximity sensor used in this project is compact and energy- efficient. It precisely measures distances and adapts sensitivity for real-time obstacle recognition. Placed at the front of the wheelchair, it provides dynamic feedback for safer navigation. The sensor's wide operating voltage range aligns well with the project's energy-efficient requirements, contributing to overall reliability.

Materials: - Raspberry Pi, Pi camera module, DC motors (two or four depending on the type of wheelchair), DC Motor driver board (L298N), Proximity sensor, Breadboard, Jumper wires, 12V battery, and Power bank (optional)

Steps:

1. Connect the Pi camera module to the Raspberry Pi's camera port.
2. Connect the DC motors to the motor driver board. Use jumper wires to connect the motor driver board's input pins to GPIO 17, 18, 27, and 22 (if using four motors) or GPIO 17 and 18 (if using two motors).
3. Connect the motor driver board to the Raspberry Pi's 5V and ground pins.
4. Connect the 12V battery to the motor driver board's power input pins.

5. Write code to capture images from the Pi camera and process them using computer vision algorithms to track eye movement.
6. Use the motor driver board to control the DC motors based on the user's eye movement and obstacle detection.
7. Test the wheelchair's functionality and adjust the code and hardware as necessary.
8. Connect the Proximity sensor which is placed at the front of the wheelchair and its output to GPIO 23, for obstacle detection.

B. Hardware implementation

Raspberry Pi

Raspberry Pi is the central component of the system. The boards are equipped with a CPU, RAM, USB ports,

Ethernet, HDMI, and other necessary components to run a variety of operating systems, such as Linux, Windows, and Android.

Pi camera

The Pi camera is positioned in a suitable location, typically near the user's face, to capture the video feed of the user's eyes. The camera captures high-resolution video frames at a specified frame rate, which contains eye movement patterns, such as pupil dilation or movement, and other visual cues. The video feed from the Pi camera is processed in real-time by the image processing algorithms running on the Raspberry Pi. These algorithms analyze the video frames to detect and track the eye movement patterns, which are then converted into control signals for the wheelchair. Image processing algorithms may involve techniques such as image filtering, edge detection, feature extraction, and pattern recognition to accurately capture the eye movement patterns. Once the eye movement patterns are detected and tracked, the software running on Raspberry Pi interprets them to determine the desired direction and speed of the wheelchair. For example, if the algorithm detects a leftward eye movement, it may indicate a command to turn the wheelchair to the left. The interpretation of eye movement patterns may be customized based on the specific requirements of the system and the user's preferences. The Pi camera may also be used for calibration and customization of the system. Calibration involves adjusting the camera settings, such as focus, exposure, and frame rate, to optimize eye movement detection accuracy. Customizations may involve adjusting the image processing algorithms or parameters to suit the specific characteristics of the user's eye movements or environmental conditions. The Pi camera may also provide visual feedback or monitoring capabilities in the system. For example, the camera feed can be displayed on a screen or a mobile app to provide real-time visual feedback to the user about their eye movements and wheelchair control. It can also be used for monitoring and recording eye movement data for analysis, evaluation, or improvement of the system's performance.

DC motor

The DC motor is typically connected to the wheels or drive train of the wheelchair and is used to provide the necessary torque and power for the wheelchair's movement. The motor is controlled by the Raspberry Pi, which processes the eye movement data from the Pi camera and sends commands to the motor driver to control the motor's speed and direction based on the user's eye movement inputs. For example, if the user looks to the left, the motor may be commanded to rotate in a certain direction to turn the wheelchair to the left. The DC motor can be controlled to provide variable speed control for the wheelchair. The speed of the motor can be adjusted based on the intensity or duration of the user's eye movement inputs. For example, a stronger or prolonged eye movement in a certain direction may result in a higher motor speed, while a weaker or shorter eye movement may result in a lower motor speed. This allows for fine-grained control of the wheelchair's movement speed, providing a smooth and responsive control experience for the user. It can be integrated with safety features, such as emergency stop or collision detection, to ensure the safe operation of the wheelchair.

Proximity sensor

The proximity sensor serves as a vital component in the wheelchair system, contributing to its safety and obstacle-detection capabilities. Positioned strategically, the sensor continuously monitors the wheelchair's surroundings, providing real-time data to the Raspberry Pi. In response to this input, the system can implement safety features such as emergency stops or obstacle avoidance. For instance, if the proximity sensor detects an obstacle in the wheelchair's path, it triggers a command to halt or adjust the wheelchair's trajectory to prevent a collision. This proactive approach to obstacle detection enhances the overall safety of the wheelchair, making it an integral element in ensuring a secure and reliable user experience.

C. Software Implementation

Python IDE

Images define the world; each image tells a narrative and includes a wealth of information that may be applied in various ways. The technology known as Python Image Processing can be used to obtain this information. It is an important component of computer vision that is used in numerous real-world applications like robots, self-driving automobiles, and object detection. Image processing allows us to change and manipulate millions of photos at once, extracting valuable information. It has numerous uses in nearly every field. Its fantastic libraries and tools aid in the efficient completion of Python image-processing tasks. Python is a high-level programing language and is open source that is, it is free to use. Image processing is done using Open CV libraries in Python IDE.

OpenCV

It is necessarily an open-source software library, and its module is to be installed in Python using pip install. Open CV was initially designed to cater to the need for a common platform or scope for applications requiring computer vision and image processing. OpenCV being an open-source platform is very helpful in the computer vision industry.

Operations done with NumPy can be combined with OpenCV which makes it such a powerful tool for image processing. Open-Source Computer Vision Library (OpenCV) contains more than 2,000 optimized computer vision and machine learning algorithms.

OpenCV can be used in Python image processing in a variety of ways, some of which are given below:

1. Converting photos from one colour space to another, such as BGR to HSV, and BGR to grey.
2. Performing image thresholding, such as simple thresholding and adaptive thresholding.
3. Applying custom filters to photos and blurring images are examples of image smoothing.
4. Using photos to perform morphological processes.
5. Constructing picture pyramids.

System Working Eye Detection and Scaling

Cv2.VideoCapture is a class for capturing videos or image sequences from cameras. A variable will get the next frame in the camera. The obtained coloured image is converted into a gray colour code so that it becomes easier to further apply image processing techniques on the eyes. Pre-trained Haar-cascade features are used for eye detection using the hardcascade_eye.xml file. Our model has a fixed size defined during training. This means that this size of eye is detected in the image if occurring. The algorithm detects the face and eyes based on its training the Detected Eyes and Improving contrast using cv2.equalizeHist () and conversion to a binary image. Cv2.equalizeHist increases the overall contrast of an image. After applying this adjustment, there is a better distribution of the intensities of contrast on the histogram. Cv2.threshold is used to convert a grayscale image to a binary image. If the pixel value being scanned exceeds a beforehand set threshold value (55 of gray colour), it is assigned a value (say white), otherwise, if it is less than the threshold value, it is allotted another value (say, black). The first argument is the source image, which is the grayscale image we obtained after the first step. The second argument is the threshold value. Finally, the third argument holds the maximum value (255 of black colour) that is to be allocated to that pixel if its value is greater than the earlier specified threshold value.

Morphological transformations

These are some simple basic operations generally performed on binary images.

Published by Impressions@MAHE, 2024

It has two parameters as input, the first input is the binary image, and the second parameter is the structuring element technically called a kernel. This kernel then decides on the type and extent of change, that is, a morphological transformation that is going to be performed on the image. It can broadly be classified into two types: erosion and dilation. These can further be subdivided into opening, closing, gradient, etc.

Closing is used to remove false negatives. Closing is done when we have detected the shape, but we still have some unwanted pixels within the object we intend to detect. Closing gets rid of them.

Erosion erodes the boundaries of the foreground object as in 2D convolution, the kernel is a matrix that slides as a filter through the image. A particular pixel of the input binary image (say, 1) will be taken as one only if every pixel under the structuring element is similar, that is 1, otherwise it is eroded,

Finding Contours using cv2.findContours(): Contour can simply be explained as a locus formed by verging all the perpetual points sharing a common property of having identical intensity along a boundary. Contours are very vital when it comes to shape analysis and object detection and recognition. This function modifies the source image. A contour in terms of image processing in Python is a Python list comprising all the contours present in an image. Each defined contour can be seen as a NumPy array of (x, y) coordinates of confinement points of the object to be detected. Extracting pupil and finding its centroid A blob is an array of connected pixels in an image that partake some common property. We intend to find the centroid of a blob that is a pupil in a binary image using OpenCV module libraries in Python. The centroid of a shape is the arithmetic mean or average of all the points in a shape. Suppose a shape consists of n distinct points x1 . . . xn, then the centroid location, c, is specified. When talking about image processing and computer vision, the centroid is the weighted average of all pixels making up the shape. We can easily find the centre of the pupil blob using moments in OpenCV. Image Moment can be defined as a weighted average of image pixel intensities. The centroid is calculated using the formula given by:-

$$C_x = \frac{M_{10}}{M_{00}}$$

$$C_y = \frac{M_{01}}{M_{00}}$$

Equation 6.1. Centroid equation

Here, Cx and Cy are respectively the x and y coordinates of the centroid of the pupil and M denotes the moment, finding the direction of gaze using the centroid coordinates of the pupil. If the coordinates of the centroid obtained lie in the centre block, the program will indicate the direction gaze as “Straight”. If the centroid location lies in the third column, it will indicate the gaze direction as “left”. Similarly, if the centroid location lies in the first column, it will mean that the gaze direction is “right”.

Table 6.1. Range of dırectıon of gaze

Direction of Gaze	Condition	Centroid Location (Cx) Range
Right	$29 \leq C_x \leq 49$	$29 \leq C_x \leq 49$
Straight	$50 \leq C_x \leq 69$	$50 \leq C_x \leq 69$
Left	$C_x \geq 70$	$C_x \geq 70$

The output image will be divided into three blocks by fixing the coordinates of each block. The coordinates of each output block are shown below. Table 6.1: Centroid Location and Direction of Gaze Right (cx >=29 and cx<=49), Straight cx >= 50 and cx<=69), and Left cx>=70 and cx=70.

VII. Future milestone of the eye-controlled wheelchair

Based on current trends and advancements in technology, we can expect the following milestones in the development of eye-controlled wheelchairs. The future scope of eye-controlled wheelchairs is vast and promising. Here are some potential directions that researchers and developers may pursue in the future:

- ***Improvement of accuracy and speed:***

One of the main challenges with eye-controlled wheelchairs is the accuracy and speed of the eye-tracking technology. Future research may focus on developing more accurate and faster eye-tracking systems, possibly using new types of sensors or machine learning algorithms.

● ***Integration with other assistive technologies:*** Eye-controlled wheelchairs can be combined with other assistive technologies, such as brain-computer interfaces, speech recognition, and environmental control systems, to provide a more comprehensive solution for people with disabilities.

● ***Enhanced user experience:***

The user experience of eye-controlled wheelchairs can be improved by integrating features such as voice guidance, obstacle avoidance, and automated navigation. Future research may focus on developing these features to make the wheelchair more user-friendly and autonomous.

● ***Increased accessibility:***

Eye-controlled wheelchairs can be made more accessible to people with different types of disabilities, such as those with limited mobility or visual impairments. Future research may focus on developing customized solutions for different user groups.

● ***Commercialization and cost reduction:***

Eye-controlled wheelchairs are still relatively expensive and not widely available. Future research may focus on commercializing the technology and reducing the cost to make it more accessible to a wider range of users.

VIII. Result and discussions

The results obtained from the experiments conducted on the developed system will be presented and analyzed in this section.

The accompanying figures (Figures 8.2, 8.3, and 8.4) visually depict the successful detection of pupil positions and corresponding wheelchair movement directions, providing clarity, and visual representation of the system's functionality.

A) Blinking:

The detection of eyes being closed for a longer period results in the wheelchair movement halting. To avoid the same result occurring when the user blinks without the intention of stopping movement, blinking is detected as well. This does not halt the wheelchair.

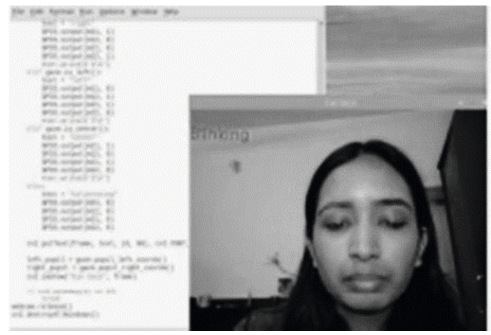

Fig 8.1. Detection of Blinking

B) Centre Position:

When the pupil is detected to be in the centre position, the wheelchair moves in the forward direction

Fig 8.2. Detection of pupils in centre position

C) Right position:

When the pupil is detected to be on the right side of the eye, the wheelchair moves in the clockwise direction.

Fig 8.3. Detection of right direction four

D) Left position:

When the pupil is detected to be on the left side of the eye, the wheelchair moves in the anticlockwise direction.

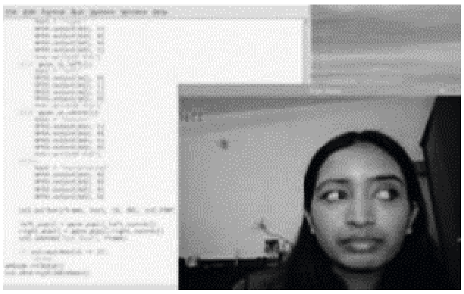

Fig 8.4. Detection of left direction

Each of these functionalities enhances the usability and control of the wheelchair system based on the detected position of the user's pupils. The system effectively translates these pupil positions into specific commands for wheelchair movement, offering improved mobility and navigation options for users with limited physical abilities.

IX. Conclusion

Accurate eye tracking: The Pi camera module and computer vision algorithms can be used to accurately track the user's eye movement and translate it into motor commands for the wheelchair.

Smooth and responsive movement: The DC motors and motor driver board can be used to provide smooth and responsive movement of the wheelchair, based on the user's eye movement and obstacle detection.

Low cost and easy to maintain: The use of off-the-shelf components, such as Raspberry Pi, and Pi camera can make the eye-controlled wheelchair relatively low cost and easy to maintain.

Customizable for different user needs: The code and hardware can be customized to meet the specific needs and preferences of individual users, such as adjusting the sensitivity of the eye tracking system or adding voice guidance.

Overall, the results for an eye-controlled wheelchair using Raspberry Pi, Pi camera, and DC motors can be promising, with the potent ial to improve the mobi lity and independence of people with disabilities. However, further testing and evaluation may be necessary to validate the performance and usability of the system.

References

1. S. Kundu, O. Mazumder, P. K. Lenka and S. Bhaumik, “Hand Gesture Recognition Based Omnidirectional Wheelchair Control Using IMU and EMG Sensors”, Journal of Intelligent & Robotic Systems, vol. 91, no. 3, pp. 529-241, 2018.
2. M. Barreto and E. C. Larson, "Eye Movement-Based Human-Computer Interaction Techniques: A Review," Foundations and Trends® in Human-Computer Interaction, vol. 8, no. 4, pp. 189-329, 2016.
3. J. B. Reswick and R. W. Rogers, "Developments in Powered Wheelchairs for the Severely Disabled," Engineering in Medicine and Biology Magazine, vol. 4, no. 4, pp. 23-29, 1985.
4. D. R. McDuff, R. W. Picard, and P. J. Maes, "Improving Computer Interface Design for Users With Physical Disabilities Through Conversational Agents and an Adaptive User Interface," Universal Access in the Information Society, vol. 9, no. 3, pp. 269- 281, 2010.
5. S. Nakanishi, Y. Kuno, N. Shimada, and Y. Shirai, "Robotic wheelchair based on observations of both user and environment," in Proceedings of IEEE/RSJ International Conference on Robots and Systems, Kyongju, Korea, pp. 912-917, 1999.
6. Y. Kuno, Y. Murakami, and N. Shimada, "User and social interfaces by observing human faces for intelligent wheelchairs," ACM International Conference Proceeding Series Archive, Proc. Workshop on PerceptiveUser Interfaces, Orlando, Florida, USA, pp.1-4, 2001.
7. R. K. McGookin and S. Brewster, "Understanding Efficiency and User

Performance in Pointing with Mouse and Keyboard," ACM Transactions on Computer-Human Interaction (TOCHI), vol. 19, no. 3, pp. 1-32, 2012.

8.] Putri Madona, Husna Khairun Nisa, Yusmar Palapa Wijaya and Amnur Akhyan, "The Design Of Wheelchair Systems With Raspberry Pi 3- Based Joystick Analog And Voice Control", Published under licence by IOP Publishing Ltd, Indonesia, Nov 2019.
9. Mamunur Rashid, Norizam Sulaiman, Mahfuzah Mustafa, et al. "Recent Trends and Open Challenges in EEG Based Brain-Computer Interface Systems", Malaysia, 24 Mar 2020.
10. Shahin, M. K., Tharwat, A., Gaber, T., Hassanien, "A Wheelchair Control System Using Human-Machine Interaction: Single-Modal and Multimodal Approaches". Journal of Intelligent Systems, Apr 2019.