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DEMONSTRATION OF AUTOMATIC WHEELCHAIR CONTROL BY TRACKING EYE MOVEMENT AND USING IR SENSORS

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ABSTRACT

People suffering from quadriplegia are unable to use both their hands and their legs. In such a scenario, they are dependent on others to move them around which results in a loss in their self-confidence. The only movements they are able to achieve are their heads and therefore their eyes. This paper leverages this movement of the eye and implements a method to track the movement of the eye to automatically control a wheelchair. A vision based system is utilized here, wherein the web-camera of the laptop is utilized to acquire images of the patient. By implementing the Viola Jones algorithm, the eyes of the patient are detected. Using MATLAB, these images undergo various morphological processes and on further analysis eye movements are tracked to determine in which direction the wheelchair is to be moved. These signals are then sent to the Arduino which forwards it on to the DC motors via the L293D IC.

Keywords: wheelchair, eye movement tracking, image processing, eye detection, viola Jones algorithm.

1. INTRODUCTION

The number of people who are paralyzed or suffering from quadriplegia due to some disease or illness and therefore are dependent on other people has increased in recent years. Making them self-reliant and not dependent on others for moving around will go a long way in reinstating their self- confidence.

Eye movement tracking is nothing but the tracking of the iris movement. The iris is the black circular region of the eye which lies on the white region. This white region is called the sclera. Figure 1 shows the eye of a human being.

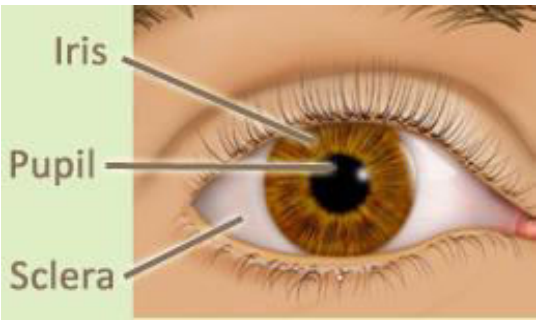

Figure-1. External eye of human being.

This difference in colour enable one to track the iris movement and therefore a researcher is able to determine in which direction the eye is looking at any given point of time and also the sequence in which their eyes are shifting from one location to another. This information can be used for various purposes like motor control or computer control without using mouse.

The Image Processing field has been massively growing in the past few years. It supports various morphological processes like edge detection, conversion of image to binary, complement of image, erosion, noise remove, image enhancement and image segmentation.

The development of electric wheelchair for paralyzed users has been fairly recent. Conventional wheelchairs are operated manually and require the patient to use his hand. It excluded those who are unable to do so. Electric wheelchairs have been developed using various techniques, other than vision base systems. Earlier methods included using ECG and EOG systems. These techniques involve the use of electrodes and other physical contacts with the face which make it very inconvenient for the patient. In [1], [2] and [3], an EOG system is used wherein; electrodes are placed in either side of the eyes. When there is a movement of the iris from the center to either corner of the eye, there is a change in potential between the electrodes which can be used to control a wheelchair. The voice recognition technique in [4] cannot be used for dumb people and is not applicable in noisy areas. The infrared radiation method mentioned in [5] makes use of IR radiation to detect eye movements. The exposure of IR rays on the eyes causes an immense strain on the patient.

The Circular Hough Transform method utilized in [6], [7], [8] and [9] is very accurate method to detect eyes. However, it works best when an existing database of eye is used and does not give value to real world applications due to its processing time in detecting the iris. Additionally, it works best on only completely circular objects, i.e., when the person is looking straight. When the person looks in the other directions, the accuracy of detecting the iris decreases.

The machine learning method used in [10] has very good accuracy. However, they are computationally very complex and require large training sets.

The main aim of this paper is to provide a cost-effective solution with minimal physical interaction with the patient. Additionally, this paper is to be implemented in real time and therefore the latency has to be very minimal and the accuracy has to be good, both of which is achieved by implementing this paper.

2. PROPOSED ALGORITHM

Figure-2 shows a high level flow chart of our entire process of eye movement detection. The MATLAB IDE was used for all of our programming.

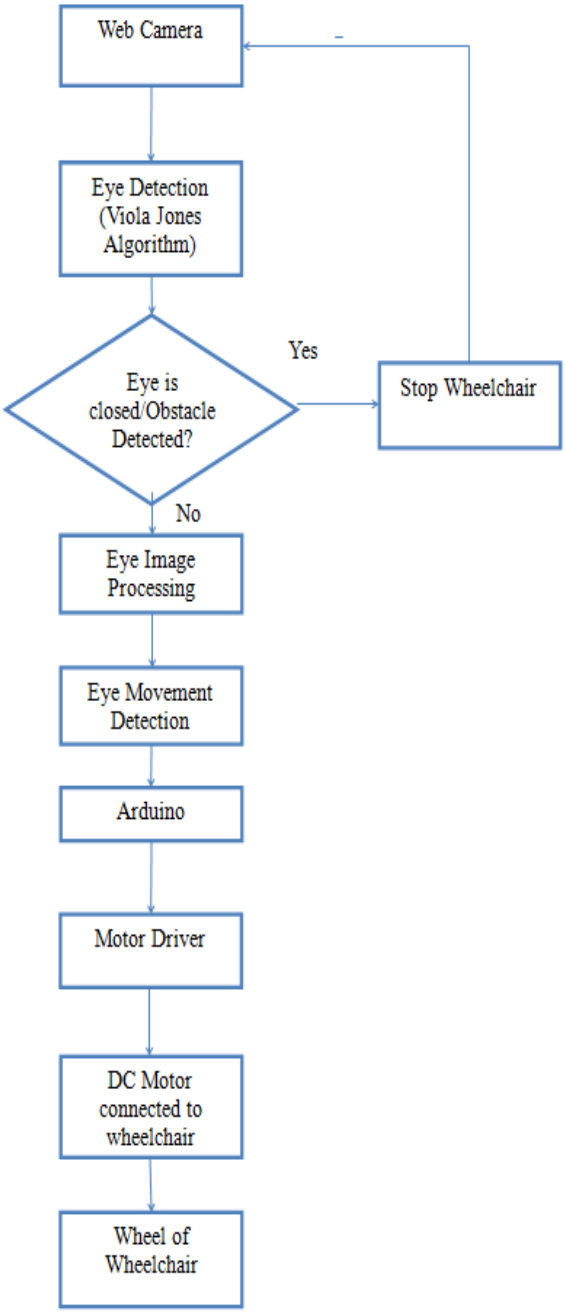

Figure-2. Flow chart of the paper.

A. Eye detection

MATLAB is configured to receive a continuous stream of video data from the web-camera of the laptop. This video stream is sampled every 25 frames. Sampling the video stream every frame is not possible as a lot of processing needs to be carried out which is impossible on a per frame basis. These 25 frames correspond to 1 second. Therefore, a snapshot is taken every second. The input image is a RGB image with a resolution of 720x1280x3.

The image undergoes few pre-processing steps before the eyes are detected. The image is converted to a grayscale image and contrasted so that the dark parts of the image become darker and the light part of the image becomes lighter. This improves the eye detecting capability of the Viola Jones algorithm. The resolution of this grayscale image is 720x1280. The Viola Jones algorithm is applied to detect both the eyes. The image is cropped according to the height and width of a valid left eye of the patient. This serves as an error handling mechanism as any other object which seems like an eye will be rejected. Figure-3 shows the eyes detected by the Viola Jones algorithm, whereas Figure-4 shows the cropped left eye of the patient.

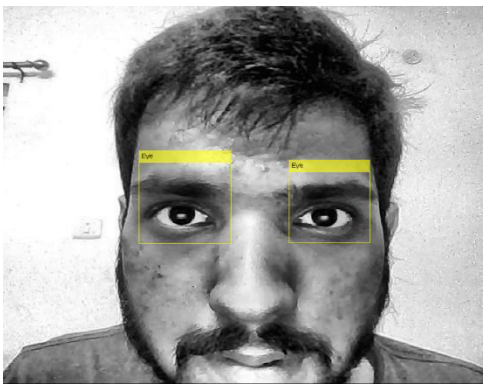

Figure-3. Eye detection using Viola Jones algorithm.

Figure-4. Cropped eye.

As seen in the flow chart, in order to stop the wheelchair, the person has to close his eyes for 1 second. This detection is carried out by finding the local maximum peaks in the image. An open eye will have a larger number of maximum peaks as compared to a closed eye. A closed eye will have its peaks spread out and therefore a lesser number of peaks. Figure-5 shows the plot of a closed eye and Figure 6 shows the plot of an open eye.

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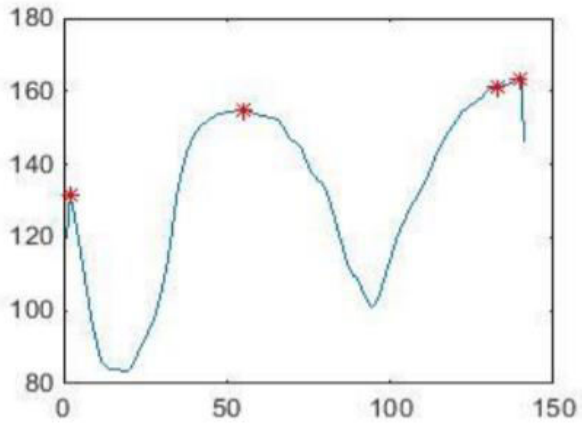

Figure-5. Peaks of image when eye is closed (Number of Pixels vs Intensity)

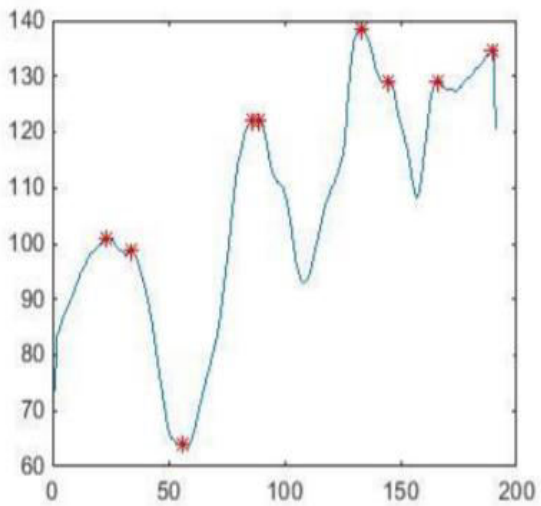

Figure-6. Peaks of image when eye is open (Number of Pixels vs Intensity)

B. Image processing

If the eye is determined to be open, it indicates that the wheelchair needs to be moved in a particular direction. The main aim now is to obtain just the iris region to determine in which direction it is facing. Therefore, the image undergoes a series of processing steps to obtain this, which is highlighted in the form of a flow chart in Figure-7.

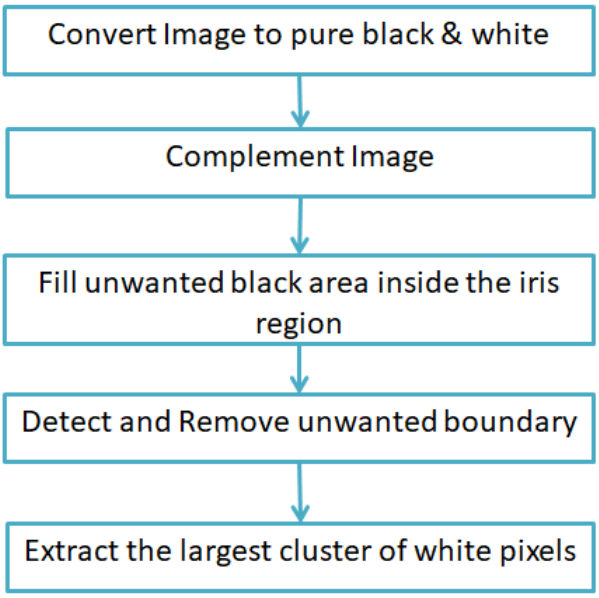

Figure-7. Image processing flow chart.

The grayscale cropped image is converted to a binary image. This means that the pixel values of the image are converted from between 0 and 1 to either 0 or 1 based on a threshold value. This threshold value is determined after numerous tests. Figure-8 shows the converted binary image of the eye.

Figure-8. Binary image of eye.

From the figure above, it is seen that the iris is black in colour. The final objective is to get a white iris image against a black background. Therefore, the image is complemented. This means that the black pixels are converted to white and white pixels are converted to black. Figure-9 shows the complemented image.

Figure-9. Complemented image of eye.

In the figure above, the middle of the iris contains few black pixels. This is an error which is due to the reflection of light on the eye. This is solved by using the 'imfill' function available in MATLAB, which detects black pixels surrounded by white pixels and replaces it with white pixels. Figure-10 shows the image of the eye without that error.

Figure-10. Image of eye without error.

The next step is to determine the largest cluster of white pixels and retain that cluster and eliminate the rest of the pixels. This is done using the 'bwareafilt' function available in MATLAB. Figure-11 shows that just the iris area of the image has been retained and the rest has been eliminated.

Figure-11. Filtered image.

C. Eye Movement detection

Once all the processes have been implemented on the image, the image is divided into 9 equal cells. The sum of all pixels of each cell is computed. If the combination of cells of 4, 5, and 6 has the largest sum, then the wheelchair should move straight. If the combination of cells of 1, 2 and 3 has the largest sum, then the wheelchair should move right. Else, the wheelchair should move left. Figure-12 shows the split image. Table-1 summarizes what constitutes a valid movement.

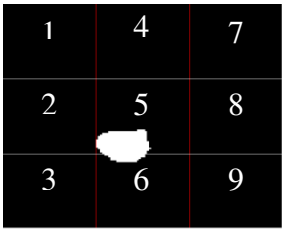

Figure-12. Splitting of image into 9 cells.

Table-1. Decision algorithm to control the motor movement.

Valid Left	Sum of Pixels of cells 7,8,8 is the highest. High signal send to the right wheel and low signal to left wheel
Valid Right	Sum of Pixels of cells 1,2,3 is the highest. High signal send to the lest wheel and low signal to right wheel
Valid Straight	Sum of Pixels of cells 4,5,6 is the highest. High signal send to both wheels

D. Safety mechanism

This paper has included a safety mechanism in this paper to prevent injury to the patient in case he is unable to see an obstacle in front of the wheelchair. We have 2 digital IR sensors placed on either front ends of the wheelchair. These IR signals, transmitted by the transmitter, are received by the IR receiver and outputs a high signal which is an indication that the wheelchair should stop. As long as the IR sensor returns high value, there is an obstacle in front of the wheelchair and the wheelchair should stop. To resume the movement of the wheelchair, simply remove the obstacle from the path of the wheelchair. Figure-13 shows an IR sensor which is used in the setup.

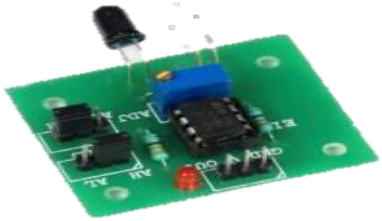

Figure-13. IR Sensor.

E. Hardware design

According to the condition in Table-1, the appropriate signal is sent to the appropriate pin in the Arduino. From the Arduino, the signal is sent to the L293D motor driver IC. This IC is used to amplify the small current coming from the Arduino into a large current which is capable of driving the DC motors. Therefore, the signal is sent to the DC motor from the L293 motor driver IC. These DC motors are connected to either wheel of the

wheelchair. Figure-14 shows the hardware circuit employed to drive the DC motors. Figure-15 shows the prototype of a wheelchair which was assembled for this task.

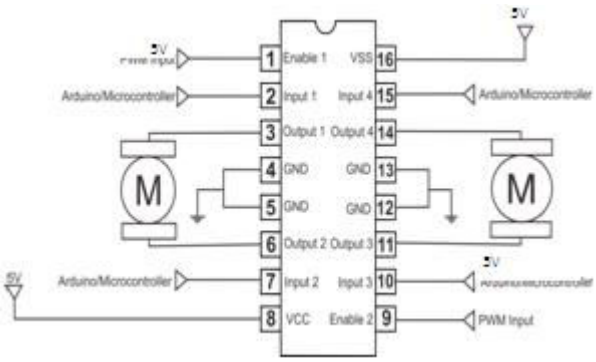

Figure-14. Hardware circuit.

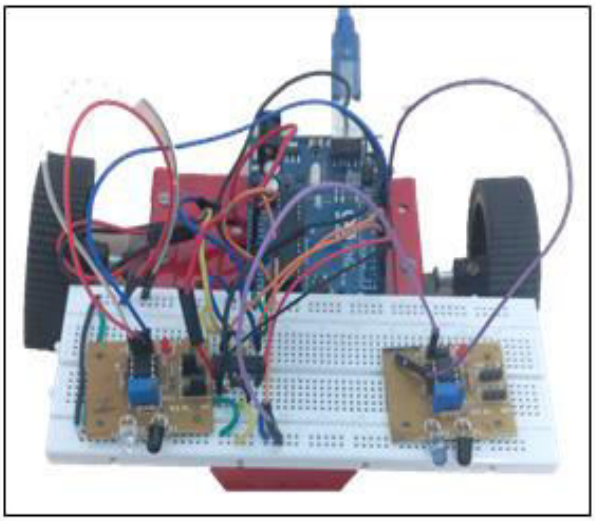

Figure-15. Wheelchair prototype.

3. PROJECT DEMONSTRATION

The image has undergone various processing stages in this project. This section discusses the results of these processes in detail. The debug screen of MATLAB was the most useful aspect of our testing strategy. Figure-16 shows complete setup of the system including the hardware and the laptop with the debug screen which constantly displays the direction the wheelchair will move in and any errors, if present.

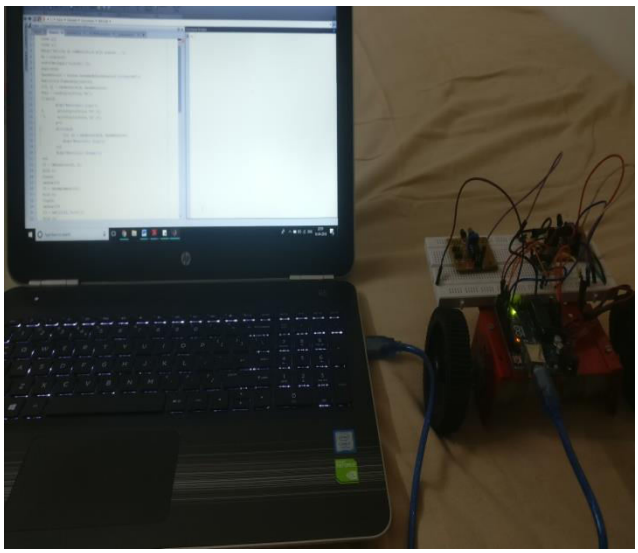

Figure-16. Complete hardware setup of the system.

4. RESULTS AND DISCUSSIONS

A. Accuracy

This system was tested on two different people with constant height and width threshold values of the eye for 100 iterations in random directions. The performance accuracy for this system lies in the range of 70-90%. Successful attempts were counted as all those attempts which resulted in movement of the wheel chair in the desired direction. Table-2 gives an overview of the accuracy obtained by our system.

Table-2.

Attempts	Successful attempts	Accuracy
100	86	86%
100	74	74%

In the first scenario in the table above, the height and the width parameters were configured for that particular person. Therefore, we observe a very good accuracy given how cost effective and practical our solution is. Using these same parameters, we implemented this solution on another person. Since the height and width of each person varies, we observe a lesser accuracy as compared to the first scenario. In order to achieve a similar accuracy as observed in the first scenario, the height and width threshold parameters must be modified for that particular person.

B. Discussions

While the initial pre-processing prior to implementing the Viola Jones algorithm helped in improving the accuracy by making the detection more accurate, better lighting conditions can always give better detection results by providing brighter snapshots to process.

For the system to be accurate, the height and width parameters of the eye must be configured for each person prior to that person using the system. This way it is ensured that the system detects the eye with high precision.

Much earlier eye movement detection methods used techniques like ECG or EOG which had various physical interactions with the face of the patient which made it very inconvenient for the patient. They were restricted in their movements and had to concentrate hard in order to move the wheelchair in the right direction.

The Circular Hough Transformation method is very popular due to its high accuracy. However, this accuracy is achieved on an existing database of eye images with a set image size. Real time implementation using this system is difficult due to the high processing time involved.

This paper aims to implement a system which overcomes the issues faced by the above two techniques. This solution provides a quick, real time solution with very good accuracy results. Additionally, there is no physical interaction with the face of the patient which proves to be very convenient for the patient.

5. CONCLUSIONS

This paper successfully implemented the system to automatically control a wheelchair by tracking eye movements and using IR sensors. This solution observed an accuracy of 70-90%. According to our results, the image capture, eye movement detection and the algorithm for validating movement attempts perform very reliably.

Although this paper produces satisfactory results, a lot of work needs to be done to make it commercially viable. One future work can be to focus on providing the patient with a means to control the speed of the wheelchair. Additionally, some sequence of events should trigger the start of eye detection as it is dangerous for the system to start moving automatically when the person is glaring randomly in different directions. Furthermore, some mechanism can be installed to open and close door locks or even electrical devices. The safety of the patient is one of the most critical aspects of this paper. Therefore, adequate safety precautions should be added to this system.

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