Eye Controlled Wheelchair Using Image Processing Techniques

Prateek Bansal[1], Ritvik Singhal[2], Vijay Khare[3]

Electronics and Communication Engineering, Jaypee Institute of Information Technology, Noida, India
b.prateek25[at]gmail.com

Communication Science Engineering, Jaypee Institute of Information Technology, Noida, India
singhal.ritvik[at]gmail.com

Electronics and Communication Engineering, Jaypee Institute of Information Technology, Noida, India
vijay.khare[at]jiit.ac.in

Abstract: ***Recent studies have observed that there are thousands of new unheard cases of paralysis in India every year. Great people like Stephan Hawking, Christopher Reeve, Charles Krauthammer and many more have suffered from this disease. Earlier many interfaces and techniques have been developed for self-controlled wheel chairs such as joystick controlled, gesture controlled, and voice controlled. But, people who are paralyzed, are unable to use these systems, because they are not able to make such movements. Hence, the idea is to implement and develop an Eye Regulated System which facilitates movement of the patient's wheelchair based on the movement tracking of the pupil. One enduring quadriplegia/paralysis is able to partially move his eyes. This study captures those movements to control wheelchair. Eye controlled wheelchair method is more convenient for handicapped people compared to other mentioned methods. By using eye controlled wheelchair, the patient is able to move wheelchair with higher accuracy.***

Keywords: Arduino, Eye Controlled Wheelchair, Gaze tracking, Healthcare, Image Processing, OpenCV, Pupil tracking

1. Introduction

Eyes and the motion or gaze of the pupils are decisive in expressing a person's point of view, desires and state of mind. The importance and implication of eye movements with regard to the insight to the ocular world is undeniably acknowledged since it is the eyes only that gather information for processing in the human brain. Quite naturally, well defined and dependable eye/pupil detection and gaze tracking have a decisive role to play in the development of human –computer interaction and computer vision and developing user Interfaces. Eye tracking is highly beneficial as an interface method. Eye movement is least likely to be enraptured by disabilities. Injuries pertaining to Spinal cord hardly affect the ability to control the eyes because the brain directly controls their motion. Hence, pupil detection and eye gaze tracking can be used for implementing an eye controlled wheelchair. This paper takes the following approach to achieve the purpose.

- The images taken by the camera are transmitted to the base station say, a computer or laptop. The images are processed using image processing techniques in python using the Open Source Computer Vision Library after detecting the eyes using pre-trained haar-cascade like features for eye-detection.
- Image processing yields the location of centroid of the detected pupil. The entire frame is divided into 3 blocks. The length and width of each block is defined in the algorithm.
- The position of centroid of pupil helps to calibrate the block in which the pupil lies, through repetitive analysis which helps us to find the direction in which the eye is gazing.
- The processing basically divides the image in three blocks namely left, right and center. If position of the pupil lies in the first block then it gives output "Right". If it lies in the third block, it gives output "Left". If the pupil lies in the center the output is "Straight". If the pupil is not being detected, the default output is "Stop".
- This output received is then communicated to the microcontroller Arduino Uno present on the wheelchair.
- The microcontroller is further connected to a L293D motor driving IC which is used to move the motors accordingly.

2. Problem Statement

We precisely aim at targeting the movements of the eye. The idea is to create an eye monitored wheelchair system where a camera constantly stares at the person's eyes and based on the movement of eye, decision is made to move the wheelchair in the direction the person desires to move.

3. Literature Survey

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 user's voice as input and based on its recognition it 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 disability.

2) EEG based wheelchair: The wheelchair moves based on brain signals and voltage differences. Technically, it is called Electroencephalogram or EEG [1]. Basically EEG signals in form of voltages are sent to the microcontroller which then takes care of movement of the wheelchair. This is more precise technique compared to the rest of the interfaces as it doesn't require any body movement and there is no addition of noise. The only drawback perhaps is that the user must be very accurate as to what he is thinking of.
3) Joystick controlled wheelchair: In this, the patient is provided with a joystick with which the user can assume control of the wheelchair. It is not much useful for people with full body paralysis as they won't be able to move their hands and hence loses its credibility when it comes to quadriplegia.
4) Gesture controlled wheel chair: It controls the wheelchair movements using hand gestures. It is a reliable method for an interface between human and computer and can be used for wheelchair movement. Web camera can be used to input gesture signals. Further, AdaBoost algorithm is brought into use to detect the location of center of hand. The output image has a resolution of 320*240 pixels which is divided into 9 blocks. The algorithm checks as to in which block the hand is located and moves the wheelchair accordingly.

4. Hardware and Software Used

4.1 Softwares

a) Python Ide

Python is a high-level programming language and is open source that is, it is free to use. Image processing is done using Open CV libraries in python IDE. OpenCV-Python is a befitting tool for various problems related to image processing and computer vision. Operations done with numpy can be combined with Open CV which makes it such a powerful tool for image processing.

b) ARDUINO IDE

The Arduino IDE is an open source application available for Windows/MacOS/Linux. It is used to write and upload programs to the Arduino board microcontroller. It has a compiler for compiling the program and creates a hex file ready to be loaded into Arduino board. The coding of Arduino UNO is done in Arduino IDE in Embedded C language

c) OPEN CV

It is necessarily an open source software library and its module is to be installed in python using pip install. OpenCV was initially designed to cater to the need of a common platform or scope for applications requiring computer vision and image processing. Open CV being an open source platform is very helpful in computer vision industry. Open CV module can be used for applying various image processing techniques to our input.

4.2 Hardware

a) ARDUINO UNO

Arduino UNO (as shown in Fig. 1) is a micro-controller based on ATmega328P and belongs to 8 bit Alf and Vegard's RISC processor family [2]. The board is equipped with a 16MHz quartz crystal and therefore works at 16 MHz clock speed. In total, there are 14 input and output pins. Of these14 pins, six pins can be used as output. Arduino UNO micro-controller is used to serially receive data from the base station and accordingly move the wheelchair in desired direction.

b) L293D Motor-Driving IC

A motor operator incorporated circuit chip (shown in Fig. 2) is generally used to control more than one motor in autonomous robotics. Motor driver IC acts as an interface between Arduino board and the motors to be driven. L293D, L293NE are the most typically used motor operating IC's. These IC's are designed and programmed to control and operate two motors at the same time. We've used L293D motor driver IC.

c) HC-05 Bluetooth Module

The HC-05 (shown in Fig. 3) is a Bluetooth module and is capable of facilitating two-way full-duplex wireless communication. It can be used to exchange data among two microcontrollers or establish communication between a device with Bluetooth connectivity and a microcontroller, Arduino.

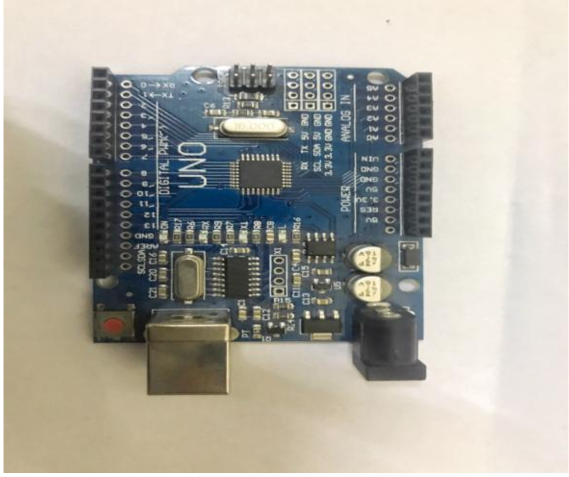

Figure 1: Arduino Uno microcontroller

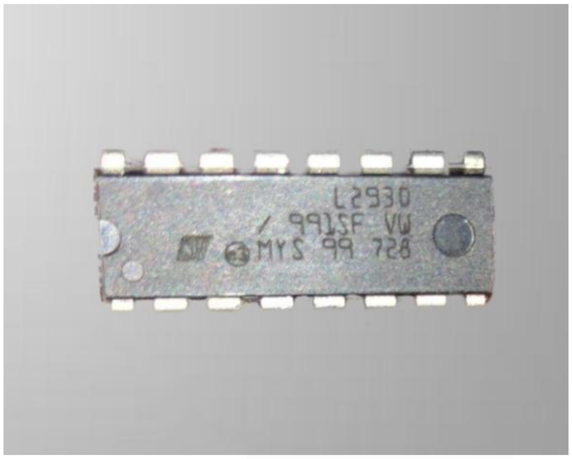

Figure 2: L293D Motor driving IC

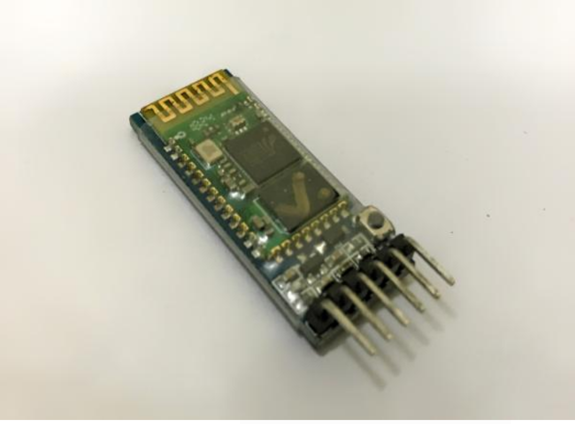

Figure 3: HC-05 Bluetooth module

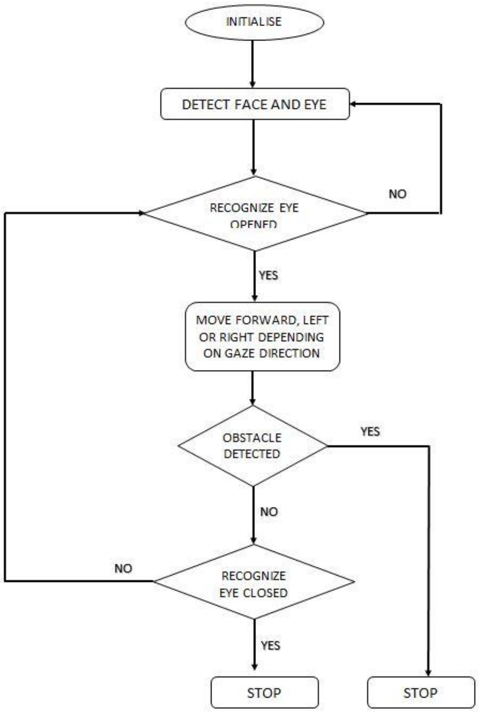

Figure 4: Flowchart diagram of system

5. Implementation

5.1 System Architecture

The flowchart diagram of the system is shown in Fig. 4 and consists of a micro-controller interfaced with L293D motor driver IC and HC-05 Bluetooth module. The output of python script that determines the direction, in which the user is looking, is serially transmitted from the laptop to the microcontroller. Further, the Arduino is coded so as to move the wheelchair in the desired direction.

5.2 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 colored image is converted into gray color code so that it becomes easier to further apply image processing techniques on the eyes. Pre trained Haar-cascade like features are used for eye detection using haarcascade_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 (shown in Fig. 5).

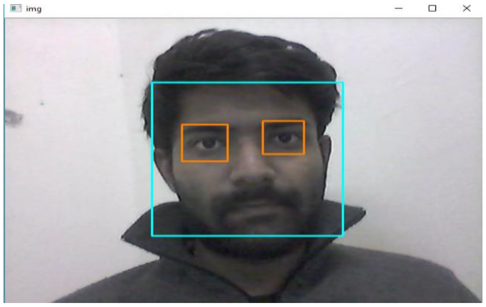

Figure 5: Detected Eyes and face

Improving contrast using cv2.equalizeHist() and conversion to binary image

Cv2.equalizeHist [3] increases the overall contrast of an image. After applying this adjustment, there is a better distribution of the intensities of contrast on histogram (shown in fig. 6).Cv2.threshold [4] 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 color), it is assigned a value (say white), otherwise, if it is less than the threshold value, it is allotted another value (say,, black) (shown in Fig. 7). First argument is the source image, which is the gray scale image we obtained after first step. Second argument is the threshold value. Finally, the third argument holds the maximum value (255 of black color) that is to be allocated to that particular pixel if its value is greater than the earlier specified threshold value.

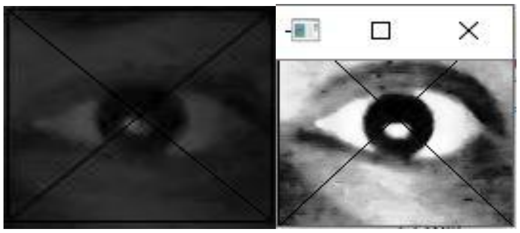

Figure 6: Before and after cv2.equalizeHist()

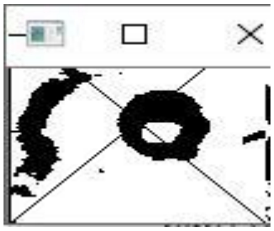

Figure 7: After thresholding and conversion to binary image

Morphological transformations

Morphological transformations are some simple basic operations generally performed on binary images. It basically has two parameters as input, first input is the binary image and second parameter is the structuring element technically called as a kernel [5], [6]**.** This kernel then decides on the type and extent of change that is, morphological transformation that is going to be performed on the image. It can broadly be classified into two types that are 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 shape, but we still have some unwanted pixels within the object we intend to detect. Closing gets rid of them. Erosion erodes away the boundaries of foreground object as in 2D convolution, the kernel basically 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 each and every pixel under the structuring element is similar, that is 1, otherwise it is eroded, or in other words, made to zero. It removes small white noises.

- **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. The 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 basically 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 [7].

- **Extracting pupil and finding its centroid**

A blob is basically an array of connected pixels in an image that partake some common property. We intend to find the centroid of a blob that is pupilin 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 [8]. Suppose a shape consists of n distinct points$x_1 \ldots x_n$, then the centroid location, c, is specified by:-

$$c = \frac{1}{n}\sum_{i=1}^{n} x_i$$

When talking about image processing and computer vision, centroid is the weighted average of all pixels making up the shape. We can easily find the center 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:-

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

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

Here, C_x and C_y are respectively the x and y coordinate of the centroid of pupil and M denotes the moment.

- **Finding direction of gaze using centroid coordinates of pupil**

If the coordinates of centroid obtained lies in the center block, the program will indicate the direction gaze as “Straight”. If the centroid location lies in third column, it will indicate the gaze direction as “left”. Similarly if the centroid location lies in first column, it will mean that the gaze direction is “right”. The output image will be divided into 3 blocks by fixing the coordinates of each block [9]. The coordinates of each output block is shown below.

Table I: Centroid Location and Direction of Gaze

Right	Straight	Left
(cx >=29 and cx<=49)	cx >= 50 and cx<=69)	cx>=70 and cx<100)

Calibration is to be done so that the error is as less as possible.

- **Interfacing with Arduino Uno**

The output of python script is serially transmitted to the microcontroller using HC-05 Bluetooth module. Required voltages are given at appropriate output pins of Arduino according to the direction in which we wish the wheelchair to move.

6. Results

The position of centroid of pupil detected is highlighted with the help of a white circle. And the position of the centroid is detected and the decision for the direction is given accordingly. The white colored circle follows the centroid of pupil (shown in Fig. 8).

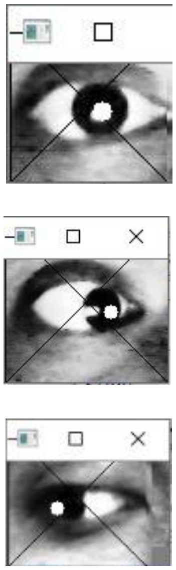

Figure 8: White circle following the centroid of pupil

The centroid location corresponding to “Straight” is calibrated and found out to be C_x>= 50 and C_x<= 69 (shown in Fig. 9). On the same lines the centroid location corresponding to “Left” is found out to be C_x>= 70 and C_x<= 100 (shown in Fig. 10). Similarly, centroid location corresponding to “Right” is found out to be C_x>= 29 and C_x<= 49 (shown in Fig. 11). A graph of the obtained values can be plotted using matplotlib.

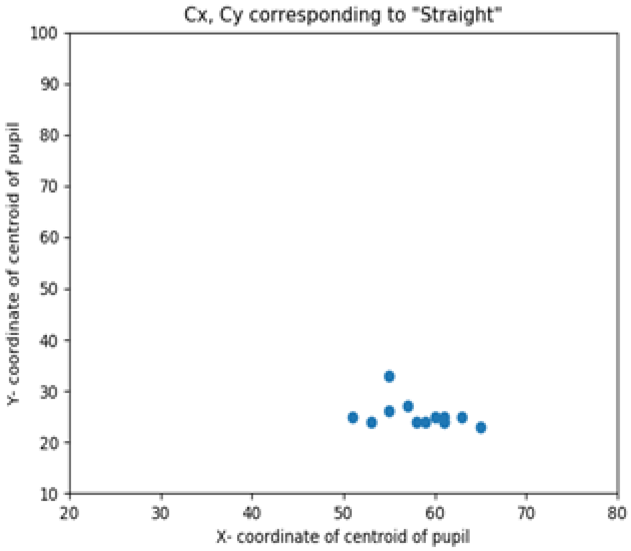

Figure 9: Centroid coordinates corresponding to Straight

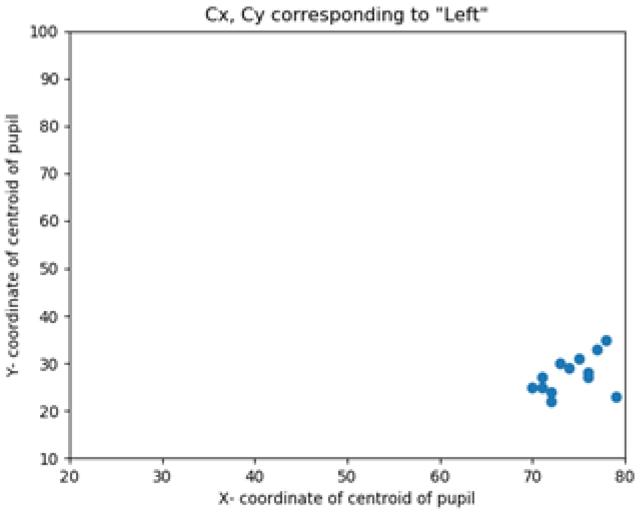

Figure 10: Centroid coordinates corresponding to Left

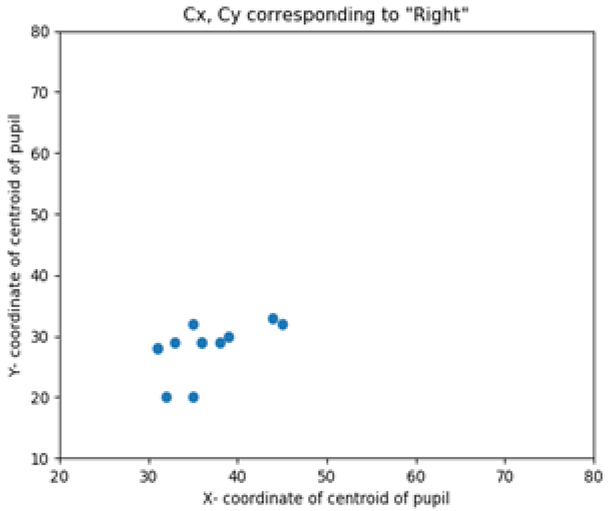

Figure 11: Centroid coordinates corresponding to Right

7. Conclusion

In this paper we have researched and developed a wheelchair system which enables the disabled patient to move their wheelchair independently in whatever direction they want to. The technique of using eye movement to move a wheelchair is challenging and fairly accurate simultaneously.

8. Future Scope

Lot of work and further extensive research needs to be done before making this concept commercially procurable and marketable as a product. There is a need to work on and restrict wheel chair motion when and if a patient is just coincidentally looking in a particular direction. The wheelchair needs to be made safer for the patient. The wheelchair can be incorporated with a lot of health sensors for live display of the health of the person sitting on it including Blood pressure and heart rate.

9. Acknowledgment

The authors thank and gratefully acknowledge the sincere contributions of our faculty and college who have been our constant support during the entire span of our project and research. We sincerely thank them for their guidance and encouragement which helped us in carrying out this project so efficiently.

References

[1] V. Khare, J. Santhosh, S. Anand and M.Bhatia, “Controlling wheelchair using Electroencephalogram (EEG)”, *The International Journal of Computer Science and Information Security*, vol. 8, No. 2, pp. 181-187, 2010.

[2] I.R. Terol-Villalobos, “Morphological image enhancement and segmentation with analysis”, P. W. Hawkes, Ed. New York: Academic,..2005, pp. 207–273.

[3] Sos S. Agaian, Blair Silver and Karen A. Panetta “Transform Coefficient Histogram-Based Image Enhancement Algorithms Using Contrast Entropy”, IEEE Trans. on Image Processing, vol. 16, no. 3, Mar. 2007

[4] Tobias OJ, Seara R. “Image Segmentation by Histogram Thresholding Using Fuzzy Sets, ” IEEE Transactions on Image Processing, 2002; 11(12):1457-1465.

[5] S. Mukhopadhyay and B. Chanda, “A multiscale morphological approach to local contrast enhancement”, Signal Process. vol. 80, no. 4, pp. 685–696, 2000.

[6] Y. A. Badamasi, "The working principle of an Arduino, "*International conference onElectronics, computer and computation (ICECCO)*, 2014, pp. 1-4.

[7] R. Awasthiand K. Khurana, “Techniques for Object Recognition in Images and Multi-Object Detection”, *IJRACET*, ISSN-2278-1323, April 2013.

[8] DulariSahu, “Camera Based Eye Controlled Wheelchair System Using Raspberry Pi”, *International Journal of Science, Engineering and Technology Research (IJSETR)*, vol. 5, Issue 1, January 2016 .

[9] G. Gautam, G. Sumanth, Karthikeyan K C, S.Sundar, D.Venkataraman, “Eye Movement Based Electronic Wheel Chair ForPhysically Challenged Persons”, *International Journal of Scientific and Technology Research*, vol. 3, Issue 2, ISSN 2277-8616, February, 2014.