EYE MOVEMENT BASED ELECTRIC WHEEL CHAIR

Abhishek[1], Abhishek Khandelwal[2], Gautam Kumar Singh[3], Kumar Rahul[4], Shilpashree P. S.[5]
Email: abhishek.1si12ec004@gmail.com[1], abhishek.1si12ec005@gmail.com[2],gautam.1si12ec038@gmail.com[3], rahul.1si12ec045@gmail.com[4], shilpa.sit@gmail.com[5]

Abstract

The disabled and elderly people who are in need of a wheelchair are estimated to be over 100 million worldwide. A lot of these disabled people cannot use the traditional wheelchairs as users may have restricted limb movements. An alternative is a powered wheel chair, a mobility-aided device for persons with moderate/severe physical disabilities or chronic diseases as well as the elderly. In order to take care for different disabilities, various kinds of interfaces have been developed for powered wheelchair control; such as joystick control, head control, and sip-puff control. Many people with disabilities do not have the ability to control powered wheel chair using the above mentioned interfaces. The planned model is a possible alternative. It is an attempt to make lives of the disabled people simpler, i.e., selfreliant, which will thereby reinstate their confidence and their happiness. The idea is to create an Eye Monitored System which allows movement of the patient's wheelchair depending on the eye movements. A patient looks directly at the camera mounted on a head gear and is able to move in a direction just by looking in that direction. The camera signals are monitored by an Open CV application, which then guides the motors wired to the Microcontroller over the Serial Interface to move in a particular direction. The system is cost effective and thus can be used by patients spread over a large economy range.

I. INTRODUCTION

The ability to move freely is highly valued by all people. However, it is sometimes difficult for a person with a physical disability. Conventional wheelchair use tends to focus exclusively on manual use which assumes users are still able to use their hands which excludes those unable to do so. Diseases or accidents injuring the nervous system also frequently make people lose their ability to move their voluntary muscle. Since voluntary muscle is the main actuator enabling people to move their body, paralysis may cause a person not move their locomotor organs such as arms and legs. Nowadays, an electric wheelchair is commercially available for disabled people. It generally requires considerable skill to operate. Moreover, some disabled people cannot drive an electric wheelchair manually, even with a joystick, because they lack the physical ability to control the movement. Therefore it is required to enable a disabled person to drive a wheelchair safely and easily so that they can enjoy a higher quality of life. The aim of the project is to design a system for electric wheelchair control using the movement of eyes. A commercially available web camera mounted on a head gear which the user wears is used to capture moving pictures of the users face. A computer mounted on the electric chair processes the captured image data, detecting and tracking movements of the user's eyes, estimating the line-of-sight vector, and actuating the electric wheelchair in the desired direction indicated by the user's eyes. One of the key essentials of the planned system is detecting and tracking the eye movements.

SYSTEM OVERVIEW

The system [2] consists of three main parts:

1. Head mounted camera and laptop system that tracks the camera wearer's eye.

2. The microprocessor takes an output from the laptop and converts the digital output to electric signals that is sent to the wheelchair wheels for movement. 3. A signal triggered Wheel Chair.

The block diagram of Eye Movement Based Electric Wheel Chair is shown in Figure 1.1. The web camera is used to detect the eyes movement which is further processed to drive the motors. Serial communication is used to communicate between the web camera and the microcontroller. The microcontroller placed on the wheel chair which is connected to the motors, driving the wheel chair in the direction the person desires to move in.

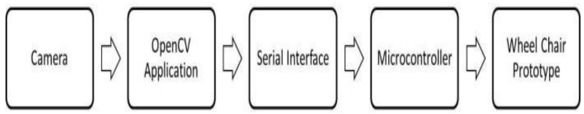

Figure 1.1: Block Diagram of Eye Movement Based Electric Wheel Chair.

A. *Camera*

The first block is the video capturing module that captures sequence of eyes images from the subject using a specially designed camera.

B. *OpenCV Application*

The camera is wired to the patient's computer that runs an OpenCV application designed to monitor and react to eye movements. Based on a series of snapshots, image processing is performed and thereafter motion of the user's eye is detected.

C. *Serial Interface*

The next block establishes the serial connection between the computer and the micro controller. The decision to move the motor in a particular direction is communicated to the microcontroller using the serial interface.

D. Microcontroller

The microcontroller on reception of signal from the serial interface forces the port pin high on which the motors have been connected for desired motion of the Wheel Chair.

E. Wheel Chair Prototype

The final block is the assembly consisting of motors, wheels and the chassis responsible for the disabled person's movement. The motors receive the electrical signal from the microcontroller and drive the wheel chair in the desired direction.

II. SYSTEM HARDWARE

The hardware components used in the system design are explained in detail in the following sections.

A. Camera

A 720 pixels high definition USB web camera of 5500 x 3640 pixels image resolution and 1920 x 1080 pixel video resolution has been used for better clarity of image. It has a frame rate of 30 frames per second for fast image processing. It uses 6 LEDs for better image processing during night time and has a cable length of 1.5 meters. The Web camera is shown in Figure 1.2.

Figure 1.2: iBall CHD20.0 Web camera.

B. AT 89S52 Development Board

With the development board one can develop and prototype any of 8051 40 pin microcontrollers. The RS232 driver on board allows easy connection with PC or other embedded hardware. The board has User buttons and status LEDs. The bridge rectifier allows this board to be powered with both AC and DC power supply adapters. The Development board is shown in Figure 1.3. It has following features:

1. RS232 Tx, Rx interface with MAX232 IC on socket
2. Quartz crystall 11.0592Mhz
3. Reset button
4. Power plug-in jack
5. Extension slot on every uC pin
6. Gnd bus
7. Vcc bus
8. Four mounting holes 3.3 mm (0.13")

Figure 1.3: AT 89S52 Development Board.

C. AT89S52 Microcontroller

The AT89S52 is a low-power, high-performance CMOS 8-bit microcontroller with 8Kbytes of in-system programmable Flash memory. The device is manufactured using Atmels high-density nonvolatile memory technology and is compatible with the industry standard 80C51 instruction set and pinout. The AT89S52 provides the following standard features: 8K bytes of Flash, 256 bytes of RAM, 32 I/O lines, Watchdog timer, two data pointers, three 16-bit timer/counters, a six-vector two-level interrupt architecture, a full duplex serial port, on-chip oscillator, and clock circuitry. In addition, the AT89S52 is designed with static logic for operation down to zero frequency and supports two software selectable power saving modes. The Idle Mode stops the CPU while allowing the RAM, timer/counters, serial port, and interrupt system to continue functioning. The Power-down mode saves the RAM contents but freezes the oscillator, disabling all other chip functions until the next interrupt or hardware reset.

D. RS 232 Standard

Communication defined in the RS-232 standard is an asynchronous serial communication method. The word serial means that the information is sent one bit at a time. Asynchronous tells that the information is not sent in predefined time slots. Data transfer can start at any given time and it is the task of the receiver to detect when a message starts and ends. The RS 232 standard defi nes the voltage levels that correspond to logical one and logical zero levels. Valid signals are plus or minus 3 to 25 volts. The range near zero volts is not a valid RS 232 level; logic one is defined as a negative voltage, the signal condition is called marking and has the functional significance of OFF. Logic zero is positive; the signal condition is spacing and has the function ON. So a logic zero represented as +3V to +25V and logic one is represented as -3V to -25V. Since RS232 voltage levels is not compatible to TTL voltage level, voltage or level converter is needed which can convert TTL to RS232 and RS232 to TTL voltage levels. MAX 232 IC includes charge pump which can generate RS232 voltage levels (-10V and +10V) from 5V power supply. It also includes two receiver and two transmitters and is capable of full-duplex Universal Asynchronous Receiver Transmitter/Universal Synchronous Asynchronous Receiver Transmitter (UART/USART) communication.

E. Motor Driver Circuit

L293D is a typical Motor driver or Motor Driver IC which allows DC motor to drive on either direction. L293D is a 16pin IC which can control a set of two DC motors simultaneously in any direction. It means that you can control two DC motor with a single L293D IC. It works on the concept of H-bridge. H-bridge is a circuit which allows the voltage to be own in either direction. As we know voltage need to change its direction for being able to rotate the motor in clockwise or anticlockwise direction, hence H-bridge IC are ideal for driving a DC motor. In a single l293d chip there two h-Bridge circuit inside the IC which can rotate two dc motor independently. Due its size it is very much used in robotic application for controlling DC motors.

III. SOFTWARE REQUIREMENTS

The softwares used for creating and programming of the various modules to obtain the desired results are as follows:

A. OpenCV 3.0.0

OpenCV (Open Source Computer Vision Library) is an opensource BSD-licensed library that includes several hundreds of computer vision algorithms. OpenCV has a modular structure, which means that the package includes several shared or static libraries.

B. Eclipse 3.8

In computer programming, Eclipse is an integrated development environment (IDE). It contains a base workspace and an extensible plug-in system for customizing the environ-ment. Eclipse is written mostly in Java and its primary use is for developing Java applications, but it may also be used to develop applications in other programming languages through the use of plugins, including: Ada, ABAP, C, C++, COBOL,OpenCV, Fortran, Haskell, JavaScript, Julia, Lasso, Lua, NATURAL, Perl, PHP, Prolog, Python, R, Ruby (including Ruby on Rails framework), Rust, Scala, Clojure, Groovy, Scheme, and Erlang.

IV. METHODOLOGY

There are two major components from the system design standpoint:

1. Eye-Detection and motion tracking.
2. Microcontroller controlled Wheel Chair Assembly.

A. Eye-Detection and Motion Tracking

A web camera is mounted on a cap, continuously staring at the users eyes. The web camera wired to the users laptop runs an OpenCV application designed to monitor and react to eye movements. Based on a series of snapshots taken and thereafter processed, the motion of the users eyes are detected and decision to move the Wheel Chair in a particular direction is taken. An image processing toolbox which uses Viola Jones Algorithm [3] is used that is capable of detecting eye-shaped objects based on their shape and size. Further the pupil of eye is detected using gradient method [4] and its centre is located. Based on the position of pupil, a movement is detected and this is communicated to the wheelchair assembly via the serial port.

B. Microcontroller controlled Wheelchair Assembly

A decision based on the processing done by the OpenCV application is communicate and received by the microcontroller. The controller on reception forces the port pin high on which the motors have been connected for desired motion of the Wheel Chair.

C. Process Flow

1. Initialization

Initially the serial communication is set up is to be used later for the interface between OpenCV and the controller, the video capture and the program variables. 2. Image and Video Processing

Then continuous video frames is taken and the input is sampled and saved as screenshots. Each frame is then converted into black and white frames. For accurate results, contrast stretching is performed on each frames to make the dark regions much darker and bright regions much brighter.

This ensures better detection of the eyes.

3. Estimation

Now, after working on each frame, the eyes are to be detected. This is done by estimation of the position of left as well as the right eye. Thus, a threshold is set and the position of the eyes are detected which can be used for the further processing. 4. Detection

Now, the eye movements are to be detected. The idea is to compare the current position of the eye with the previous position. The difference in the coordinates helps to predict the motion in the particular eye. But sometimes, it might be possible that only one of the either eye is detected. In that case, the eye that is detected correctly is preferred. 5. Error Handling

To avoid errors in detection, an error handling mechanism is incorporated, which specifies a threshold for the height and width of a valid eye, through calibration of system for a particular user. If the detection results give a height and width value lesser or greater than the threshold, the value is avoided and it is not considered for the decision making. 6. Motion

Now after detection of the eye movements, a decision algorithm needs to be considered that helps the controller drive the motors accordingly:

a) Valid Left: The decision to turn left is considered as valid if the eye turns left and stays there for a cycle. This action is detected as a left turn request. After that, the patient turns right to again look forward.

b) Valid Right: Similarly, the decision to turn right is considered as valid if the eye turns right and stays there for a cycle. This action is detected as a right turn request.

c) Valid Straight: The signal to go straight is when a person looks upwards. This is detected as a forward movement request.

d) Halt: The decision to bring the wheel chair to a halt is considered when the pupil is in center or the patient is looking directly into the camera.

D. Eye Centre Localisation by means of Gradient A multi-stage scheme is followed that is usually performed for feature-based eye centre localisation (see Figure 4.1), and following observations are made:

1. A novel approach for eye centre localisation, which defines the centre of a circular pattern as the location where most of the image gradients intersect. Therefore, a mathematical function is shown that reaches its maximum at the centre of the circular pattern. By using this mathematical formulation a fast iterative scheme can be derived.
2. We incorporate prior knowledge about the eye appearance and increase the robustness.
3. We apply simple postprocessing techniques to reduce problems that arise in the presence of glasses, reflections inside glasses, or prominent eyebrows. Furthermore, we evaluate the accuracy and the robustness to changes in lighting, contrast, and background by using the very challenging BioID database.

Figure 4.1: A face detector is applied first; based on the face location rough eye regions are

extracted (left), which are then used for a precise estimation of each eye centre (middle and right). The relationship is described mathematically between a possible centre and the orientations of all image gradients. Let c be a possible centre and gi the gradient vectorat position xi. Then, the normalised displacement vector di should have the same orientation (except for the sign) as the gradient gi (see Figure 4.2). If we use the vector field of (image) gradients, we can exploit this vector field by computing the dot products between the normalised displacement vectors (related to a fixed centre) and the gradient vectors gi. The optimal centre c* of a circular object in an image with pixel positions xi,.
i ϵ {1,...,N }, is then given by

$$c^* = argmax\{\frac{1}{N}\sum_{i=1}^{N}(d_i^T g_i)^2\},$$

$$d_i = \frac{x_i - c}{||x_i - c||_2},$$

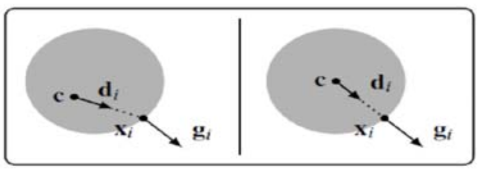

Figure 4.2: Artificial example with a dark circle on a light background, similar to the iris and the sclera. On the left the displacement vector di and the gradient vector gi do not have the same orientation, whereas on the right both orientations are equal.

E. Flowchart

The process flow is shown in Figure 4.3.

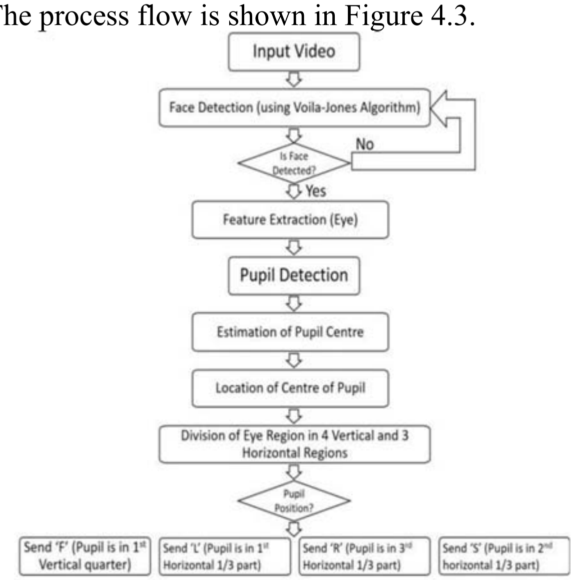

Figure 4.3: The Process Flow of Eye Movement Detection

V. EXPERIMENTAL RESULT

The objective is to guide a wheel chair prototype using a person's eye's movement. The user wears a head gear which has a web camera mounted on it (shown in Figure 5.1). Initially, the user needs to familiarize itself with the head mounted camera so that the eye movements are detected properly. A new user may require some time with the camera to make the system detect eye movements accurately. A high definition USB web camera of 1920 x 1080 pixel video resolution is used to capture the live video. The web camera continuously monitors the field of view for a face at a frame

Figure 5.1: User with the Head Mounted Gear

rate of 30 frames per second. The 6 LEDs in built with the web camera help improve the lighting condition during night time. The OpenCV program first extracts face from the captured video. Figure 5.2 shows the captured video and face extracted from it. After the extraction of face from video, eye region is located in the frame.

Figure 5.2: Captured frame and face region extracted from it

A. *Testing Strategy*

After detection of the eye, a rectangular box is created around the eye. The rectangular box is divided vertically into four parts and horizontally into three parts as shown in Figure 5.3. If the pupil is found in the 1st horizontal division (shown in Purple), the wheelchair moves forward. Similarly if it is found in the centre of horizontal as well as vertical division or in the

3rd horizontal division (shown in Brown), the wheelchair halts. If the pupil is found in the 4th vertical division (shown in Blue), the wheelchair turns left. If the pupil is found in the 1st vertical division (shown in Pink), the wheelchair turns right.

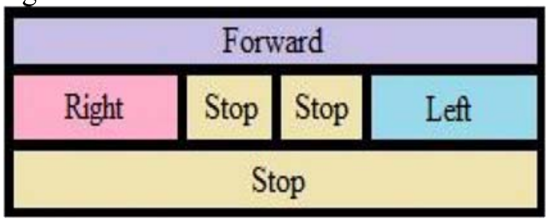

Figure 5.3: Division of eye's rectangular box

B. *Results*

The various eye movements detected by the system corresponds to the movement of wheel chair in the indicated direction. Figure 5.4 shows a person who looks straight into the camera, the pupil is detected in the centre of the rectangular box which is processed by the system as centre and therefore makes the wheel chair halt. Similarly, Figure 5.5 shows a person with movement of eye in right direction, the pupil is detected in the 1st vertical division that leads to right turn of wheel chair. Figure 5.6 depicts a person with left eye movement, the pupil is detected in the 4th vertical division that corresponds to the left turn of wheel chair. Figure 5.7 shows a person who looks upward, the pupil touches the 1st horizontal division, unlike Figure 5.4 where the pupil lies in the centre, the system guides the wheel chair forward.

The system is tested on four users under different lighting conditions (day, night, dim light, no light) for 100 to 200 attempts. The numbers of successful attempts are noted against the total number of attempts and accuracy is computed for each user which is tabulated in Table 5.1. The accuracy results after testing is found to be more than 90%.

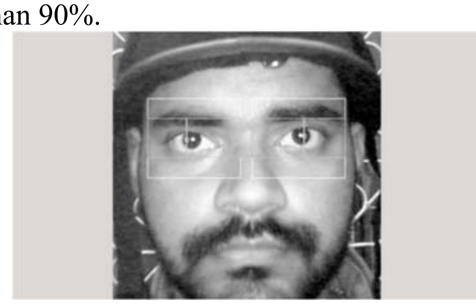

Figure 5.4: Person looking in the centre, wheel chair doesnt move (or stops).

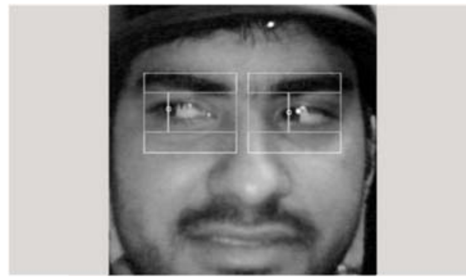

Figure 5.5: Person looking right, wheel chair turns right.

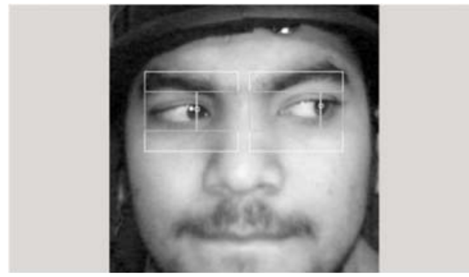

Figure 5.6: Person looking left, wheel chair turns left.

Figure 5.7: Person looking up, wheel chair moves forward

Table 5.1: Accuracy Results

Name	Attempts	Successful Attempts	Accuracy (%)
Abhishek	200	181	90.5
Abhishek Khandelwal	100	91	91
Gautam Kr. Singh	100	92	92
Kumar Rahul	100	91	91

VI. CONCLUSION

The aim of the project is to contribute to the society in a small way by setting out an idea for a system which could actually better the lives of millions of people across the globe. A prototype for an electric wheel chair that moves based on the movement of eyes, is designed, which could help patients with limited or no limb movement. The design processes the video, taken by the web camera, uses Viola-Jones algorithm and pupil detection for eye movement direction which is communicated serially to the wheel chair via a microcontroller. The system functions with an accuracy rate of more than 90% which is above expectations.

The prototype, however, works with certain limitations; the user needs to be familiar with the camera's functioning, lack of eye sequence to trigger start-stop, and limited number of directions for the prototype to move.

Though the prototype performs satisfactorily, a lot of work needs to be done before making the product commercially viable. Some sort of sequence of events should trigger start of detection, because one would not want the wheel chair to move when the person is just casually glaring in different directions. Also since the criticality of the application is so high, a lot of safety precautions, like controlled speed and movement, need to be incorporated.

REFERENCES

[1] Kohei Arai and Ronny Mardiyanto. Eyes based electric wheel chair control system. International Journal of Advanced Computer Science and Applications, 2(12):98-105, November 2011.

[2] Gunda Gautam, Gunda Sumanth, Karthikeyan K C, Shyam Sundar, and D.Venkataraman. Eye movement based electronic wheel chair for physically challenged persons. International Journal of Scientific and Technology Research, 3(2):206-212, February 2014.

[3] Yi-Qing Wang. An analysis of the viola-jones face detection algorithm. Image Processing On Line, 4:128-148, June 2014.

[4] Fabian Timm and Erhardt Barth. Accurate eye centre localisation by means of gradients. Proceedings of the Int. Conference on Computer Theory and Applications (VISAPP), 1:125-130, 2011.