EYE MOVEMENT OR HAND GESTURE BASED WHEELCHAIR CONTROL USING ACCELEROMETER AND OPENCV

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Abstract – *Movement is referred to as the act of moving or changing one's position. The loss of the ability to move some or all of your body is termed as paralysis. It can have lots of different causes, some of which can be serious. It may be temporary or permanent depending on the cause of injury. Amyotrophic Lateral Sclerosis [ALS] is a progressive nervous system disease that affects nerve cells in the brain and spinal cord, causing loss of muscle control. Motor neuron loss continues until the ability to eat, speak, move, and finally the ability to breathe is lost. The nerve cells present in person's spinal cord control the muscles, whose location is identified by lateral. The main objective of the proposed work is to provide the motion control for the paralysed people and make them less dependent on others in terms of movement. Even in severe cases of ALS, the patient can still move their eyes. Hence using the hand gesture for partially paralysed people or using the eye movement for fully paralysed people, the motion of the wheelchair can be controlled by the patients independently.*

Key Words: **movement, Amyotrophic Lateral Sclerosis (ALS), motion control, hand gesture, eye movement**

1. INTRODUCTION

Every year there are thousands of people who become partially or fully handicapped due to some accidents which makes them dependent on wheelchairs. Some people suffer from disease like ALS where the patient might lose complete control over their movements and ability to communicate where they can communicate with their eyes only. But the conventional wheel chairs are manually driven making those people dependent on others.

There is no known cure for ALS till date. Spine stimulation, human-comp interface and exoskeleton are a few technologies that were developed as an alternate. Unfortunately, these technologies require the implantation of electro devices, which is very difficult and expensive. Therefore, these technologies were not as efficient as expected.

Even in severe cases of ALS, the patient can still move their eyes. This ability is utilized here. In this proposed project, the wheel chair can be controlled by the eye movement or the hand gesture and can be moved in left, right, backward or forward direction. Hence the patient can move without depending on others.

Almost everyone faces hardships and difficulties at one time or another. But for people with disabilities, barriers can be more frequent and have greater impact. The World Health Organization [WHO] describes barriers as being more than just physical obstacles.

Often there are multiple barriers that can make it extremely difficult or even impossible for people with disabilities to function. Transportation barriers are due to a lack of adequate transportation that interferes with a person's ability to be independent and to function in society. Examples of transportation barriers include Lack of access to accessible or convenient transportation for people who are not able to drive because of vision or cognitive impairments.

1.1. MOTIVATION

Paralysis can result from brain or spinal cord injury or by diseases such as multiple sclerosis or ALS. In partially paralyzed condition, the patient will be able to move their palm region of hand. But in severe paralysis patient, communication abilities are extremely restricted. Even in extreme cases the patient can control muscles around the eyes like eye movements or eye-blinks. This motivated to pursue with this project where it helps them to control the wheel chair by eye movements and hand gesture to move in different directions and therefore make them less dependent on others.

1.2. PROBLEM STATEMENT

Wheelchairs are used by the people who cannot walk due to physiological or physical illness, injury or any disability. Recent development promises a wide scope in developing smart wheelchairs. The existing systems emphasize on the need for a system which is useful for paralyzed patients. The main aim of this work is to provide a system which is useful for patients suffering from diseases like ALS in such a way that they can control the movement. Therefore, a control system for patients suffering from diseases like ALS is necessary which is convenient to use, efficient, and affordable for the patients.

1.4. OBJECTIVES

1. The accelerometer sensor integration with the Blynk app and adding authentication key to Raspberry Pi.
2. Linking the Blynk app to Raspberry Pi and detection of hand gesture from the Blynk app.
3. Rotation of the motors to move in either left, right, forward, backward directions or to stop based on hand gesture input.
4. Detection of the eye from Pi Camera and detecting the movement of the eye.
5. Rotation of the motors to move in either left, right, forward, backward directions or to stop based on eye movement input.

2. IMPLEMENTATION AND WORKING

A. Block Diagram

The block diagram of the proposed project is shown in Fig-1. The proposed work uses Raspberry Pi 4 with 4 GB RAM which is the heart of the system. The Pi camera attached to it captures the face region of the person. The various operations are performed on this image to get the output signal. The Raspberry Pi then analyses the output signal based on the eyes position and sends the control signal to the motor driver circuit. The motor driver circuit controls the movement of wheels either in a clockwise or counter-clockwise direction or stops. The accelerometer sensor in the mobile phone detects the movement of the hand and calculates corresponding tilt angle and is provided to the Raspberry Pi which then sends the control signal to the motor driver. The motor driver circuit controls the movement of wheels either in a clockwise or counter-clockwise direction or stops. Two separate motors are mounted on each wheel.

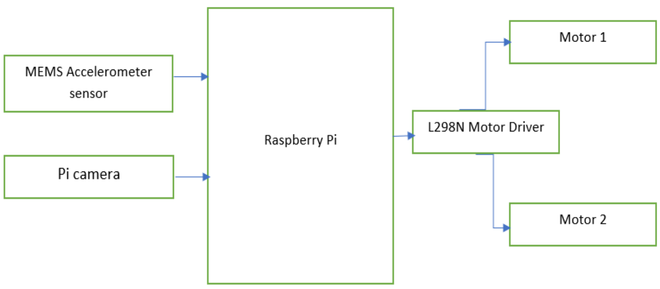

Fig-1: Block diagram

B. Hardware Requirements

- Raspberry Pi Board:

The Raspberry Pi Board, considered as the heart of the system, 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.

- Pi Camera:

The Pi Camera module is a lightweight portable camera that supports Raspberry Pi. Raspberry Pi Board has Camera Serial Interface (CSI) interface to which Pi Camera module can be directly attached using 15-pin ribbon cable. In this proposed work, Pi Camera is used to capture movement of the eye.

- DC Motor:

Two 12 V DC motors is used to control wheelchair movements in front, back, left and right. DC motors take electrical power through direct current, and convert this energy into mechanical rotation.

- 12V Battery:

An electric battery is a source of electric power consisting of one or more electro-chemical cells with external connections for powering electrical devices. When a battery is supplying power, its positive terminal is the cathode and its negative terminal is the anode. The terminal marked negative is the source of electrons that will flow through an external electric circuit to the positive terminal.

- L298N motor driver:

The L298N is a dual H-Bridge motor driver which allows speed and direction control of two DC motors at the same time. The module can drive DC motors that have voltages between 5 and 35V, with a peak current up to 2A.

C. Software requirements

- OpenCV:

It is a library of programming functions. These functions are mainly aimed at real time computer vision. OpenCV is used to process the image that appears in the webcam.

- Dlib:

Dlib is a modern C++ toolkit containing machine learning algorithms and tools for creating complex software in C++ to solve real world problems. This library is used to detect the facial landmarks in order to detect eyes.

- Blynk:

With Blynk, the smartphone applications can easily interact with microcontrollers or even full computers such as the Raspberry Pi. The main focus of the Blynk platform is to make it super-easy to develop the mobile phone application. In this work, Blynk app is used to access the accelerometer sensor of the mobile to detect the hand gesture.

- Python:

Python is a programming language that aims for both new and experienced programmers to be able to convert ideas into code easily. It is well supported among programming languages in the area of machine learning, that is why many developers use Python for Computer Vision(CV). CV, on the other hand, allows computers to identify objects through digital images or videos. Implementing CV through Python allows developers to automate tasks that involve visualization. While other programming languages support CV, Python dominates the competition.

- VNC Viewer:

Virtual network computing (VNC) is platform-independent. There are clients and servers for many GUI-based operating systems and for Java. Multiple clients may connect to a VNC server at the same time. Popular uses for this technology include remote technical support and accessing files on one's work computer from one's home computer, or vice versa. Raspberry Pi comes with VNC Server and VNC Viewer installed.

D. Hardware Implementation

This section describes the hardware implementation of the proposed work.

Hand gesture detection: Micro Electro Mechanical Systems(MEMS) accelerometer consists of a micro-machined structure built on top of a silicon wafer. This structure is suspended by polysilicon springs. It allows the structure to deflect at the time when the acceleration is applied on the particular axis. Due to deflection the capacitance between fixed plates and plates attached to the suspended structure is changed. This change in capacitance is proportional to the acceleration on that axis. The sensor processes this change in capacitance and converts it into an analog output voltage. This Accelerometer module is a three-axis analog accelerometer IC, which reads off the X, Y, and Z acceleration as analog voltages. By measuring the amount of acceleration due to gravity, an accelerometer can figure out the angle it is tilted at with respect to the earth. By sensing the amount of dynamic acceleration, the accelerometer can find out how fast and in what direction the device is moving.

The accelerometer sensor of the mobile phone is accessed using the Blynk mobile application to sense the movement of the hand. This mobile application acts as the client. The authentication key of the Blynk app will be provided to the Raspberry Pi. The Raspberry Pi reads the input from the mobile phone accelerometer. Based on the control signals from the

Raspberry Pi, the wheels of the motors are rotated through motor driver. The motor driver is connected to the Raspberry Pi using GPIO pins.

Interfacing Pi Camera with Raspberry Pi: Pi Camera module is a tiny board that can be interfaced with Raspberry Pi for capturing pictures and streaming videos. Pi Camera module is attached with Raspberry Pi by CSI interface. The CSI bus can handle exceptionally high data rates and is only used to transport pixel data. The camera communicates with the Raspberry Pi processor through CSI bus, a higher bandwidth link that relays pixel data from the camera to the processor. This bus follows the ribbon cable that connects the camera board to Raspberry Pi. The Pi Camera board connects directly to the Raspberry Pi CSI connection. It allows users to capture images with a 5MP resolution and shoot 1080p HD video at 30 frames per second. After selecting the proper cable, Pi Camera with Raspberry Pi board will be connected. After booting the Raspberry Pi, open VNC viewer and click on Raspberry Pi configuration.

Remotely accessing Raspberry Pi desktop on VNC Viewer: VNC is a tool for accessing the Raspberry Pi graphical desktop remotely. Setting up VNC is really easy but it usually only gives the access from another computer that is on the same network as the Raspberry Pi. Pi-tunnel is a service for remotely accessing the Raspberry Pi and the projects that are built on it. A device monitor and remote terminal is included, and can also create own custom tunnels to access services running on the Raspberry Pi.

The first step is to enable VNC server on your device. The easiest way to do this is as follows:

- Open a terminal on the Raspberry Pi or use the Pi-tunnel remote terminal.
- Enter the command sudo raspi-config.
- Use the arrow keys to select 'Interfacing Options' and press Enter. Later select the 'VNC' option and press enter.

Driving the motor: The motor driver is used to control the rotation of the motor through Raspberry Pi. OpenCV is

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installed on Raspberry Pi and Pi Camera will be interfaced with it. Raspberry Pi Camera is used to capture the real time images of the person's eye and is sent to continuously running OpenCV script. After processing the image the command is given to the motor driver to move left, right or in forward direction. Similarly, the data obtained from the mobile accelerometer is given to the driver to control the movement.

E. Software Implementation

This section describes regarding the software implementation of the proposed work.

Eye movement detection: The proposed system consists of two main modules namely Eye Blink Detection and Eye Motion Detection. The programmed algorithm first detects the face using facial landmark detector inside Dlib and detect the eye region and draw a bounding box around the localized eye co-ordinates. Then the eye region is scaled and converted into grayscale. The computer monitors the movement of eye towards left or right or detects blinks. The contour lines are then detected via a cross-mark on the iris of the eye. The output from these algorithms can be used as the input parameters for the required computer interface. In order to detect the motion of the eye, the face landmark detection is needed to extract the eye region.

a. Face detection: The facial key point detector takes a rectangular object of Dlib module as input, which is nothing but co-ordinates of face. In order to find faces, Dlib is used, which is an inbuilt frontal face detector. Initially the "dlib.get_ frontal_ face_ detector ()" will be used to detect the four corner coordinates of the face. It is a pre trained model which makes use of Histogram of oriented Gradients (HOG) and Linear SVM techniques. HOG is used primarily as an object detector. It provides information about pixel orientation and direction .The Linear SVM method is used to differentiate and group similar objects together. The Dlib provides both of these methods combined for face detection. The Fig-2 is obtained by joining the coordinates obtained from the function.

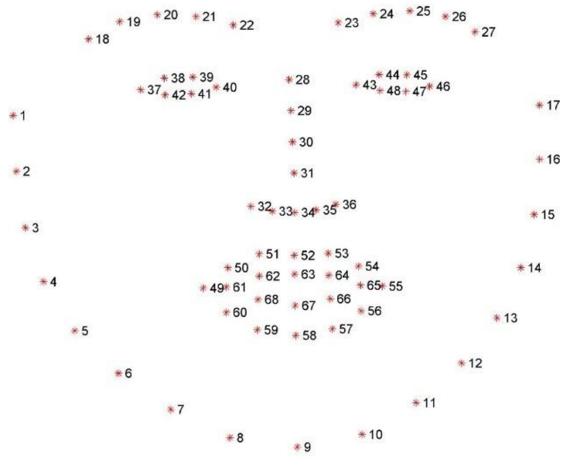

Fig-2: Facial landmarks

b. Eye detection: The next task is to detect the eyes. For this the trained model file," shape_ predictor_ 68_ face_ landmarks.dat" will be used, and will pass it to dlib.shape_predictor( ) function. This will return 68 points on the face. The region of interest is the points from 36 to 47 as these points are around the eyes. In this way isolation of the eyes from the face is done.

c. Eye blink detection: Blink detection can be calculated with the help of the Eye Aspect Ratio (EAR)

In this algorithm, the detected blink is classified into two sections, voluntary eye blinks and involuntary eye blinks. The voluntary eye blink duration is set to be larger than 250ms. The EAR is a parameter used to detect these blinks. The EAR is a constant value when the eyes are open, but quickly drops when the eyes are closed. Human eyes are clean. The program can determine if a person's eyes are closed when the aspect ratio of the eye falls below a certain threshold.

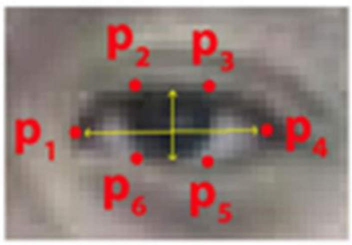

Fig-3: Eye facial landmark

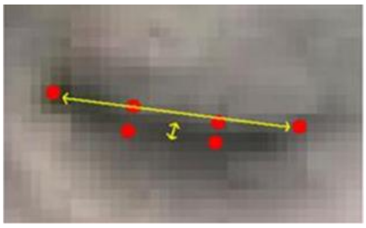

Fig-4: Eye closed

d. Eye motion detection: The region of the left eye corresponds to landmarks with indices 36, 37, 38, 39, 40 and 41. The region of the right eye corresponds to landmarks with indices 42, 43, 44, 45, 46, 47. Work in the region of the left eye. The same procedure follows for the area of the right eye. Having received the coordinates of the left eye, a mask will be created that accurately extracts the inside of the left eye and excludes all inclusions. A square shape is cut in the image to remove the eye portion so that all the end points of eyes (top left and bottom right) are considered to get a rectangle. Then get a threshold to detect our eyes. If the sclera is more visible on the left, the eyes look to the right. To determine whether the sclera's eyes are converted to gray levels, a threshold is applied and white pixels are calculated. Then separate the left and right white pixels and get the eye ratio. The gaze ratio shows us where a particular eye is looking. Usually both eyes look in the same direction. Therefore, in order to truly recognize the gaze of one eye, the gaze of both eyes can be found. If the user only looks to the right on one side, the user points the pupils and iris in the right direction, while the rest of the eye is completely white. The others are irises and pupils, so it's not completely white and in this case it's very easy to find how it looks.

If the user sees from the other side, the opposite is true. When the user looks in the middle, the white portion between left and right is balanced. The eye area is extracted and makes a threshold to separate the iris and pupils from the whites of the eyes. In this way, the eye movements are followed. Based on this, the system provides instructions for wheelchair movement. The system works according to the eye pupil position and moves the wheelchair left, right and forward. When the pupil of the eye moves to the left, the wheelchair motor runs on the left side, and when the eye moves to the right, the right side of the motor must move. If the eye is in the middle, the motor must also move forward. If problems are found, the system stops working. Eyes blink logic applies to starting and stopping wheelchair systems. The Pi Camera is installed in front of the user. The distance between the eyes and the camera is fixed and must be in the range of 15 to 20 cm.

3. RESULTS

The proposed idea could be implemented successfully and the system could fulfil the requirements. In the hand gesture detection part, the accelerometer sensor of the mobile phone detected the tilt angle of the hand movement through Blynk app and sent the resulted axis values to the Raspberry Pi. The Raspberry Pi then sends a control signal to the motor driver to rotate the wheels according to the direction of hand gesture. The bot moves towards left, if the hand is tilted towards left. Similarly, if the hand is tilted to right, then the bot moves towards right. If the hand moves forward or backward, the bot moves in respective directions.

The side view of the hardware implementation of the proposed work is shown in the Fig-5.

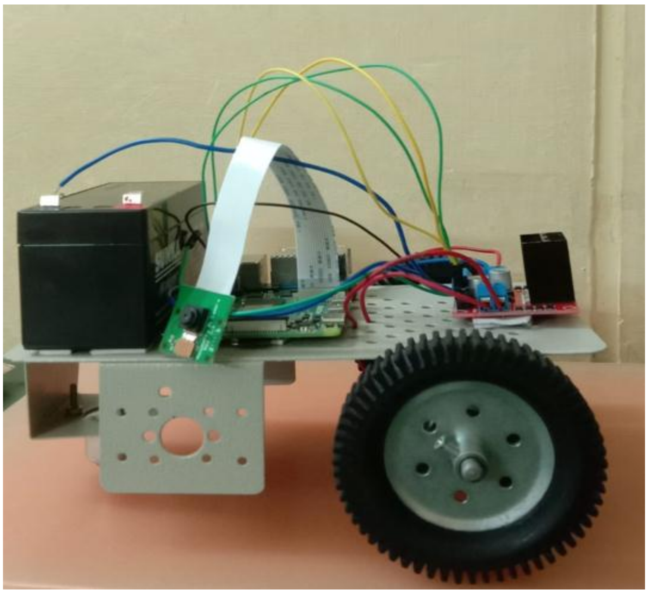

Fig-5: Side view of the hardware design

The top view of the hardware implementation of the proposed work is shown in the Fig-6.

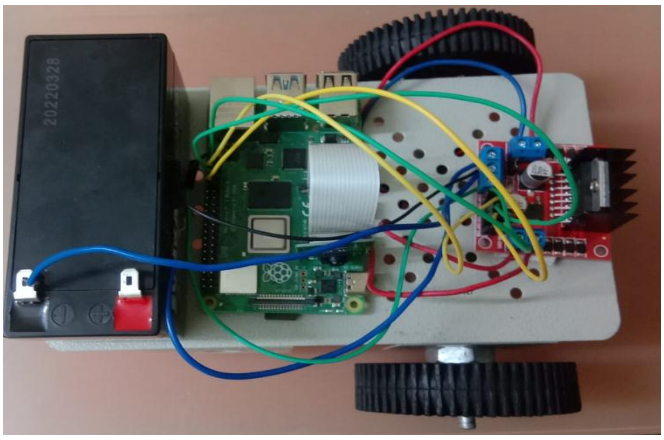

Fig-6: Top view of the hardware design

The accelerometer is added to the Blynk app. The created project is shown in the Fig-7.

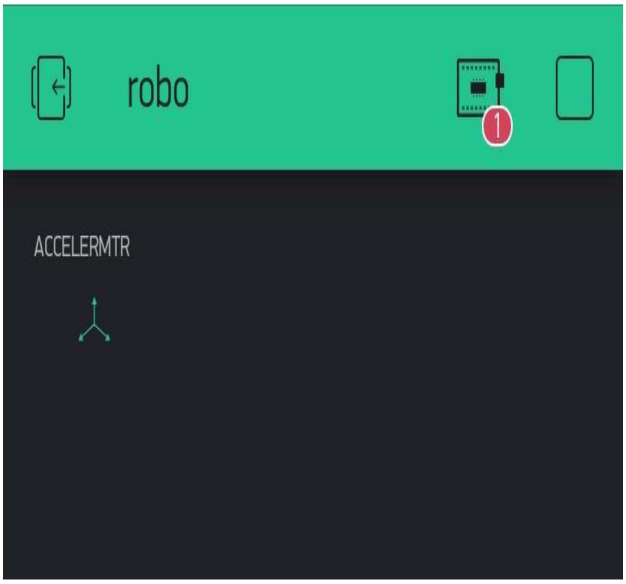

Fig-7: Application developed for hand gesture recognition

The below images shows the detection of eyeball movement which is provided to control the rotation of motor.

The facial landmark shown in the Fig-8 is used to detect the face region and later to extract the eye region.

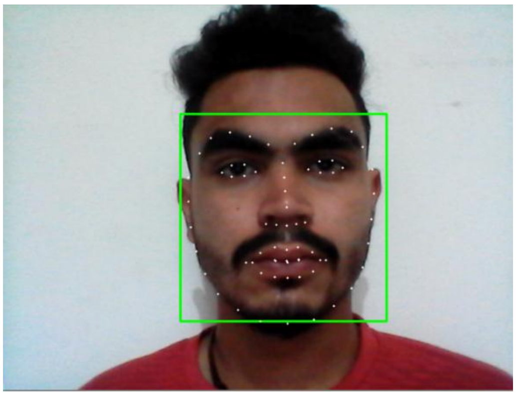

Fig-8: Detection of facial landmarks

The detection from the Pi Camera of the person looking towards straight is shown in the Fig-9. This control is provided to the motor driver to rotate the wheels in the forward direction, i.e., in the clockwise direction.

Fig-9: Person looking in forward direction

The detection from the Pi Camera of the person looking towards left is shown in the Fig-10. Hence this message is passed to the motor driver to rotate the left wheel in anti-clockwise direction and right wheel in the clockwise direction to move towards left.

Fig-10: Person looking in the left direction

The detection from the Pi Camera of the person looking towards right is shown in the Fig-11. Hence this message is passed on the motor driver to rotate the right wheel in anti-clockwise direction and left wheel in the clockwise direction to move towards right.

Fig-11: Person looking in the right direction

The detection from the Pi Camera of the person blinking his eye is shown in the Fig-12. Hence this message is passed on to the motor driver to start or stop the wheel rotation.

Fig-12: Person blinked his eye

4. CONCLUSION

The prototype of wheelchair was designed and implemented. The bot was successfully moving in the desired direction based on the gesture of hand which was detected by the accelerometer sensor of the mobile phone through Blynk app. Based on the movement of hand, control signals were passed to control the motor through the motor driver and to rotate the wheels either in clockwise direction or anti-clockwise direction and to move either in forward, backward, left, right directions or to stop.

The eye movement was successfully detected by the Pi Camera and respective control signals were provided from the Raspberry Pi for the movement of the bot in respective directions. Therefore all the objectives of the proposed project was fulfilled and implemented successfully.

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