Eye Monitored Wheel Chair Control for People Suffering from Quadriplegia

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Abstract – *Statistics suggests that there are 11,000 new cases of quadriplegia every year in United States of America. Great people like Stephen Hawking and Max Brito have been suffering from this crippling phenomenon. Our project is an attempt to make lives of the people suffering from this phenomenon simple and by simpler we mean self-reliant, 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. We know that a person suffering from quadriplegia can partially move his eyes and tilt his head, thus presenting an opportunity for detecting those movements. We have created a device where a patient sitting on the Wheel Chair assembly looking directly at the camera, is able to move in a direction just by looking in that direction. The camera signals are monitored by a MATLAB script, which will then guide the motors wired to the AtMega1284P 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.*

Keywords: *Automation and Control, Mind reader, Electroencephalography, Arduino, Brain-Computer Interface.*

1. INTRODUCTION

The number of persons who are paralyzed and therefore dependent on others due to loss of self-mobility is growing with the population. The development of the wheelchair for paralyzed users is surprisingly recent starting with the conventional manually powered wheelchairs and advancing to electrical wheelchairs. Conventional wheelchair use tends to focus exclusively on manual use which use which assumes users still able to use their hands which excludes those unable to do so. Diseases or accidents injuring the nervous system also frequently because people lose their ability to move their voluntary muscle. Because voluntary muscle is the main actuator enabling people to move their body, paralysis may cause a person not move their locomotor organ such as arm, leg and others? Paralysis may be local, global, or follow specific patterns. Most paralysis are constant, however there are other forms such as periodic paralysis (caused by genetic diseases), caused by various other factors.

Scientist Stephen W. Hawking is perhaps the most well-known victim of major paralysis – Hawking was diagnosed with incurable Amyotrophic Lateral Sclerosis (ALS) in 1962, thereafter using a wheelchair to move. Many of those suffering close to or complete paralysis usually however still can control their eye movement which inspired us to develop an eye-controlled electric wheelchair.

2. PROBLEM STATEMENT & SOLUTION

STATEMENT: The main theme of this project is to design a vision based wheelchair system. Using the camera to acquire user images and analyzing user intent using head gestures.

For the eye detection, we came up with multiple strategies. One was to detect the eye moments using the infrared light. The idea behind this method was to concentrate the infrared light onto the eyes from the forehead. The voltage rating of the infrared light is under the permissible levels that can be used to concentrate in the eyes. The infrared light concentrated through the forehead of the user will be collimated through the pupil of the eye and we can use this collimated light to obtain a voltage drop across the photodiode which will drive the motors.

We built the photo detector circuit and tested this method on one of the group members. During the testing of the circuitry, we found that we were not able to obtain accurate results and the voltage drop across the photo diode was not constant and kept on varying. Thus, the issue with this idea was that the voltage drop obtained across the diode was just 0.7 Volts and it was not sufficient to detect accurately. Thus, we had to come up with an alternative in order to obtain an accurate method to detect the eye as that is the most crucial part of the system and needs to be done with great precision.

The second alternative that we came up with was to connect the web camera to the Raspberry Pi directly which would then process the snapshots, eliminating the need to have the camera

attached to the laptop. But, we found out that the time taken to understand the new controller board is a lot. Also, normally these days such users have a laptop somehow attached to their wheel chair and thus we decided to rather go ahead with a microcontroller board that we already understand. The alternative design which we finalized, captures the images using a webcam that will be attached to the laptop placed on the wheelchair of the user. These captured images will be used to detect the eyes and hence detect the movements using a MATLAB script running on the laptop, which then sends serial commands to the microcontroller circuitry driving the motors attached to the wheel chair.

3. PRODUCT DESIGN

There are two major components from the system design standpoint -

a) Eye-Detection and motion tracking.
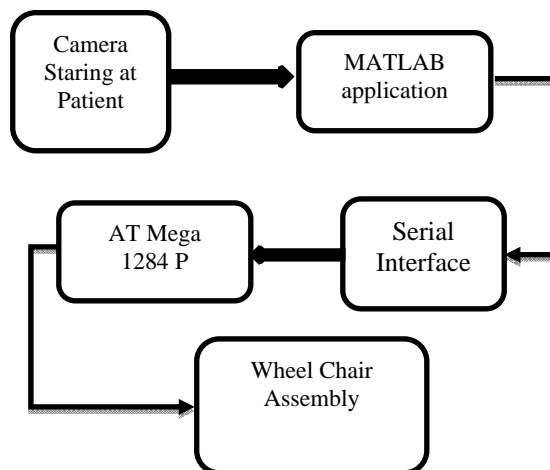b) ATMega1284P controlled Wheel Chair Assembly

Fig. 1: Block Diagram

Eye-Detection and Motion Tracking: A webcam is mounted on a cap, continuously staring at the user's eyes. The webcam wired to the patient's laptop, is running a MATLAB application designed to monitor and react to eye movements. Based on a series of snapshots taken and thereafter processed, the motion of the user's eyes are detected, decision to move the Wheel Chair in a particular direction is taken and communicated serially to ATMega1284P microcontroller. MATLAB 2013 has an image processing toolbox which we utilized for the eye detection. We used the 'Cascade Object Detector' capable of detecting eye-shaped objects based on their shape and size. It uses the Viola Jones Algorithm for the same. A description of the Algorithm is given in the software section of the report. Continuous snapshots of every 25th frame are taken and feature points extracted are saved i.e. we capture approximately 1 snapshot every second and process it. Based on the position of the feature points in previous

snapshot and current snapshot, a movement is detected and this is communicated to the wheelchair assembly via the serial port.

ATMega1284P controlled Wheel Chair Assembly

A decision based on the processing done by the MATLAB application is communicated and received by the ATMega1284P. The controller on reception forces the port pin high on which the motors have been connected for desired motion of the Wheel Chair.So, now we will have a look at the overall code structure of our algorithm and the logic behind the decision making.

There are two parts in the code structure. The first part is to detect the eye movements and the other part is to drive the motors.

1. *Initialization*: Initially we set up the serial communication that will be used later for the interface between MATLAB and the controller, the video capture and the program variables.

2. *Image and Video Processing*: We then take continuous video frames and sample the input and save it as the screen shots. Each frame is then converted into the black and white frames. For the accurate results, we perform contrast stretching on each frames to make the dark region darker and bright region brighter. This will enable the detection of the eyes better.

3. *Estimation*: Now, after working on the each frame we try to detect the eyes. This we do by estimating the position of left as well as the right eye. Thus, we set the threshold and detect the position of the eyes which can be used for the further processing.

4. *Detection*: Now, in this step we actually detect the eye movements. The idea is to compare the current position of the eye with the previous position. Thus, the difference in the coordinates will help us to predict the motion in the particular eye. But sometimes, it may be possible that only one of the either eye will be detected. In that case, we will give preference to the eye that is detected currently.

5. *Error Handling:* To avoid detection errors, we incorporated an error handling mechanism, which specifies a threshold for the height and width of a valid eye, by calibrating it for the user. If the detection results give a height and width value lesser or greater than the threshold, the value is voided and not considered for the decision making

6. *Motion*: Now after detecting the eye movements, we have to come up with a decision algorithm that will help the controller to drive the motors accordingly:

a. Valid Left: The decision to turn left will be considered as valid if the eye turns left and stays there for a cycle. This action will be detected as a left turn request. After that, the patient will turn right to again look forward. Thus, this signal should be considered as void.

b. Valid Right: Similarly, the decision to turn right will be considered as valid if the eye turns right and stays there for a cycle. This action will be detected as a right turn request. After that, the patient will turn left to again look forward. Thus, this signal should be considered as void.

c. Valid Straight: The signal to go straight is when a person looks left and right or right and then left. This will be detected as to go straight.

7. *Safety Considerations:* Given the application of the system, we incorporated a safety mechanism, wherein based on the blink detection the wheel chair halts. If the user wants to halt the wheel chair in case of an emergency, he can blink thrice, causing the wheel chair to halt.

8. *Serial Communication:* Now according to the detected command, the MATLAB application will transmit 0, 1 or 2 for left, right and straight respectively to the controller which will drive the motors.

4. IMAGE PROCESSING

MATLAB Component: The MATLAB design can be structured into many small sub-parts each of which is described below -

(i) Initialization of variables and setting up serial communication - MATLAB 2013 can easily be configured to serially transmitting data on the Port mentioned in the code. Initially all the already set up serial ports are disabled. After which, we need to mention the current port, by checking the 'Device Manager' which indicates the port in use. The baud rate of communication is set to 9600. The communication is set to have no flow control and parity check is disabled.

After setting up the serial communication to enable the data link between MATLAB and AtMega1284P, we reset the variables needed in the course of the program to their initial valuables.

(ii) Image Capture and Eye Detection:

MATLAB 2013 equips an Image Processing Toolbox, which we have used majorly in this section of the Software Design. We use a Microsoft LifeCam HD-5000 web camera which is connected via a USB cable to the Computer on which the MATLAB script is running. We can stream continuous video signals on MATLAB coming from the camera using the video processing toolbox available. The function 'imaqhwinfo' is used to recognize all video capture adaptors. Identifying the correct device and then using it to stream the video signal is the next step. The requirement of our design was to continuously look at different frames, based on which determine motion. It is practically impossible to do a lot of processing on a per frame basis. That is why we try to sample every 25th frame. So, a snapshot of every 25th frame is captured and processed. We used the 'get snapshot' command to capture these snapshots.

The image is then converted to grayscale image, as we do not need colour information to detect eye feature points. The conversion infact makes the detection easier. The 'imadjust' command is used then to contrast stretch the image to make darker sections even darker, enhancing the eye feature points useful for the application.

This pre-processing of the image makes the image easier to process and extract the eyes from. After the initial pre-processing, we move towards the eye detection. The Eye Detection is done using the Viola-Jones Object Detection Algorithm. Primarily this algorithm was designated for face detection though it is used for all sorts of object detections. The algorithm is designed to work on sum of pixels in a rectangular area. Viola-Jones algorithm [5] says that face can be detected by looking for rectangle. And then the large rectangle is made up of many such smaller rectangles, which are fundamentally feature points on a human face.

(iii) Image Processing -

Initially, all we do is monitor if any eye feature points have been detected or not. If not set a flag and display it on the debug screen. To increase the detection accuracy, we wanted to neglect all other points on the screen except the actual eye of the person. The reason being, if anyone except quadriplegic person comes in front of the camera, the person should not affect the system. Also certain things seemingly looking like eyes should be rejected as well. The way we incorporated this is taking into account the height and length of the eye. After repeated testing, we decide a length and height of a valid eye, sets a range around the threshold and reject everything which is outside it.

The blink detection section is not compute intensive. We use a flag which is set each time no valid eyes are detected. If in corresponding frames the flag value sets, it indicates a blink. A series of 3 such blinks command the motors to freeze, halting the wheel chair.

What is assumed is that the position of the camera is fixed, relative to which the left and the right eye approximate positions can be estimated. Using this, we try to distinguish and store left and right eyes in different matrices. This helps getting a clear discrimination between both the eyes, helping in easy movement detection.

(iv) Movement Detection:

The movement detection is done with a very basic principle. We take in the feature points for both left and right eyes and save it. Thereafter take the difference in pixels of the left eye position and right eye position in the current snapshot from the previous snapshot. We define the threshold for the minimum movement of the eye required to be qualified as a valid attempt. In each snapshot the difference is evaluated, and if this difference above the threshold in any direction left or right, the flags indicating left movement or right movement are set. If the difference is not above the threshold, the flag which says that no movement has occurred is set.

(v) Motor signals -

The way we qualify a valid right, left and straight attempts to move, we need to incorporate many factors. The way a valid right is recognized is by tilting face on the right side and stay there for a second, after which the wheel chair starts moving. But the person's face is still tilted on the right. If the person now tries to go back to the initial position by tilting left, the system will detect it and lead to an otherwise invalid left movement of the chair. This has to be avoided.

We set flags for left and right movements each time the wheel chair moves, avoiding precisely this unwarranted behavior of the system. The way a valid straight movement is detected is titling in corresponding frames in left and right directions. Over here as well, the effect of the offset coming into picture are avoided in the same fashion with the help of flags.

As already mentioned, three corresponding blinks should halt the motors. Along with the motion command, a halt command is also transmitted to the microcontroller assembly which thereby halts the motors as per the user's desire.
After determining which direction the wheel chair has to be moved in, the decision is transmitted to the micro-controller via the serial port. The only thing sent is a one digit decision, saying right, left or straight movement.
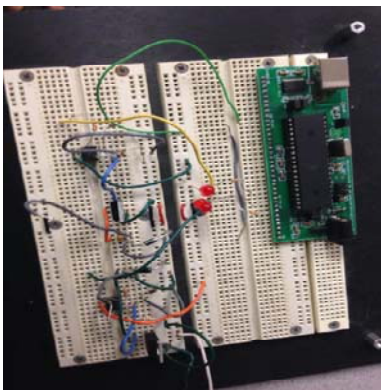
5. HARDWARE MODEL

Fig. 2: Hardware model of proposed system

6. RESULT

Speed of Execution

We were never actually limited by the speed of execution. We could go upto 15 frames a second, evaluating and determining the face tilt. But there were couple of issues because of which we limited the speed of execution. One being, we do not want the person to get a jerk whenever he wants to move. Hence we compute and drive the motor at a slow pace, as compared to the ability we can escalate the speed to. Also, we want to keep the system secure by taking a while to evaluate the movement and thereafter making a decision, given the criticality of the application.

Accuracy

The project performs satisfactory with performance accuracy of around 70-90%. The results after testing it for 100 to 200 attempts to move in a random direction were made by both the project members

Safety Features

The safety features incorporated in the system were -
a) Controlled speed of detection and wheel chair drive.
b) Eye height and width threshold.
c) Controlled movement in either direction for limited time period.
d) Less jerk by incorporating delay in the wheel chair drive.
e) Halt control using blink detection.

7. CONCLUSION

The system functions with an accuracy rate of 70-90 % which was above our expectations. The image capture, eye movement detection and the algorithm for validating movement attempts perform very reliably as our results suggest. The aim of this project is to contribute to the society in our small way by setting out an idea for a system which could actually better the lives of millions of people across the globe. We believe we have done great justice to the idea, and ended up getting more than satisfying results.

8. FUTURE SCOPE

Though our prototype performs satisfactorily, but 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 we do not want the wheel chair to move when the person is just casually glaring in different directions. Similarly, we can incorporate certain sequence for turning ON and OFF electrical devices, or door locks. Also since the criticality of the application is so high, lot of safety precautions need to be incorporated. It needs to be made sure that the system is not fatal to the health of the person. A lot of

testing needs to be done before making such a product a reality.

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