Eye and Blink Controlled Robot with Fuzzy Logic Based Obstacle Avoidance System for Disabled

K.S.Sabarish, A.M.Suman

Abstract- In present world, robots have become part of our life. Continuous research is being carried out to make the control of robot easier, simpler and user friendly. In this paper, we propose to control robot based on eyeball movement and eye blink. Image of the eye is captured by camera and the eyeball is extracted using MATLAB. Then based on the movement of eyeball, the robot's locomotion is decided. The blink of the eye is also detected and it is used to toggle the robot state of motion. A buzzer is used as a feedback system. A fuzzy logic based obstacle avoidance system is also implemented to enhance the safety of the robot when it navigates through small openings. By this, the control of robot becomes much easier and hands free. This approach can be very helpful for controlling military robot and in helping the movement of handicapped people.

Keywords- Blink Detection, Eyeball Control, Fuzzy logic, Image processing, Obstacle detection

I. INTRODUCTION

There are many techniques available in recent times to enhance the mobility of robots and most of the time fine and accurate control is not possible. A great deal of computer vision research is dedicated to the implementation of systems designed to detect user movements and facial gestures and use them to control robots. These robots are very efficient and enable the user to move around with ease as no external remote controls are required. In recent times, various control systems have been developed for specialized people with various disorders and disabilities. There are many assistive systems using visual aids like videooculography systems, infrared oculography, etc. These above mentioned systems, get the eyeball movement as a parameter for controlling the robots locomotion. These can be applied to the development of robotic wheelchair which is quite popular among people with limited upper body mobility. There are certain drawbacks in these systems.

They cannot be used by people of higher disability because they require fine and accurate control which is most of the time not possible. Moreover the existing systems are very much vulnerable to collision.

Thus our proposed system overcomes all these difficulties faced by the existing systems, which is mainly used for assisting disabled to move comfortably with easy user controls. This system can be utilized by users who can comfortably move their eyes and can blink normally. The collision problem is overcome here by using obstacle avoidance system based on ultrasonic sensors. This avoids wrong commands from the user and ensures the safety of the robot and also to the user by sounding an alarm and automatically stopping the robot before it collides or it takes appropriate action automatically to avoid collision. The obstacle avoidance system is based on fuzzy logic because it takes less computation time and also makes the system more precise. Such robotic wheelchairs helps the user to move in environments with ramps and doorways of little space without worrying about collision or falling down the ramp. robots of this kind can be applied in various fields because of easier control and reliability. This work is based upon our work with a small robot which was successfully controlled with eyeball movement. Generally a robot should be interactive, and robotic wheelchairs must be highly interactive to enable the system to work most efficiently. Our proposed system is highly interactive with the user so that the system is highly effective and the system can be properly put to use.

II. PROPOSED SYSTEM

We propose a robotic system, that can be comfortably controlled with help of eyeball movement without the worry of collision. Various parts and the working of it is explained below with the help of block diagram (Fig 1).
A camera with resolution of 2 MP was used for capturing the image of the eye. It was positioned in such a way so that it captures only the image of the eye. Micro camera is much preferred as it can be tied to spectacles for taking the image of the eye. Two IR emitting diodes were used for the purpose of illumination and it was made sure that it didn't fall directly on the user's eye, so that damage to eye can be minimized. LDR is used to control the intensity of the IR based on surrounding brightness. Fig 2 shows the image of the eye captured by the camera.

**A. Camera Position**

The image captured from the camera is fed to processor. Since the image consists of only the eye, as shown in Fig 1, basic thresholding [1] method is sufficient for the extraction of the eyeball. For that purpose, first the RGB image is converted into a gray scale image. Then with proper threshold value, the eyeball is extracted. Along with the eyeball, even the eyelashes get extracted. They are filtered based on the area of the extracted region. The eyeball region has the occupies maximum area in the image and thus the eyeball region is extracted by filtering the regions of eyelashes on the basis of area difference. Then the centroid of the eyeball is found out to track the eyeball.

We used MATLAB and its image processing toolbox for processing the image. We first converted the image into gray scale image (using the function rgb2gray [2]) and used threshold value of 0.79 to convert it into binary image (using function im2bw [2]). Fig 3 shows image of the eyeball after applying thresholding method. It is clear from the image that the extracted region of eyelashes occupies smaller area compared to the eyeball region. Using the MATLAB inbuilt function 'regionprops' [2] we found out the area of the extracted image and their respective centroid. Based on the area of various regions, the eyeball region and its centroid is found. In Fig. 4, the centroid of the eyeball is marked after applying the above procedure.

**B. Eyeball Extraction**

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**C. Blink Detection**

Based on blink, we toggle the state of the robot. Image of the eye is captured and it is converted into grayscale image. The threshold method which was used to get the eye is applied. The area (say x) occupied by the eyelashes when eye is closed is estimated when the robot starts for the first time. This value is used to differentiate between eyeball and blink. Since the eyeball is absent and only the eyelashes are visible when the eyes are closed, no region is found whose area is greater than value (x) which was estimated. By this method the blink is detected.

We filtered out involuntary blinks as follows. When the blink is detected, the buzzer is made to sound. Then after 0.8 seconds, the buzzer sounds again. If the eyes are still closed then the blink action is taken, else it is considered as involuntary blink and no blink action are taken. Thus this buzzer system acts as a feedback system. This makes the robot more interactive with user and to make user comfortable to use the robot.

The blink is used to toggle the state of the robot as explained in section below.
D. Obstacle Avoidance System

Though proper control can be obtained by eyeball movement method, sometimes due to distraction or while passing through doors, probability of collision is quite high. Thus to avoid collision and to ensure safety of the robot and the person using it, detecting obstacles are necessary. Ultrasonic sensors have been used to detect obstacles and the robot takes proper action to avoid collision automatically [3]. This makes the robot semi-automatic and reliable.

The ultrasonic detection module transmits ultrasound at particular frequency. The ultrasound which was transmitted gets reflected by the object nearby and the echo is detected by the receiver present in the module. By noting the time taken for the ultrasound to get reflected by the object and get detected by the sensor and by knowing the speed of ultrasound, we can calculate the distance between the object and the ultrasound module.

We used 3 ultrasound detection modules which were mounted on the robot and were placed in such a way that, first ultrasonic sensor detects obstacles in the front and second sensor on the right and the other on the left of the robot. The position of the ultrasonic detection modules helps in reducing the crosstalk [5]. Also the modules are placed 6-7deg inclined to the floor so that unwanted reflection from the floor can be minimized [6].

We have designed fuzzy logic based obstacle avoidance system [4]. Fuzzy logic was used because the speed of computation is high which increases the response time and it greatly improves the precision of the system.

The membership function is used to convert the sensors reading into fuzzy values. Three membership function are defined, one for distance, another for translational speed and the other for turning. Thus for distance inputs, the output will be either far or not that far (NF) or near, for translational speed the output will be either fast, medium or slow and for turning the output will be steep right turns (StRT), small right turns (SRT), no turn (NT), small left turn (SLT) steep left turn (StLT) and U turn (UT).

Table I

<table>
<thead>
<tr>
<th>Rule No.</th>
<th>Left</th>
<th>Front</th>
<th>Right</th>
<th>Speed</th>
<th>Turning</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Near</td>
<td>Near</td>
<td>Near</td>
<td>Slow</td>
<td>UT</td>
</tr>
<tr>
<td>2</td>
<td>Near</td>
<td>Near</td>
<td>Far/NF</td>
<td>Med</td>
<td>StRT</td>
</tr>
<tr>
<td>3</td>
<td>Near</td>
<td>Far</td>
<td>Near</td>
<td>Fast</td>
<td>NT</td>
</tr>
<tr>
<td>4</td>
<td>Near</td>
<td>NF</td>
<td>Near</td>
<td>Med</td>
<td>NT</td>
</tr>
<tr>
<td>5</td>
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<td>Far/NF</td>
<td>Fast</td>
<td>SRT</td>
</tr>
<tr>
<td>6</td>
<td>Far/NF</td>
<td>Near</td>
<td>Near</td>
<td>Med</td>
<td>StLT</td>
</tr>
<tr>
<td>7</td>
<td>Far/NF</td>
<td>Near</td>
<td>Far/NF</td>
<td>Slow</td>
<td>UT</td>
</tr>
<tr>
<td>8</td>
<td>Far/NF</td>
<td>Far/NF</td>
<td>Near</td>
<td>Fast</td>
<td>SLT</td>
</tr>
<tr>
<td>9</td>
<td>Far/NF</td>
<td>Far/NF</td>
<td>Far/NF</td>
<td>Fast</td>
<td>NT</td>
</tr>
</tbody>
</table>

Depending upon the rule base created above, the output is calculated for different combination of the readings from the ultrasound sensors.

But there might be a possibility that a object (probably a human), comes suddenly near the robot. In such cases the robot must stop or slow down. This is achieved by the following condition: When the sensor reading changes from Far to Near suddenly (Not from Far to NF to Near), Then the robot stops immediately. Is helps is avoiding sudden collision. When the robot stops due to the above condition, the buzzer sounds three times in a row and waits for the user to blink to start the robot again.

Thus the fuzzy logic based obstacle detection systems, greatly improves the robot performance compared to other obstacle avoidance system, because of less computation speed. With this system, the reliability and safety of the robot are greatly improved.

E. Communication

The camera is directly connected to the laptop and the communication between the robot and laptop is carried out by Bluetooth. The laptop has inbuilt Bluetooth device while the microcontroller (Atmega328) on the robot was connected to BTbee 2.0 via Xbee shield v1.0 for Bluetooth communication. We used Bluetooth as a medium for communication because the data transferred was less and the communication distance was less than 20 feet.

F. Calibration

First the time taken for 90 degree turn is found out experimentally. When the robot is started for the first time, the user is asked to close his/her eyes for few seconds. This is done to estimate the area occupied by the eyelashes when the eyes are closed. This helps in detecting the blink and this was
done because the area occupied by the eyelashes differ from person to person. Then, the user is asked to keep the eyeball on the corner most position so as to find the centroid of the eyeball. Then, then user is asked to keep the eyeball at centre and the centroid of the eyeball is found.

When the eyeball moves from the centre position to the corner position, the robot takes a 90 degree turn. It was found that, our robot takes 0.75 seconds for 90 degree turn (Which depends on the voltage applied to the motors). With the formula mentioned below, the delay time which must be given to robot to turn for per unit change in eyeball.

$$T = \frac{(Time \ taken \ for \ 90^\circ \ turn)}{(x1 - x2)} \quad (1)$$

Where, T is the time delay to be given for corresponding change in the eyeball position, x1 and x2 are the x coordinate of the eyeball at corner position and centre position respectively. This delay time (T) is multiplied with the position change in the eyeball and given to the robot.

The fuzzy based algorithm for obstacle detection ultrasonic sensors need to be calibrated. To find the fuzzy values for the output, the values for each translational speed and turn is calculated. The values are found out by trial and error method. The minimum distance was decided to be 30cm. Thus when the robot is 30 cm away from the obstacle, the membership function's output will be near. The NF and Far values must be decided appropriately to enhance the reliability of the robot. In the similar manner, the delay time is calculated for the turns.

**G. Toggling Robot State**

Robot's state is toggled based on the number of blinks and also based on frequency of blinks. When blink is detected, it starts or stops the robot's motion. When the robot is in stop state and then the two blinks are detected consecutively, then the robot's direction of motion is reversed.

**G. Algorithm Implemented**

Algorithm which we have implemented for controlling the robot with eyeball is as follows:

- Step 1: Get the input from ultrasonic sensor. And check whether any object is nearby. If there are no objects detected nearby then jump to Step 3, else continue.
- Step 2: Based on the fuzzy algorithm take appropriate action based on the sensor readings. then jump to Step 1.
- Step3: Get the image
- Step 4: Convert the image into binary image using the thresholding method mentioned above.
- Step 5: Check for blink.
- Step 6: If the blink is detected, sound the buzzer and wait for another 0.8 seconds and then capture the image and check for blink, if the blink is confirmed continue, else go to Step 8.
- Step 7: Toggle the robot state as explained and then jump to Step 1.
- Step 8: Get the image of the eye after 0.3 seconds and again check for blink. If blink detected, continue else jump to Step 10.
- Step 9: Toggle the robot state and then jump to Step 1.
- Step 10: Calculate the change in the position of the eyeball and also calculate time T.
- Step 11: Send the data to the robot via Bluetooth, whether it has to take right/left for the time period T.
- Step 12: After the Time T, go to step 1.

**III. EXPERIMENT RESULTS**

To implement the robotic system mentioned above as especially to test the accuracy of the detectors (camera, Ultrasonic Sensor) since the detectors give the overall accuracy of the system. The system was developed and tested using a windows 7 PC with an Intel core i7 2 GHz - 2.9Ghz processor and 8 GB Ram. Video was captured with an Intex Webcam at 30 frames per second. All video was processed as gray scale images of 640 x 480 pixels using MATLAB Image Processing Toolbox. Though we used Intex webcam for testing purpose, micro-cam is preferred because of its small size which makes it easier to mount it on the spectacles. We used BTbee 2.0 for Bluetooth communication between the robot and the PC. Atmega328 microcontroller was used for controlling the robot based on the commands given from the MATLAB. Our robot implemented differential drive which was driven by 300rpm motors and L293D (H-Bridge) was used to control the motors. The component used are shown below:

![Fig 7: Eyeball tracking robot](image)

The complete robot is shown above (Fig 7).

The optimum threshold value and the various fuzzy output parameters where determined experimentally. The threshold value was found out to be 0.80 and the delay time (T) was calculated to be 0.0058. The Near value was decided to be 20cm and not so far was decided to be 50cm. Distance greater than 50cm was taken to be Far value. The medium speed was decided to be 75% of full speed and slow speed was decided as 50% of full speed. The 70 deg turn was considered as steep turns and 30 deg turn was considered as small turns.

The normal blink and voluntary blinks was well differentiate by our system. This was tested as follows, The user was asked to blink two short blinks followed by a long
(voluntary) blink, or were asked to blink twice voluntarily followed by a short (involuntary) blink. These test results serve to show how well the system distinguishes between the voluntary and involuntary blinks and all blinks are indicated by a small pulse of sound and confirmed blink is indicated by a continuous pulse of sound from the buzzer serving as a feedback system.

When the user started the robot for the first time, the usual calibration procedure was started automatically to decide the delay time to be given for unit change in eyeball position and the area covered by the eyelashes when the eyes were closed.

Finally the system was made to run in real time open environment. The robot reacted to eyeball movements properly and avoided collision with the objects. Even when the object was thrown in front of the robot suddenly the robot came to halt immediately and avoided collision. It was found that the robot was 92.3% accurate in proper suitable environment, and an accuracy of 86.5% was achieved under critical lighting environments.

Lighting conditions were found to be reducing the system accuracy which is eliminated by using constant lighting using two white LEDs. This proved to improve the accuracy of the system and problems with thresholding processes were eliminated.

In addition numerous other experiments were also conducted to determine the effectiveness of the system under varying circumstances, such as alternative camera placements, lighting conditions, and distance to the camera.

IV CONCLUSION

Our proposed robotic system, tries to control the robot using eyeball movement, making it easier to control as there is no requirement of external remote controls and makes it hands free. This makes it a excellent method of design of robotic wheelchair for disabled persons especially for people with paralyzed body. With the help of blink detection, the user can interact with the robotic system through feedback sound. Algorithm designed for the system, makes it very user friendly and the system response is greatly improved. The reliability and safety of the system is highly improved by making the system semi automatic with the help of ultrasonic sensor for automatically detecting obstacles and taking appropriate actions to avoid collision automatically. Thus our system can be used reliably in various fields, especially in helping disabled persons and in military field, with hands free and user friendly controls.

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