A Study towards Interface of Intelligent Wheelchair with the Eyeball Tracking Mechanism

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Abstract: Any sort of physical disorder creates mobility difficulty especially impossible for patients with lower limb paralysis making them highly dependent on fellow human beings. To assist such patients a robotic wheelchair synchronized with eyeball motion has been developed where patients' own body part is used to help in movement. This paper devises visual research experiments to innovate the viability of an eye ball driven robotic wheelchair. It investigates the Eye-ball IR sensing and Shoulder Pressure sensing behavior linked with physical movement of patients. There are three ideas in this study. First, the correlation between Eye ball sensor behavior and the hardware model to start and stop the wheelchair. Second, shoulder pressure sensing mechanism to turn the wheelchair left and/or right. Third, Ultrasonic sensing to sense and avoid the obstacles in the path to helping free and safe movement. Experiments on different age groups show quick response at ages less than 20 for both normal and paralyzed patients with 40 and 33mV and with the ages above 45 this value reduced to 28 and 16mV respectively.

Key words: Eyeball control, IR sensing, shoulder control, ultrasonic sensing, wheelchair automation.

1. Introduction

Robotics have played an important role in human life. This has provoked significant research techniques to device automation. Lack of high-quality interfaces remained a long standing barrier to effective robotics [1]. Users found it tough to identify healthy solution because of earlier vague information. The Camera; Image & Video processing device; primarily governs the types of interfaces found in automated wheelchair today [2]. Eye tracking counts an adaptive method [3] for visual tasks that has the ability to work on user's need from eye movements [4]. Physically disabled and paralyzed patients find their movements quite hard using existing assistive maneuvers [5]. Despite several robotics have been offered during last few decades to empower their motility, the patients need precise, fine and accurate control which is often not possible in cases of sophisticated disability [6]. Many different control systems [7] have been developing specifically for people with several disabilities and disorders [8]. This project preliminary works in design of an electric wheelchair system that uses shoulder kinematics and movement of eyeball to guide the chair, a proposed model in the study. The system helps the rider mainly paralyzed patients to control and give directional movement to the chair, Ultrasonic sensors mechanism facilitates to sense & alarm the riders of hurdles encountering track of motion in order to avoid collision. The chair will assist patients to go around in areas

with ramps, slopes and entries of little space.

Various studies have presented application of electric wheelchair EWC for assistance in mobility. A solution is proposed on the basis of three different human inputs to plan and control motion of wheelchair [7]. As first input, planning is incorporated to the system using visual interfacing. Secondly patient or rider of wheelchair will use reactive controller in order to abstain obstacles. Thirdly patient could operate EWC by providing velocity command using joystick. Want *et al.* [9] proposed ceiling light landmark based strategy to identify location and obstacle using cameras based navigation. Identification was carried out using fluorescent ceiling light as landmark. Also there is head gesture based solution for EWC [10]. Head gesture is recorded by identifying position of nose and frontal face. The system has used adaboost face recognition. In another study gaze direction and eye blinking based solution was proposed to automate EWC [3]. According to a clinical survey nearly 10% patients trained for using powered wheelchair exhibited difficulty in performing daily life activities with serious constraint of such powered wheelchairs was found when 40% patients showed difficulty in steering and maneuvering activities [2]. This has still left them dependent on others for their mobility. In a similar study [1] such patients often suffer low energy level causing less control for guiding the powered wheelchair posing inefficiency of the system. Some eye ball tracking techniques are in practice such as electro-oculogram EOG, lens tracking mechanism LTM. These techniques are complex in terms of monitoring and computing positing of pupil. EOG applies use of electrodes placed on the face of patients which is itself cumbersome. LTM involves complex circuitry using mirror or magnetic coil affixed on contact lens to be placed in eye. The mirror records reflection of light and computes position of pupil. Though this mechanism shows high resolution and accuracy yet application magnetic coil is practically prohibited [8]. To fill the identified gap an eye ball tracking mechanism with IR sensor attached on the goggle instead of on body parts of patient is proposed in this study.

1.1. The Eye

Eye is a multifaceted detecting device comprising a series of optical elements: an aperture (pupil), two lenses (cornea and eye lens), and a light sensitive transducer (retina) that transmutes electromagnetic energy into neural impulses which further conveyed to visual cortex through optical nerve [11]. Fig. 1 shows the basic structure of the human eye.

Fig. 1. The eye.

The retina carries light sensitive receptors (photoreceptors) containing on average 127 million cells can

detect relative small amounts of lights and 7 million cones can picture the colors of the human visible light spectrum. The receptor cells are non-homogeneously distributed over the retina. Fovea (foveola) is a region of high receptor density (mostly cones) in retina. It makes high spatial resolution in the centre of the retina. Exterior to this, an area of radius of near one degree of visual angle, the density drops exponentially with increasing eccentricity. This means that we occupy very comprehensive vision in the centre of our visual region and only abrasive perception in the peripheral fields. In foveola the image of the object of people's fixation forms. This physiological phenomenon shows that humans have built-in and precise control of eye motions. The visual axis is the line from the foveolar centre through the corneal sphere centre, also recognized as the optical node point of eye. The eye's optic axis is declared as the axis of symmetry for the eye's optical system. The location of the foveola is generally offset from the eye's optic axis, so the optic axis is distinct from the visual axis. The foveola of the eye is usually located to the temporal side of the eye, causing the visual axis of the eye to point to the nasal side of the optic axis. The angle between the optical and visual axes of the eye, which is about 5° has a standard deviation of about 2° over the human population. The surface of the cornea is approximately spherical. The corneal sphere is smaller than the eyeball and its surface protrudes out of the eyeball sphere by approximately 1.5mm. The typical radius of curvature for the cornea is 7.7 ± 2.0 mm. Fixations are regarded as miniature high frequency oscillations (drifts and micro saccades), which prevent the image from fading away triggering the scene becoming blind. Saccades are the countenance of the aspiration to voluntarily alter the focus of attention. During saccades, the eyes are stirred to a different part of the visual scene and happens in a sequence of fast, sudden jumps rather than continuously. Planning a saccade normally involves peripheral processing to determine the saccades landing point, particularly in non-figurative scenarios when only little contextual information is given. While the saccades initialization can be voluntary, the actual movement is ballistic, i.e. their trajectory cannot be amended after initialization. During the saccade, only blur can be perceived and no visual information is obtained. The recognition of saccades and fixations are primary requirements for eye ball movement analysis [12].

2. Methodology

2.1. Vision Based Tracking

Several steps were followed to experience wheelchair tracking and detection. Probably the most important was the mounting of goggles at patient's head. Fig. 2 shows goggles with IR sensor fitted. Furthermore, the following molds were made to abridge the tracking activity:

Wheelchair motion was restricted to locally flat ground plane.

Fig. 2. IR Sensor fitted on the right-side of goggle.

Direction sensing involves the basic principle of wavelength of color of eyes. Human eye has pigments for

two colors i.e., white and black. These colors possess different wavelengths in electromagnetic spectrum. White color has the lowest wavelength in the spectrum. Therefore the wavelength of white light is set as the standard parameter. White light can be measured by IR sensors. The infrared light ray measures and reflects the wavelength emitted by the white portion and based on it the eyeball sensor is fabricated. Fig. 3 shows the forward movement of the chair accompanied by movement of eyeball.

2.2. Shoulder Pressure Based Tracking

Shoulder tracking mechanism helps the patient to take left/right turn. Pressure is being exerted on the Pressure sensors (limit switches) leads to indicate the wheelchair the direction it has to in. Fig. 4 explains application of pressure sensor to move the chair in left and/or right direction.

Fig. 3. Eye ball sensor makes the wheel chair to move forward.

Fig. 4. Pressure sensor makes the wheel chair to move left/right.

2.3. Ultrasonic Sensor Based Tracking

The chair is equipped with ultrasonic sensors to facilitate the rider of the hindrances encountering the path of motion. Sensor operates as transceiver it sends signals continuously and makes a sound whenever it receives signals back upon striking any obstacle present in the path. The received signals function to stop the chair when perceived at a distance of 30 cm. For distances longer than this value the chair will continue to move till it is reached at the specified distance from the obstacle. This sound generation is more indication to the rider of the chair that an object restricting further movement is observed and thereby the wheelchair is stopped automatically. Fig. 5 shows the ultrasonic sensor used in the study.

Fig. 5. Ultrasonic sensor.

Fig. 6 & 7 show transmitter and receiver circuitry of ultrasonic sensor.

Fig. 6. Transmitter circuit of ultrasonic sensor.

Fig. 7. Receiver circuit of ultrasonic sensor.

2.4. Wheelchair Movement

Movement of the chair is integrated function of multiple inputs and single output i.e. motion of the chair to enable paralyzed patients independent in daily life movement. The proposed system receives one input from IR sensor signaling to start or stop the chair as desired. Secondly the pressure sensors/switches send signal for left and right directional movement. The chair does not operate until these inputs from the respective sources are fed into microcontroller. The controller upon reception of signals generates an output corresponding nature of the signals identified according to the program burnt. Closure of eyes lasting more than three seconds stops the wheelchair (Fig. 8).

Fig. 8. Wheelchair modeled in laboratory.

3. Program

This section presents complete source code for the prototype modelled wheelchair. First microcontroller is initialized with various bits.

```
#include <AT89X51.H>
sbit INPUT0=P1^0;
sbit INPUT1=P1^1;
sbit INPUT2=P1^2;
sbit OUTPUT0=P2^0;
sbit OUTPUT1=P2^1;
sbit OUTPUT2=P2^2;
sbit OUTPUT3=P2^3;
void main()
```

The following portion allows forward movement by the model with opened eyes.

```
{
while(1)
{
if ( INPUT0==0&&INPUT1==1&&INPUT2==1 )
{
OUTPUT0=0;
OUTPUT1=1;
OUTPUT2=0;
OUTPUT3=1;
}
}
```

The following portion describes the code when any obstacle encounters and/or eyeball is closed to stop the model.

```
if ( INPUT0==1&&INPUT1==1&&INPUT2==1 )
{
OUTPUT0=1;
OUTPUT1=1;
OUTPUT2=1;
OUTPUT3=1;
}
```

The next two if statements presents the condition of left right movement by the application of pressure sensors for either side.

```
if ( INPUT0==0&&INPUT1==0&&INPUT2==1 )
{
OUTPUT0=0;
OUTPUT1=1;
OUTPUT2=1;
OUTPUT3=1;
}

if ( INPUT0==0&&INPUT1==1&&INPUT2==0 )
{
OUTPUT0=1;
OUTPUT1=1;
OUTPUT2=0;
```



```
OUTPUT3=1;
```

```
}}}
```

4. Results and Discussion

The designed model was tested under different age groups to check effectiveness of the system targeting both normal and lower limb paralyzed patients. Fig. 9 shows a person with goggles.

4.1. Case I

Patients; other than paralyzed; of age groups between 15 to 50 years of age were exposed to IR sensor test. Test results clearly show strong and prompt response by young patients as compared to adults. A difference of 12 mV is observed in response to IR sensor among patients of age 20 and 45 years. Fig. 10 shows results of the test.

Fig. 9. A person with IR sensor mounted goggle.

Fig. 10. Eyeball response VS age of normal patients.

4.2. Case II

Secondly, vast range of age groups were tested to evaluate eye ball sensor behavior for lower limb

paralyzed patients. The obtained results are plotted in Fig. 11. Results once again revealed a prompt and strong response for age group below thirties. Above this age factor brings natural weakness and thereby response with some disorder was not healthy.

Fig. 11. Eyeball sensor response by various paralyzed patients.

The use of limit switches as Shoulder Pressure Sensor showed positive response to both group of patients though paralyzed patients responded at low level in comparison as shown in Fig 12. Anyhow limit switches remained helpful for left/right directional movement. Furthermore, the use of ultrasonic sensor to mitigate the problem of obstacles in the path of mobility of patients had proved its significance and had helped patients in safe journey all the way. Table 1 shows the small circuitry and components used in the development of this intelligent wheelchair.

5. Future Work

This study lays foundation for new experiments to determine role of human vision intelligence for further facilitation to mankind. Use of eye ball color wavelength can further ease the so developed interface and start/stop mechanism of related devices.

Fig. 12. Shoulder pressure sensor response for normal and hemiplegic patients.

6. Conclusion

This study involves design and development of an efficient, user friendly and economically assistive robotic wheelchair for spiked patients. The structure can reduce the dependence of handicapped persons upon others. It has proved most effective to those having eye-motor and shoulder coordination working mechanism. Eye and shoulder movements demand marginal effort and permit direct adaptive techniques.

Table 1. Small Circuitry

Power Supply	Transformer	Relays
Capacitor	Resistors	Diodes
Crystal Oscillator	1015 (PNP transistor)	BD139 (NPN transistor)
LM 358 OP AMP	Regulator 7805	HEF4093B NAND IC
8051 microcontroller		

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