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EYE TRACKING ELECTRONIC WHEELCHAIR FOR PHYSICALLY CHALLENGED PERSON

Chee F. P.[1], Duinong, M.[1], Chang H. W. J.[2], Awang A.[1], Francis A. S.[1] and Dayou J.[1]
[1]Energy, Vibration and Sound Research Group (e-VIBS), Faculty of Science and Natural Resources, Universiti Malaysia Sabah, Jalan UMS, Kota Kinabalu, Sabah, Malaysia
[2]Preparatory Center for Science and Technology, Universiti Malaysia Sabah, Jalan UMS, Kota Kinabalu, Sabah, Malaysia
E-Mail: fpchee06@ums.edu.my

ABSTRACT

A robotic wheelchair with novel ideas which integrates three different options to all kinds of impairment as well as disabilities was designed in this project. The first option allows users that are not capable of moving their limbs, to navigate the wheelchair using their eye, namely the optical detector. The optical detector allows user that suffers severe disability such as amyotrophic lateral sclerosis (ALS) that paralyzes the victim mobility entirely to move by moving their eye to desired location. The secondary option provides common wheelchair users who are suffering from less severe disability to navigate using a touch input option which is accessible via their smart phones, namely touch and go APP. The touch and go APP can be controlled easily as well as adjusting the speed of the wheelchair. The third option works for users with limited mobility by using a voice command application. In addition, the robotic wheelchair is integrated with multiple safety features, an ultrasonic sensor and dual bump sensor. The ultrasonic sensor is to create a threshold distance between the user and obstacle in front and to prevent collision. The bump sensor works as a failsafe, where an object that is in contact with it will reverse the robotic wheelchair to a safe distance. This research combines both ease of access navigational technology with a safety features to help those who are in need of such technology to move with a high safety element. The newly designed wheelchair does not discriminate any kinds of disabilities with the integration of the three navigational options.

Keywords: optical navigation, smart phone, obstacle detection, wheelchair.

1. INTRODUCTION

Wheelchair is a type of mechanism that has the basic form of a chair but with wheels. The vital role of a wheelchair is to help specific individuals who have impairments that restrict their ability to walk like a normal person. The wheelchair is designed in a way that it has a seat which is supported by two large wheels attached on the back and another additional set of two wheels known as the castors engineered in the front part of the wheelchairs.

In statistical terms, the estimation shows that at least 650 million which is equivalent to 10% people with disabilities in the world, 400 million presently live in the Asian and Pacific region and over 40% of them live in poverty [1]. There is no clear data on the number of people with disabilities in regards to those that require mobility devices namely wheelchairs [2]. The only data that surface was in 2003 where it estimated 20 million individuals require a wheelchair for mobility but did not have one. There also indications that show only a minority of those in need of wheelchairs has access to them, while majority do not have access to wheelchairs or appropriate wheelchairs [1].

In 1933, the first portable wheelchair was developed by Harry Jennings and his disabled friend Herbert Everst who were both mechanical engineers. Till to date, the concept wheelchairs still follow the original pattern design of the "X-BRACE". The present however, has improved the past wheelchair by mechanizing the wheelchair for better navigation control. The mechanized version of its predecessor is known as the powered chairs, an electric motor and navigational controls; usually a joystick is mounted on the armrest rather than manual power. The use of electrical powered wheelchair has become increasingly important as assistive technology and rehabilitation device has increased considerably.

Normally wheel chairs are controlled by a manual manpower, however this may not be suitable for certain disabled people. In this modern futuristic era, the Human Machine Interface (HMI) based techniques include joysticks controllers, finger movement, voice recognition, electro-monography are integrated in the wheelchair design. In term of the wheelchair usage, it is not limited to just one disability where an individual mobility can be solved with just a regular wheelchair. Studies show that there are four major disabilities that relate to the efficiency of wheelchair mobility [3]. The first is leg paralysis where an individual is unable to move due to muscle function loss. Leg paralysis is a common disability either an individual was born with it or external determining factors like an accident or any similar cases. In most cases, joystick controllers are designed in a way where an arm-rest mounted joystick with additional controls to allow the user to tailor sensitivity or access multiple control modes [4]. The controller may be swing-away to aid in side-transfers. For users who are unable to use a hand controller various alternatives are available such as sip-and-puff controllers, worked by blowing into a sensor [5].

In some cases, the controller may be mounted by an aide behind the chair rather than by the user. However, its fatal weakness would be those who suffers additional disability. Complication arises especially when an individual suffers not only on walking mobility, but the loss of the five basic senses. Foremost, it would be visual

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impairment, where a person loses completely or partially the ability to see. Though it does not affect the person's mobility in moving the wheelchair, but it is difficult to navigate due to the fact that they are unable to determine their own direction. In order for the handicapped with an additional loss of sight to move around they would need a navigator or a computer aided voiced positioning system [6].

Next would be individuals who suffer hearing lost, deaf. This particular group on the other hand has a difficulty in hearing. They tend to expose to incoming danger that requires sound perception. Though hearing aid is a solution but not for the most severe cases where a person loses sound perception completely. One solution that is commonly used for hearing-impaired individual is a wheelchair equipped with Global Positioning System (GPS) [7] that has sensors that detects sirens, an abnormally long honk.

For certain handicap people that are incapable of operating a joystick wheelchair or sound recognition system, the use of an eye tracking wheelchair operator better known as the eye gaze retina tracking is crucially essential. The movement of the eye is one of the simplest mechanisms that is capable of maneuvering even the most complicated sets of mechanical movement. A commercially available web camera on a head-mounted display (HMD) wears is used to capture moving pictures if the user's face [8]. A computer mounted on the electric chair processes the captured image data. From the image, the system detects and tracks the movements of the user's eye estimating the line-of-sight vector and actuating the electric wheelchair in the desired direction indicated by the user's eye.

Though an eye tracking wheelchair proves to be useful for most individuals, it still presents a weakness [9]. The first and most vital thing in retinal tracking is the accuracy in determining the eye position. Problem arises when the eye tracking sensor has a very low sensitivity where it is only compatible to a certain group of eye sets.

Furthermore, an autonomous reaction must also be considered, because most people tend to move their eyes simultaneously, making it difficult to see the surroundings when moving. And finally the eye strain, moving the eye too much causes extra stress to the eye thus progression has been implemented to enhance the sensitivity of retinal tracking to reduce eye strain. In this study, a robotic wheelchair that integrates multiple options and sensor is developed for better navigation control of the wheelchair itself in consideration for individuals with multiple disabilities.

2. RESEARCH APPROACH

The focus of this research is to target users with mobility difficulties. The navigational optionis an application based software where individuals can access and the retinal tracking hardware utilizes a normal webcam camera that is accessible in almost every computer store. The robotic prototype does not target specific age groups but targets users with mobility problem.

2.1 Algorithm of the optical navigation

The optical navigation development was created using a sub program that is within the LabVIEW known as the IMAQ Vision. The IMAQ create VI was placed under the variable name as "Eye Image" outside of the while loop acting as a memory storage for image input received from the webcam. The image memory of type RGB(U32) would be stored and it allows only coloured images to be displayed at the later loop. This was then followed by creating the vision acquisition panel to store the type of image. The high resolution webcam was used as image acquisition tool in this section. The vision acquisition panel was conditioned to use the webcam provided, and selected as a continuous acquisition, where the image from the webcam will be acquired every second.

The output image from the vision acquisition that was acquired through the use of the webcam will then be transferred to the IMAQ SetColorPixleLine2 VI which changes the colour image acquired to be converted into a line of pixels, then the convertion of an array clusters coding of image (RGB U32) into an array of pixels will be performed by a set of control Line Coordinate to specify and readjust the coordinate line of the x-axis and y-axis to allow the program to lock on the target of the image acquired from the webcam. The IMAQ graphical algorithm is as shown in Figure-1.

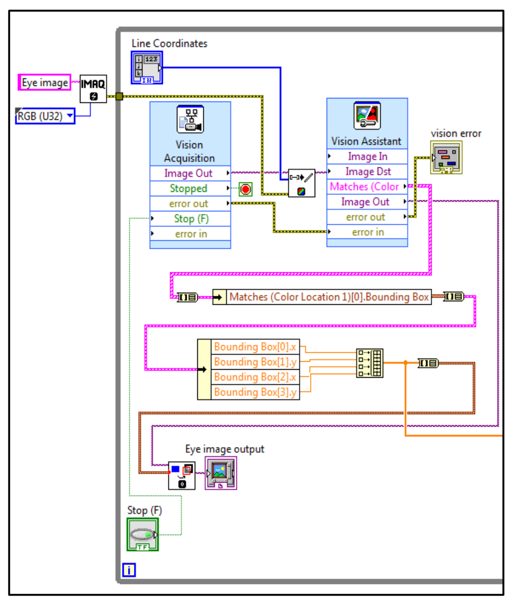

Figure-1. IMAQ Graphical algorithms that show all the Virtual Instrumentation (VIs) to read the image output from the webcam.

2.2 Vision acquisition and retinal lock

The acquired retinal image from the webcam will be calibrated via the vision assistant panel. User's will then be prompted to lock on a specified target area (red box) of the eye followed by a bounding box (green box) creating a threshold of the retinal movement. The acquired vision is as shown in Figure-2.

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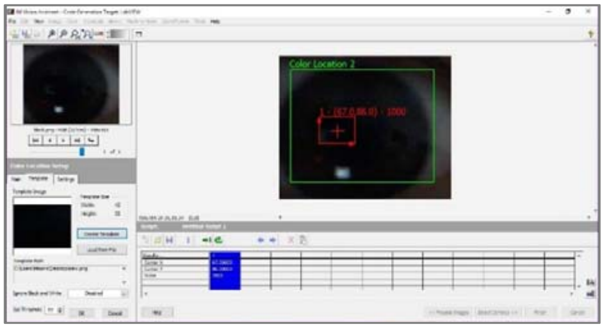

Figure-2. Vision assistant panel that shows the acquired image from the webcam.

2.3 Development of wheel chair motion

The development of the wheelchair motion programming was achieved by the use of a sub program called MINDSTORMS Robotics that is within the LabVIEW. This part of algorithm was to process the output instruction received from the optical navigation. In addition, three sensors which act as a safety mechanism and a failsafe sensor were integrated in the prototype wheelchair design and therefore their algorithm were also implemented at this subprogram. A switch case statement was developed to enable the movement of the wheelchair to left, right, forward, backward, or stop. The switch statements were divided into five types of cases statements from 0 to 4 as shown in Figure-3. Their navigation direction following the case statement is as shown in Table-1.

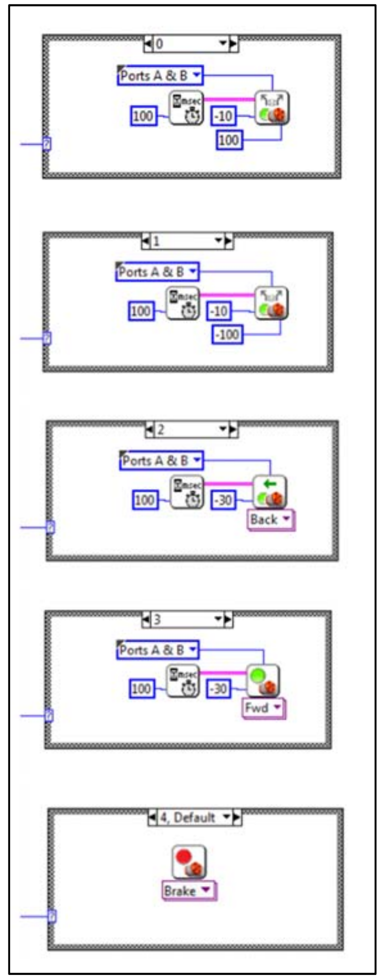

Figure-3. The switch case statement algorithm connected to the Math Script that controls the wheelchair motion.

Table-1. Motion of the prototype wheelchair as set by the switch case developed using MINDSTORMS Robotics blocks.

Input case	Motion
0	Steering left
1	Steering right
2	Backwards
3	Forward
4	Stop

2.4 Optical navigation geometry

The optical detection software was developed to estimate the direction of gaze in real-time from the image recorded using a webcam of 5x5 matrix scale. Figure-4 shows the 5x5 geometry referencing matrix. The detection of the eye gaze of an individual is dependent on the sensitivity of the webcam to capture the motion of the eye. The tracking of the eyes movement is dependent on the software.

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Figure-4. The switch case statement algorithm connected to the Math Script that controls the wheelchair motion.

The eye detection system was developed using a LabVIEW since it has the best compatibility with the Lego EV3 core. The LabVIEW system was used to program the EV3 robotic platform. The developed software provides connectivity with the webcam, devices, sensors and also on the wheelchair.

2.5 Secondary option

The development of the secondary navigation, Touch and Go mobile application, was developed using android studio. The mobile application developed provides a remote option via android smartphone to navigate. The connection was established via Bluetooth into the Lego Bricks. The touch and Go mobile application moves the wheelchair relying on the input of the user interface provided with a power option navigation allowing user to control the movement speed.

In addition, the application was also implemented a reverse option, where users who are keen to gaming may prefer an inverted/reverse navigation (Frost., 2006) where each direction is opposite of the specified purpose. The use of the Touch and Go mobile application is easily accessible via Android smartphones with an operating system above 4.4. The graphical user interface (GUI) of the mobile application is as shown in Figure-5.

Figure-5. GUI for navigating the motorized wheelchair.

2.6 Tertiary option

The third option enables user to navigate the wheelchair using audio command via the voice recognition APP. The application is to help individuals with limited limb mobility thus allowing them to move without the need of a 3rd party to help them. The audio command was set up to 5 different navigational command namely, go (front), left, right, back and stop. The idea is that users will be equipped with a mouthpiece microphone to prevent audio interference from the surroundings. The application platform was based on Lego Commander (Lego, 2013) application as shown in Figure-6.

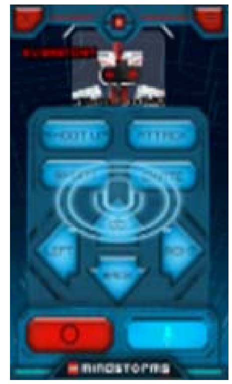

Figure-6. Virtual platform for voice command.

3. IMPLEMENTATION OF SAFETY FEATURES

The robotic wheelchair was integrated with multiple safety features, an ultrasonic sensor and dual bump sensor. The ultrasonic sensor was to create a threshold distance between the user and obstacle in front and to prevent collision. The bump sensor works as a failsafe, where an object that is in contact with it will reverse the robotic wheelchair to a safe distance. This research combined both ease of access navigational technology with a safety features to help those who are in need of such technology to move with a high safety element.

The ultrasonic sensor was attached at the top of the wheelchair. The use of the device was to set a threshold between the user and an obstacle. The ultrasonic sensor can detect an object up to a distance of 200 cm where the detection can also be calibrated accordingly up to a minimum of 2 cm. The algorithm of this sensor was linked to the motor where if an object is within the range of detection, the movement will halt.

The ultrasonic obstacle detection was developed by using the Sonar VI panel. The Sonar VI panel was compared with the controllable numeric VI known as the “distance reference” where the Boolean operator used was “Less Than” comparison function. If the distance reference was set to a range of distance where the obstacles distance is fulfilled, the output is true thus reversing the algorithm to avoid the obstacle. The wheelchair will continue reversing until the range distance between the robotic wheelchairs is greater than the distance set via the distance reference panel. However, if the output was false, then the false case statement’s algorithm will continue to run. This algorithm is as shown in Figure-7.

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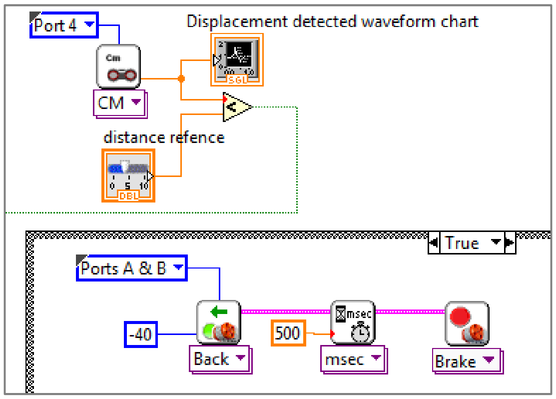

Figure-7. The sub program ultrasonic obstacle detection algorithm.

3.1 Dual bump sensor

The robotic wheelchair was equipped with dual sensors located in the front and the back of the wheelchair. The bump sensors acts as a bump detection, where if users were to collide with an object, the algorithm is set to an autonomous response to reverse or go forward clearing the user to a safe position. The bump sensor detection was developed by using the Lego VI panel. The Lego VI panel was where the Logic gate "OR" gate is used in linking the motor where the wheelchair will stop if either one of the sensor is triggered. This algorithm is as shown in Figure-8.

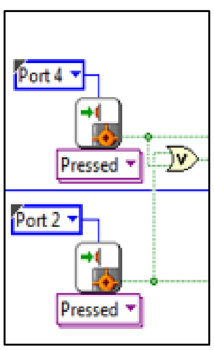

Figure-8. The bump detection algorithm.

The core of the Eyeball Control Wheelchair's algorithm was developed using the LabVIEW's Virtual Instruments (VIs) of graphical programming. Figure-9 shows the combination of the three parts of algorithms which was used to control the wheelchair by the user using eye motion as well as the safety features implementation. These algorithms included interface algorithm, eyeball tracking algorithm and the wheelchair motors algorithm. The algorithm was placed in a while loop and will continuously run until the "STOP" button is triggered. The full algorithm is as shown in Figure-9.

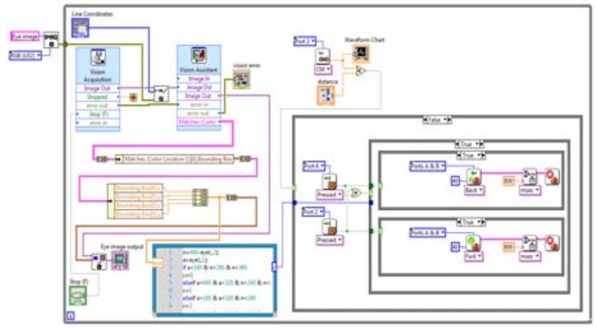

Figure-9. The completed algorithm of the optical navigation developed via LabVIEW interface.

4. ACCURACY AND PRECISION OF THE MATRIX

A total of 20 samples were carried out on an individual to test the accuracy and precision of the sensitivity of the webcam in detecting the user's eyes movement. Figure-10 presents the samples dots that fall in the 5 regions of eyeball mapping geometry.

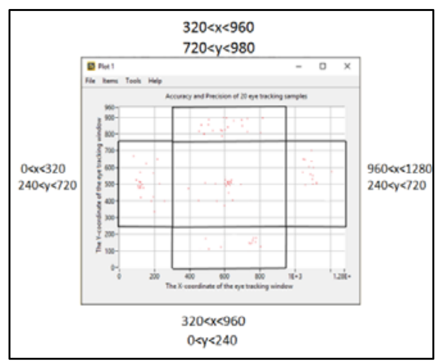

Figure-10. The 5 regions that determine the navigation of the optical robotic wheelchair.

The 20 samples that were carried out shows the optical detection navigation operates with a high accuracy of 93% and a precision of 43%. Table-1 shows the data tabulation of the percentage of accuracy and precision of the eye tracking at 5 different ranges.

Table-2. Date tabulation of the percentage of accuracy and precision of the eye tracking at 5 different ranges.

Regions	Left	Right	Centre	Upper	Lower	Average
Accuracy	95%	90%	100%	85%	95%	93%
Precision	50%	45%	25%	55%	40%	43%

5. CONCLUSIONS

The core of the project which is the hardware and software development of the Advanced Optical Robotic Wheelchair is achieved. The aim of this research is to enhance the previous optical tracking by increasing the matrix scale as well as implementing a secondary touch-and-go navigation for optimal usage of regular handicaps. The matrix expansion enables a greater accuracy which makes the optical control a smoother navigation.

The secondary option replaces the idea of joystick control wheelchair to a much more convenient and accessible platform. The fully integrated Advanced Optical Robotic Wheelchair allows all kinds of users with different disabilities to navigate with multiple options according to their preference.

The future research for theEye tracking Electronic Wheelchair for Physically Challenged Person is to integrate the novel ideas onto a real powered wheelchair. The implementation gives an opportunity to experience the full features of a useable motorized wheelchair that is easily accessible.

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