Eye-Controlled Wheelchair using Infrared Detection

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***Abstract* - A design of a microcontroller-based wheelchair controlled by the motion of the eye is presented. The user wears a set of electronic eyeglasses used to detect the movement of the sclera and then transmits control signals to the wheelchair via Bluetooth. Detection of sclera movement is done via infrared sensors. The wheelchair is equipped with an obstacle detection system utilizing ultrasonic sensors. To operate the wheelchair, the user presses a button to move forward, and moves his eyes to turn the chair in a specific direction. The sensors can detect four directions of eye movement: half left, full left, half right and full right. Tests for response to eye movement, delay in the transmission of control signals, reliability of transmission and reliability of the ultrasonic sensors in terms of obstacle detection shows that the design met the objectives to ensure proper and safe operation of the wheelchair.**

Keywords – wearable, infrared, MCU, obstacle, wheelchair

I. INTRODUCTION

The ability to move at will is an important thing for a person. However, not all people are capable of making such motion especially those who have physical disability or person who is paralyzed. In study, "there are nearly 1 in 50 people living with paralysis -- approximately 6 million people". This is the same number of people as the combined populations of Los Angeles, Philadelphia, and Washington, D.C. and that number is nearly 33% higher than previous estimates. It means that we may all know someone -- a brother, sister, friend, neighbor, or colleague -- living with paralysis [1]. Paralysis is the loss of muscle function in either one or more muscle groups which is accompanied by the loss of sensory feelings and the inability to control the affected muscle areas [2]. The inability to move the lower half of the body referred to as the paraplegic paralysis and the serious one being quadriplegia, which disables the person to move both arms and legs. Rehabilitation treatment is the main key to fully recover; however, others have no choice but to totally depend on supporting equipment. Automated or electronic wheelchairs are invented to give the paralytic some mobility to move independently but, not all paralytic persons are able to control them even with the use of a joystick. According to statistics, "clinicians indicated that 9 to 10 percent of patients who receive wheelchair training find it extremely difficult or impossible to use the wheelchair for activities of daily living" [3]. Other researchers proposed electronic wheelchair for paralytic persons that can be easily maneuvered using different techniques. Some electronic wheelchairs were bio-signal-based which use electrooculography (EOG), electroencephalography (EEG), and electromyography (EMG), others are voice-based that use voice commands and there are vision-based that employs a camera to acquire images and analyze the user's intent via image processing. In this research study, the proponents proposed an MCU based eye-controlled wheelchair with obstacle detection.

The eye movement recognition for wheelchair motion control using infrared light is operated by looking or gazing to the direction of desired movement or location. The eye tracking device is in a set of wearable eyeglasses that emits infrared light to the eyeball and sclera of the eye that both serves as an obstruction. The sclera reflects the infrared light and sends the information via Bluetooth while the eyeball absorbs the infrared light. The amount of light reflected from those surfaces changes because of differences in their reflectance and because the eyelids are closer to the transducers. "The additional infrared exposure because of the glasses does not pose a health risk, being less than 2% of the safe limit according to the relevant standard, AS/NZS 2211.1:2004" [4]. The challenging aspect will lie on how accurate tracking of the eye movement is and the reliable transmission of information through Bluetooth. The response of the wheel chair to input eye movement, the speed of the response, the reliability of the obstacle detection system and the reliability and delay in the transmission of the control signals via Bluetooth was tested.

A. Objectives

The study aimed at coming up with a design of a wheelchair that can be independently used by paralysis patients to provide mobility. Part of the design is a wearable controller that detects eye movement as control signals and transmits these control signals as commands to the wheelchair. The output angle of the wheelchair is aimed to be 95% accurate. For fast response, the transmission delay of the control signal is aimed to be limited to 1.5 seconds, while the Bluetooth transmitter is expected to work reliably at least 95% of the time.

The wheelchair was equipped with an obstacle detection system utilizing ultrasonic sensors. It is aimed that the detection system must be 95% reliable when detecting obstacles within 1.3 meters from the front of the wheelchair.

B. *Scope and Delimitation*

The wheelchair was designed to move forward only and turn into four directions: half left, full left, half right and full right. The wheelchair can only be used in flat and smooth surfaces and indoors. For this study, the wearable controller was designed for a specific person, but can be calibrated when used by another. The wheelchair was designed for paraplegic persons without eye disabilities such as strabismus.

C. *Conceptual Framework*

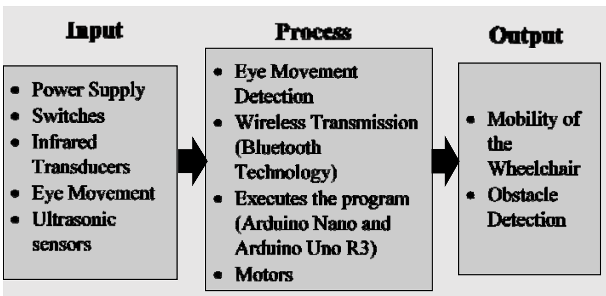

Figure 1. Block diagram showing the relationships of inputs, processes and outputs to the system

Figure 1 shows the interconnection of subsystems making up the wheelchair. The whole system can be divided into two: the system that processes the input to the wheelchair – the wearable controller – and the wheelchair itself having an obstacle detection system. The switch that initiates the forward motion of the wheelchair, and the infrared sensors that detect eye movement are inputs to the Arduino microcontrollers. The microcontroller in the wearable controller – the Arduino Nano – sends the interpreted eye movement as signals via the Bluetooth module connected to it; this determines the direction of the motion of the wheelchair. The microcontroller on the wheelchair – the Arduino Uno R3 – on the other hand, processes the input from the switch to initiate forward motion, and the received control signal from the wearable controller, which processes and translates this signal to voltages applied to the motors. There are two motors connected to the left wheel and right wheel of the wheelchair. Both motors are switched on when the wheelchair is moving forward, while turning off one of the motors turns the wheelchair in a certain direction. This is how the wheelchair achieves its mobility.

Another system that is connected to the wheelchair os the obstacle detection. The ultrasonic sensors detect objects at front and near the wheelchair. When an obstacle is detected, the signals are sent to the microcontroller, which stops both motors of the wheelchair.

A power supply is needed to run the motor, as well as the electronic circuits in the wheelchair, and in the wearable controller.

II. METHODOLOGY

The study followed three processes in coming up with the design of the system: deficiency identification, comparison to existing products or system and solution implementation. The flow diagram is shown in figure 2.

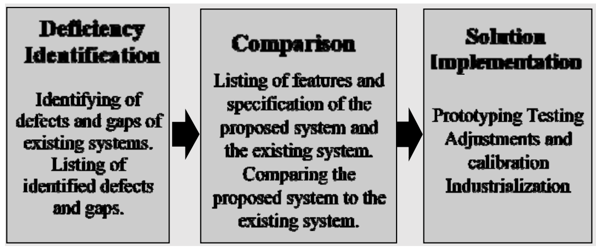

Figure 2. Methodology employed in this study

Deficiencies and gaps in the existing system were identified. These gaps were addressed by listing possible features of the proposed new system and finding solutions on how these possible features can be implemented. Everything is integrated in a prototype, which undergoes iterative adjustments and calibration to produce a final system that addresses the gaps between the existing and the proposed systems.

D. *Solution Implementation*

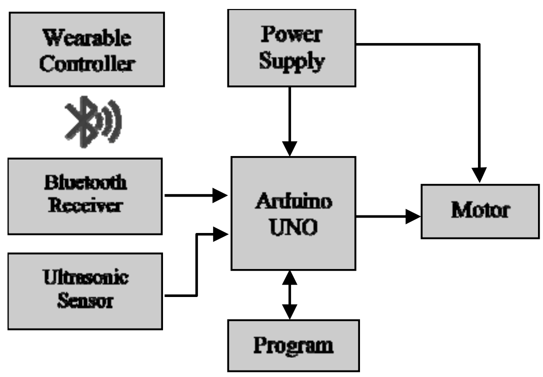

Figure 3. System interconnection

The power supply supplies the necessary power to drive the motor and the microcontroller. Upon activation via a

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toggle switch, pressing a push button switch beside it activates the motors to do a forward motion. The motors are then controlled by a microcontroller programmed to send appropriate motor switching action. Both motors stop when the ultrasonic sensors detect an obstacle. A full left turn or a full right turn is achieved by turning off the left or the right motor, respectively for a certain amount of time *t*. A half left turn or a half right turn is achieved by turning off the left or the right motor, respectively for half of the time *t*, or *t/2*. A full turn or a half turn can be executed by signals received from the wearable controller, which interprets the angle of eye movement.

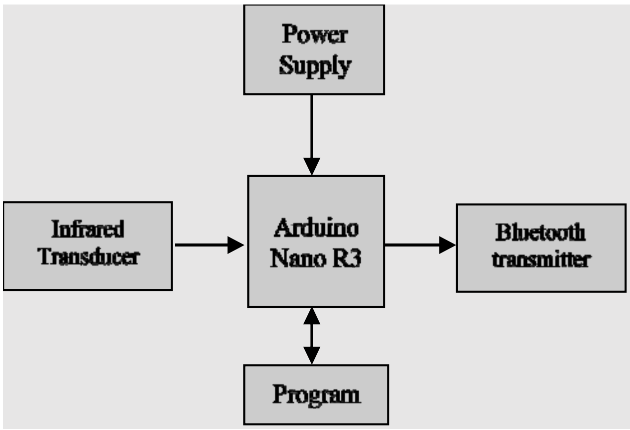

Figure 4. System interconnection for the wearable controller

The infrared transducer scans the eyes of the user for movement. It works by transmitting safe levels of infrared light to the eyes and detecting reflected levels when the infrared light hits the sclera. An analog-to-digital converter converts the reading of the reflected infrared light and sends this to the microcontroller for processing. The program calculates the angular movement of the sclera and translates this as an input to the main system, via the Bluetooth transmitter/receiver, to which the motors respond accordingly.

E. Design of Experiment

The reliability, and the time delay of the Bluetooth transmission, and the detection of obstacles within 1.3 meters from the wheelchair was to be tested, as well as the accuracy of the angular response of the wheelchair.

The reliability of the Bluetooth transmission was determined by observing if the wheelchair responds to eye movement input. The time delay between the eye movement and the response of the wheelchair was also measured and averaged.

The detection of obstacle is determined by placing an obstacle in front of the wheelchair and observing if the wheelchair stops upon the detection of obstacle. The distance between the obstacle and the point at which the wheelchair stops was noted.

The accuracy of the angular response is determined by measuring the actual angle of turn given that the user moves his eye partially or full to the left or right. A partial eye movement means an input command of 45 degrees, while a full eye movement means an input command of 90 degrees. A 19.5-inch protractor is used to measure the actual angle of turn of the wheelchair.

F. Determination of the Number of Trials for Testing

To determine the number of trials to be done, the fundamental formula of gambling is used

$$1 - DC = (1 - P)^N . \quad (1)$$

where *DC* is the reliability value, *P* is the probability of error and *N* is the total number of trials. Setting *DC* = 98% and *P* = 2% and solving for *N*, the number of trials required for the experiment is 194.

G. Percent error and Accuracy

The percent errors in the output angular response of the wheelchair is obtained by comparing the desired angular response (*DR*) to the actual angular response (*AR*). The percent error *E* is then computed as

$$E = \left|\frac{DR - AR}{DR}\right| \times 100 \quad (2)$$

The desired angular response is determined based on the user input. The user moves his eyes according to his desired angular turn (half or full, left or right). A half turn means a desired angular response of 45 degrees, while a full turn means a desired angular response of 90 degrees.

Accuracy measures how close the actual angular response to the desired angular response is. In this study, it was computed based on the average percent error in all of the trials conducted, using the formula

$$A = (1 - APE) \times 100 \quad (3)$$

where *A* is accuracy level in percent terms and *APE* is the average percent error.

H. Reliability of Components

The reliability of components was measured using the formula

$$R = \left(1 - \frac{N_e}{N}\right) \times 100 \quad (4)$$

where N_e is the number of errors, *N* is the number of trials and *R* is the reliability in percent terms.

III. Results and Discussion

I. The Prototype

The prototype wheelchair is composed of Arduino uno, multi hop Bluetooth module, electrical relays, power supply,

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ultrasonic sensor, switches, DC wiper motors and customized wheels.

The prototype wearable controller is composed of infrared transducers, Arduino Nano R3, multihop Bluetooth module and power supply.

Figures 5 and 6 show the prototypes.

J. Reliability and Delay of Signal Transmission.

Experiments showed that in 194 trials conducted, the Bluetooth transmission failed only seven (7) times, resulting in reliability of 96.4%. This meant that in these seven times, the user tried to move his eyes but the wheelchair kept on running, indicating that the wheelchair is not responding to the user input, thus, an indication of failure of connection between the controller and the wheelchair.

Figure 5. Image of the wheelchair prototype.

Figure 6. Image of the wearable controller prototype.

In the seven times that the transmission failed, it was observed that it was due either to low voltage output from the power bank or some loose connections, which cannot really be attributed entirely to failure of transmission of the Bluetooth module.

The time delay between the user input via his eye movement and the response of the wheelchair was also measured. The average time delay was computed to be 1.27 seconds. It was noted in this experiment, the delay corresponded to the time between the user input and the response of the wheelchair until it comes to a complete stop. Because of momentum of the wheelchair when stopping, the signal was actually received earlier than when it completely stopped. Thus, the weight of the wheelchair, as well as that of the user also played a role in this delay.

Results for the experiment that measured the reliability of the control signal transmission and the time delay showed that the objectives set for these parameters were met by the prototype. These parameters are important in ensuring that the system will respond reliably to input at the shortest time possible. These are important to ensure the user friendliness and safety of the user while using the wheelchair.

K. Reliability of the Ultrasonic Sensors in Obstacle Detection

In the design of the obstacle detection system for the wheelchair, an ultrasonic sensor whose detection range was specified to be 30 to 130 cm was used. This was chosen so that the wheelchair maintains a safe distance from the obstacle, and also to give enough clearance for the user to maneuver the wheelchair once it stops after detecting the obstacle.

In all 194 trials, the sensors were successful in detecting obstacles with the wheelchair stopping 1.20 meters from the detected obstacle on the average. This resulted into 100% reliability for the obstacle detection system, working within the objective clearance of 1.5 meters from the obstacle.

It was noted that even though the sensors are good to detect obstacle as far as 1.3 meters as specified, the average stopping distance was less than the specification mainly because of the momentum of the wheelchair while moving. Thus, it is really important that enough distance must be cleared by the wheelchair for the safety of the user.

L. Accuracy of the Angular Response of the Wheelchair to Eye Movement Input

The experiment on the angular response of the wheelchair to the eye movement input showed that the average percent error for each turn is 0.99% for full left turn, 2.47% for the half left turn, 1.11% for full right turn, and 2.59% for the half right turn.

This translated to 99.1% accuracy for full left turn, 97.5% for half left turn, 98.9% for the full right turn, and 97.4% for the half right turn. The average accuracy was computed to be 98.2%.

The designed wheelchair achieved the accuracy objective of 95%. In the experiment, it was observed that the system had to be calibrated based on the weight of the user. A heavy user requires more time for the microcontroller of the wheelchair to process because the motor tends to move slower than when a user is less heavy.

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IV. Conclusions and Recommendations

Using the concept of infrared light reflection via the sclera of the eye, an eye-controlled wheelchair was designed. This goes to show that eye movement can be detected via infrared and can be used to control a device. Wireless transmission of control signal from a wearable controller to the wheelchair was made possible by Bluetooth module. The installation of the obstacle detection system is very relevant in ensuring the safe use of the system. Tests showed that the prototype was accurate in detecting eye movement and translating this to angular turn of the wheelchair, was reliable in transmitting control signals via Bluetooth with minimal delay, and reliably detects obstacles within a safe distance. Many of the parameters of the output response of this wheelchair was observed to be dependent on the weight of the user; hence, it is an important factor that must be considered in the design of the wheelchair.

The turns that can be made by the wheelchair that was designed was limited to the extent of eye movement that can be detected by the infrared transducers. Greater mobility can be achieved further if the transducer be made more sensitive. A way to switch the wheelchair forward and backward other than a push button may be explored in the future.

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Reference

[1] Christopher & Dana Reeve Foundation, One Degree of Sepation: Paralysis and Spinal Cord Injury in the United State, New Jersey, 2009.

[2] "Spinal cord Injury," 2014. [Online]. Available: http://www.apparelyzed.com/quadriplegia-quadriplegic.htmlhttp://www.apparelyzed.com/quadriplegia-quadriplegic.html. [Accessed 29 September 2015].

[3] S. Pai, S. Ayare and R. Kapadia, "Eye Controlled Wheelchair," Internatinal Journal of Scientific & Engineeing Research, vol. 3, no. 10, pp. 1-5, 2012.

[4] M. W. Johns, A. Tucker, R. Chapman, K. Crowley and N. Michael, "Monitoring eye and eyelid movements by infrared reflectance oculography to measure drowsiness in drivers," Samnologie, vol. DOI: 10.1007, no. s11818-007-0311-y, pp. 234-242, 2007.

[5] S. Gunda, K. C. Karthikeyen, S. Shyam and D. Venkataraman, "Eye Movement Based Electronic Wheel Chair For Physically Challenged Persons," International Journal of Scientific & Technology Research, vol. 3, no. 2, 2014.

[6] S. Pai, S. Ayare and R. Kapadia, "Eye Controlled Wheelchair," International Journal of Scientific & Engineering Research, 2012.

[7] R. Barea, L. Boquete, M. Mazo, E. Lopez and L. M. Bergasa, "EOG Guidance of a Wheelchair using Neural Networks".

[8] C. S. Tsui, P. Jia, J. Q. Gan, H. Hu and K. Yuan, "EMG-based Hands-Free Wheelchair COntrol with EOG attention Shift Detection," Sanya, China, 2007.

[9] D. Hareesh, R. Raja Kishore and K. Satyavathi, "Sensor Based Automated Wheelchair," International Journal of Research in Computer and Communication Technology, vol. 2, no. 9, 2013.

[10] K. Arai and R. Mardiyanto, "Eyes Based Electric Wheel Chair Control System," International Journal of Advanced Computer Science and Applications, vol. 2, no. 12, 2011.

[11] D. Purwanto, R. Mardiyanto and K. Arai, "Electric Wheelchair Control with Gaze Direction and Eye Blinking," Artificial Life and Robotics, 2009.

[12] "Teaching Eye Movement," [Online]. Available: http://www.liv.ac.uk/~pcknox/teaching/Eymovs/emeth.htm. [Accessed 27 September 2015].

[13] B. L. B. De Leon, A. J. T. Laigo, R. V. L. Ligan and H. N. A. Lim Hong, Quasi Autonomous Fuzzy Logic Controlled Wheelchair for Quadriplegic Persons, Undergraduate Thesis, Department of Electronics and Communication, College of Engineering: De La Salle University, Manila, 2004.

[14] C. M. P. Adriano, P. J. P. Costales, A. M. A. Espinos, P. F. Galgo and C. L. Go, A Pc Based Eye position tracker guided high quadriplegic wheelchair using image processing with obstacle detection system, Undergraduate Thesis, Department of Electronics and Communication, College of Engineering: De La Salle University, Manila, 2002.

[15] L. E. s. Arellano, D. J. E. Arias, F. M. A. G. Luna, A. C. Santillan and J. C. Teme, Speech Controlled DC-Motor Operated Wheelchair with Elevation System, Undergraduate Thesis Mapua Institute of Technology, 2011.

[16] Navy Electricity and Electronics Training series, 1998.

[17] S. Uluagac, "ECE gatech," 2013. [Online]. Available: (http://www.ece.gatech.edu/academic/courses/ece1882/docs/ece1882-Bluetooth-Fall2006.pdf).

[18] R. Mary, "Engineers Garage," 2011. [Online]. Available: http://www.engineersgarage.com/articles/bluetooth-technology. [Accessed 4 September 2015].

[19] P. Marian, "Electro Schematics," 2010. [Online]. Available: http://www.electroschematics.com/3552/ultrasonic-sensor-circuit/. [Accessed 23 September 2015].

[20] "Elprocus," 2010. [Online]. Available: http://www.elprocus.com/motion-detector-circuit-with-working-description-and-its-applications/. [Accessed 25 September 2015].

[21] "Electronics Hub," 2 February 2015. [Online]. Available: http://www.electronicshub.org/ir-sensor/. [Accessed 25 September 2015].

[22] Torino, "Arduino," 2015. [Online]. Available: https://www.arduino.cc/en/Main/arduinoBoardUno#techspecs. [Accessed 19 September 2015].

[23] "Future Electronics," [Online]. Available: (https://www.futureelectronics.com/en/Microcontrollers/microcontrollers.aspx). . [Accessed 4 September 2015].

[24] "Future Electronics," 2013. [Online]. Available: http://www.futureelectronics.com/en/switches/toggle-switches.aspx. [Accessed 19 September 2015].

[25] "Renold," [Online]. Available: (http://www.renold.com/UploadedFiles/Brochure_Sprockets.pdf). [Accessed 4 October 2015].

[26] "Galco," [Online]. Available: http://www.galco.com/comp/prod/relay.htm. [Accessed 23 October 2015].

[27] "Future Electronics," 2013. [Online]. Available: http://www.futureelectronics.com/en/switches/push-button-switches.aspx. [Accessed 19 September 2015].

[28] "The Illustrated Dictionary of Electronics," 2001.

[29] S. Gibilisco, Teach Yourself electricity and electronics, New York City: The McGrawhill Inc, 2001.

[30] H. R. Chennamma and X. Yuan, "A Survey on Eye-Tracking Techniques," Indian journal of Computer Science and Engineering, vol. 4, no. 5, pp. 388-393, 2013.

[31] T. Rajavenkatesan, S. Nagalakshimi, K. P. Ram Presath and S. Venkataraman, "Automatic wheelchair using eyeball sensor," International Journal of Advance Technology in Engineering and Science, vol. 3, no. 1, 2015.

[32] A. Thakkar and D. Shad, "Eye Monitored Wheelchair control for people suffering from Quadriplegic," School of Electrical and Computer Engineering, Cornell University, 2014.

[33] R. Venkatesh and R. Karthick, "Automatic Wheel Chair Control Using Eyeball Movement for Physically Challenge People," Interrnational Journal of Scientific Reseaarch, vol. 3, no. 3, 2014.

[34] N. Pearson, "Tutor Vista," 2015. [Online]. Available: http://physics.tutorvista.com/waves/wavelength-of-light.html.