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Electric-Powered Wheelchair Control Using Eye Tracking Techniques

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ABSTRACT: This paper presents a system to control an electric-powered wheelchair using the movement of the eye, through an infrared eye tracker sensor. Eye tracking techniques consists in recording the eye movements from a stimulus, and then determining where the individual is gazing at through interpolation of points. Thus, people who have some kind of severe motor disability would be able to control a wheelchair with the help of this technique, acquiring some autonomy in locomotion. According to the results obtained, this technique was a promising alternative to be considered.

KEYWORDS: Assistive technology; electric-powered wheelchair; eye tracking

I. INTRODUCTION

According to census data provided by Brazilian's IBGE in 2010, which shows the statistics of the population with disabilities every 10 years, currently there are approximately 45,606,048 people with disabilities in Brazil. Of these 45 million, 2.33% (about one million) are people who have cases of severe motor disability [1]. Data provided by the World Health Organization in 2011 showed that more than 1 billion people have some kind of disability. This represents approximately 15% of the world population [2].

Included in this number there are many cases of individuals who do not possess control over their lower and upper limbs, them being the targets of this research. Those individuals need affordable and efficient strategies to help in their daily activities. These needs became the objectives that have guided the development of new Assistive Technologies (AT) [3].

This work presents the control of an electric-powered wheelchair (EPW) through the eye movement as an alternative to use conventional wheelchairs, which are controlled by joystick.

II. RELATED WORK

Several solutions have been developed as attempts to provide greater autonomy for people with severe motor disabilities. In [4] the authors present difficulties encountered by people with motor neuron disease (MND), especially regarding the communication, and propose an augmented and alternative communication system (AAC) based on principles of eye tracking using a webcam, focusing mainly on the possibility of low cost and accessibility. In [5] the control of an assistive technology device is made using a simplified technique of EOG (electroculography) to determine the direction of gaze in a range of ± 40°, both vertically and horizontally. By relying on electrodes for electrical signal collection and processing, this alternative requires a bit more preparation before using the system, such as positioning of the electrodes and a calibration process before each session. In [6] the authors present a proposal for a low cost device for eye tracking compatible with tablets, through webcam image processing. Unlike the previous works, this design takes into account the position of the head in their algorithm, allowing small movements of the head without immediate need for another calibration of the system in question. Although patients with motor neuron diseases have lost most of their voluntary movements, the degree of variability of stages of those diseases suggests that some of them still retain movement of the head and neck, so that an algorithm that adjusts itself to the movement of the head is an important part of the system. In [7] the authors question the difficulty that individuals with severe physical disabilities have in controlling an EPW, even with many of the alternative control systems currently developed. The eye tracking

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technique is used as an alternative for these individuals, using image processing and model analysis of the eyeball (for object tracking) to estimate the direction of gaze. The device responsible for making the collection of images is attached to the user's head, with a camera positioned in front of the right eye, and the video signals are sent to the LabView interface for processing.

III. PRESENTATION OF THE MAIN CONTRIBUTION OF THE PAPER

The technique of tracking the eyeball position consists in calculating the point of interest of the user's gaze, how or what the user is looking at [8].

To create the eye tracking module was used a sensor for tracking the eyeball (eye tracker) from The Eye Tribe® and a microcomputer. The position on the screen that the user is looking at is calculated through a reflection in the pupil caused by an infrared that is emitted by the sensor in the user's eye direction. The reflection of this infrared is captured by the sensor which then uses proprietary algorithms to interpolate the direction of the user's gaze. The position is determined relative to a screen in which the person is looking and is represented by a pair of coordinates (x, y).

The dimensions of the sensor are 20 x 1.9 x 1.9 cm, it communicates with the computer via the USB 3.0 protocol, provides accuracy of 0.5 ° - 1, works in ideal conditions in around 45-75 cm of distance and a calibration should be performed before each use, where the user must stand in front of a screen with the sensor directed to his eyes, as shown in the representation of the Fig. 1.

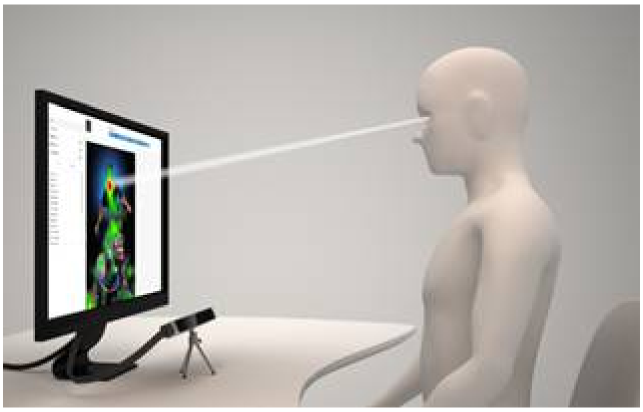

Fig. 1.User in front of an eye tracker sensor (source: http://dev.theeyetribe.com/general/)

The feedback that indicates that the sensor is properly detecting the eye position is given via the calibration software, in which is displayed the image of the eyes and the green light indicating the user's eye position, as shown in Fig. 2.

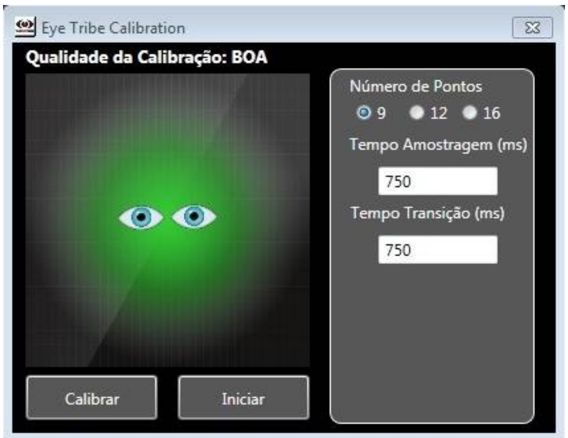

Fig. 2. Calibration interface of the system

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The sequence of events that determines the correct functioning of the eye tracking module is shown in the simplified diagram of Fig. 3.

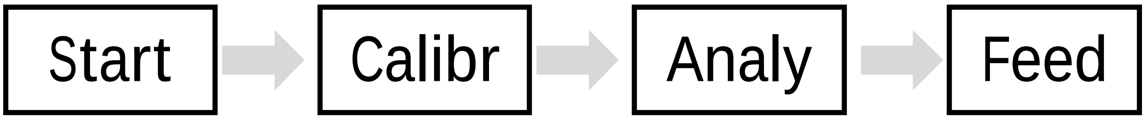

Fig. 3.Sequence of events of the eye tracking module

In the calibration the user is required to follow a circle that moves to certain key positions in the reference screen (either in a 3x3 grid, 3x4 grid or 4x4 grid, for a total of 9, 12 and 16 points, respectively). The possible results of the calibration are: Excellent, Good, Moderate, Poor and Redo. After this step, considering a result of good or excellent calibration, the sensor can now interpolate any position that the user is looking at the reference screen.

IV. PROPOSED METHODOLOGY

To validate the effectiveness of using an infrared sensor to control the EPW, a test was performed in which an experimental interface for control of the wheelchair was developed, as shown in Fig. 4.

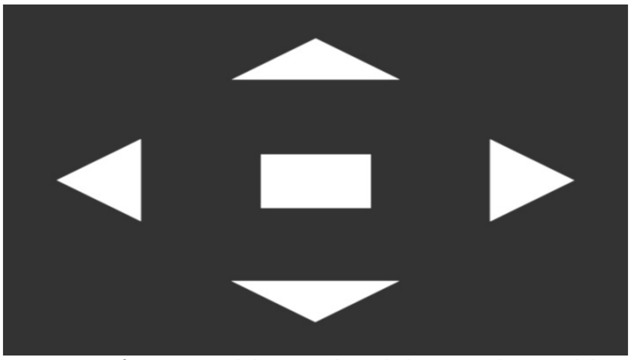

Fig. 4. Interface to control the EPW through the eye tracking module

In order to create the experimental protocol, a total of 10 commands were generated for the user to look for a particular position (top arrow, bottom arrow, right arrow, left arrow and center square). To avoid learning bias (to prevent the user to memorize the sequence), the commands were created randomly.

For validation it was recorded the number of correct inputs and the sensor response time (the moment when the timer started counting until the computer recognized the position that the user was looking). It was considered only the first position that the volunteer looked at after the command. This study was conducted with 30 participants. According to [9], when you want to evaluate independent variables it is necessary to have a minimum sample of five individuals for each item to be evaluated, as a general rule. However, the same study shows that for a better evaluation it is recommended 15 to 20 observations for each variable, in order not to create very specific results, thereby allowing the generalization of the study. Considering that the variables were the sensor response time and the number of correct inputs, both being independent variables, the test was repeated for a total of 30 participants, all healthy participants who used first the calibration system and then the proposed protocol.

After the validation process it was performed a test with the electric-powered wheelchair in the Núcleo de Tecnologias Assistivas of the Federal University of Uberlândia (NTA-UFU), in which the user would control the wheelchair only through the eyes in an interface similar to that presented in validation process. The project was approved by the Ethics Committee CAAE 37756614.0.0000.5152.

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V. Experimental Results

As a result of the validation process it was obtained an average of 95% correct input cases, with an average response time of 27,73ms.

From those results, it was determined that the variable time is not a limiting factor for using this system. Wardle, in 1998, conducted an experiment to determine the time of perception of human vision, in which the user would press a button when a light was lit, and found that there was an average delay of 180ms between the time that the light was lit and the instant in which the button was pressed [10]. He also conducted the same experiment using sound signals, in which the user would press the button after hearing a beep, obtaining as a result an average delay of 140ms. Some effects were considered to explain these delays: time for the information to reach the sensory organs, time for information to reach the brain, for the brain to interpret it and then send the motor command to push the button. One can notice that vision takes about 40ms more than the hearing. Considering the gaze perception time is at least 40ms, the test sensor has a satisfactory response time, without limiting the application to CRM control.

In relation to the average value a statistical calculation based on the confidence interval was done. As the sample size was of 30, the population had a normal distribution and the population standard deviation was unknown it was used the student's t-distribution to calculate the 99% confidence interval. Thus the lower limit was 9.18, the average of 9.5 and the upper limit of 9.96. As such, with a confidence level of 99%, the mean score for the population is between 9.18 and 9.96, with 21 subjects (70% of the sample) with 100% of the score, over the confidence interval, six participants (20% of the sample) with 90% of the score, two participants (6.67% of the sample) with 80% of the score, and one participant (3.33% of the sample) with 70%. The graph of Fig. 5 shows the results obtained.

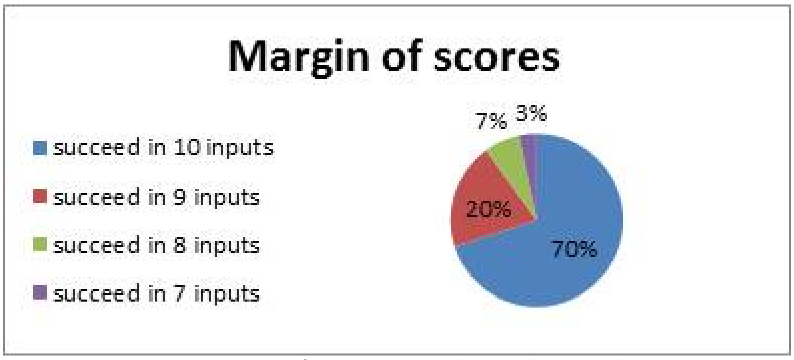

Fig. 5.Margin of correct inputs in the sample acquired

The boxplot graph generated from the sample data shown in Fig. 6 indicates that the median number is 10 correct inputs, average of 9.5 correct inputs, and indicates that the data are positively asymmetric, this type of graph is used to represent and evaluate an empirical data distribution, and it can be observed that most of the data obtained is close to its ideal values [11]. The graph of Fig. 7 shows the mean score (where is data distribution is concentrated, considering all samples) with the standard deviation. Through the standard deviation it is possible to see the dispersion among the samples [12].

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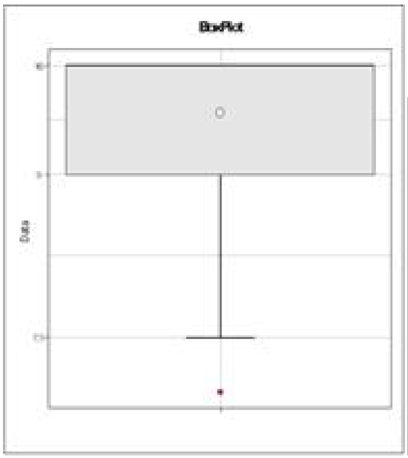

Fig. 6.Boxplot for the mean of correct inputs

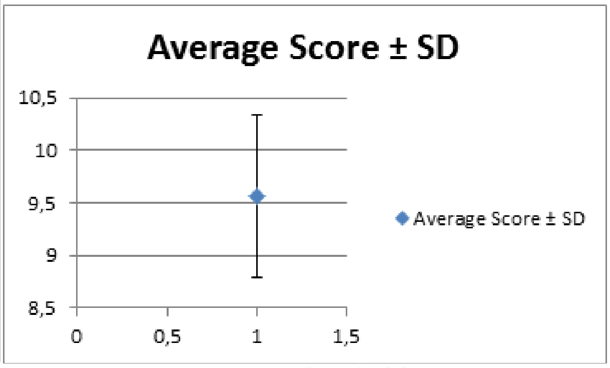

Fig. 7. Mean score and standard deviation

VI. CONCLUSIONS

After the validation of the eye tracking control module, each command was sent to an EPW adapted in NTA-UFU. Thus, for the control of an EPW for this module, the only need is that the user performs a calibration and then proceed to look at the command desired on the screen.

Tests conducted with volunteers indicated that the solution proposed meets with the needs of locomotion. Also there were some suggestions for some adjustments in future versions of the work, in order to improve the system. One of the most relevant considerations was that the presence of the notebook on the front seat might hinder the view of obstacles and environment ahead. Thus, it is recommended to use smaller displays compatible with the eye tracking module, such as tablets and smartphones.

Another important point was about keeping the head still, in order to not invalidate the calibration process made because of the change of the reference. It is noted that for users with immobility of the neck, which are the main targets of the system, this problem would not occur. It is suggested, for future versions, to create an automatic calibration every time the reference is lost.

Despite having some suggestions for improvements in future works, the module solution presented here was satisfactory to its initial objectives, providing greater autonomy in mobility for wheelchair users that are not able to move the upper limbs, thus not being able to make use of conventional forms of control.

VII. ACKNOWLEDGEMENT

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BIOGRAPHY

Ludymila Ribeiro Borges is a graduate in Biomedical Engineering in 2014, participates in the Post-Graduation Program in Biomedical Engineering at University of Uberlândia developing her research in Assistive Technologies.

Felipe Roque Martins is a graduate in Biomedical Engineering in 2015; currently is part of the Post-Graduation Program in Biomedical Engineering at the Federal University of Uberlândia and member of the Núcleo de Tecnologias Assistivas (NTA). His research interests are Assistive Technologies, alternative control, biomedical sensors, etc.

Eduardo Lázaro Martins Naves received Master of Science degree in 2001 and Doctor of Science in 2006, both in the area of Biomedical Engineering. In 2006 he joined the School of Electrical Engineering UFU, where he works as a teacher and researcher to date. He is a member of the French research institute in assistive technology (Institut Fédératif de Recherche sur les Aides Techniques pour le Handicap or IFRATH) and coordinator of the Núcleo de Tecnologias Assistivas (NTA-UFU). Acts as coordinator and collaborator in various research projects in the fields of Biomechanics, Assistive Technologies and Rehabilitation Engineering.