Designing of an Eye Tracking Intelligent Command System for People With Spinal Cord Injuries

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Abstract— **Eye movement tracking models include three categories; invasive, non-invasive and semi-invasive. The method of choice in this research is non-invasive and traceable in visible light. The novelty of this research is the use of the tracking process for issuing control commands in the intelligent home command system by individuals with spinal cord injury and physical disabilities. This algorithm is based on the facial features of a chosen method for tracking eye movements. There is no weakness for people of different ages and gender with different hair/eyebrow/eyelash types. In terms of speed, this algorithm can receive command in less than five seconds. On the other hand, the use of face detection method based on certain facial features does not limit this algorithm for a particular person or a group of individuals. It can be executed by only one calibration for each person. Twenty people were tested at 270, 90 and 50 luxuries and the commands were taken accurately in 95% of cases. MATLAB environment was used to program the software, and a simple VGA camera to detect the eye movements.**

Keywords; Rehabilitation software; Eye movement tracking; Intelligent home control; Non-invasive method.

I. Introduction

About 2% of Iran's populations (about 1,300,000 people) have different forms of disabilities with special needs to receive various rehabilitation services. 35% of them are female and 65% are male. In addition to 2,200 health rehabilitation centers, civic institutions also service to 100,000 disable people [1]. According to recent statistics in 2016 in Iran, about 5,000 people become disabled with spinal cord injury annually [2]. On the other hand, these people suffer from many psychological and emotional problems in society. With the design of an eye-command system, they can fulfill their basic needs, such as angular motion of their bed, ambient light control, temperature control, sending alarms, and communicating with a computer. Therefore, the need for continuous care is getting weaker and, on the other hand, it has a great psychological effect on these individuals who can somehow communicate with technology.

In fundamentals of face recognition, there is a concept called "locating a point of view". Face detection is the same as facial recognition, but there is a difference which in detection there is one picture for sure. One way is to place a rectangle frame on the picture, and search for the eyes, nose, eyebrows and mouth through an algorithm inside the frame. In this way, the algorithm divides the image into two groups of face and non-face. In artificial intelligence systems, learning and execution time, number of trainings and error value are very important. There are four methods to detect/locate faces; knowledge-based, feature-based, template-based and appearance-based.

Holmqvist [3] published a book with all available information and techniques about tracking the eye movement. The latest eye movement tracking method was introduced by Tobii industry [4] in 2017 to control the mouse movement and user recognition in home systems. This company is a pioneer in this field for the past 15 years, and now is expanding the sixth generation of infrared-based chase-runners. In face recognition methods based on skin color, generally color space transformers are used with one or more thresholds, and morphological operators for segmenting the image [5]. Although these methods are very fast, the threshold levels need to be clearly identified to improve accuracy [6]. For example, Wang and Yuan [7] proposed a face recognition method in complex background where images were first segmented based on the skin color, and then identified the facial components and detected the eye region as the human face. In this scheme, they achieved the identification rate of 91.1% in 583 ms. Yao and Gao [8] introduced a kind of conversion coordinate that could improve the color of the skin and the lips, then identify the human beings among other objects in complex-background images. The algorithm could process twenty six images per second, and had a success rate of 95.4%. Hsu et al. [9] introduced a face recognition algorithm for color images in various lighting and complex backgrounds, which is based on a self-described illumination compensator and a non-linear color conversion to the YCBCR color space. They also first removed the segments containing the color of the skin, and performed face recognition by eye and lip detection. Aldasouqi and M. Hassan [10] introduced rapid face-identification algorithm using morphological techniques in the HSV color space. Singh et al. [11] combined HIS, YCBCR, RG color spaces to introduce a face recognition algorithm based on skin color.

Several other methods are based on boosting algorithms. A sample was introduced by Viola and Jones [12]. In this method, the average intensity difference between the two rectangular regions is encoded by the Haar-Like attributes. Lienhart and Maydt [13] extended the Jones and Viola method with the use of fine tuning for various facial expressions. Zhang et al. [14] used the AdaBoost machine learning meta-algorithm to identify a set of local face features and their weights according to the LBP features. Wu and Ai [15] combined the AdaBoost algorithm and the skin-color segmentation to detect the face in color images. In this method, a Gaussian model and morphological operators were used to segment the image. Of course, other methods based on the Gaussian model are introduced [16]. Ge et al. [17] introduced another algorithm that combined AdaBoost with image partitioning based on skin color and LBP for faces recognition.

II. RESEARCH METHOD

Care needs to be taken into consideration on how to treat people with spinal cord injury. The head angle and height depends on the patient's type and amount of injury. The standard way for these patients is shown in Fig. 1. The angle of the camera and its distance are determined according to this standard. The research was performed in three steps:

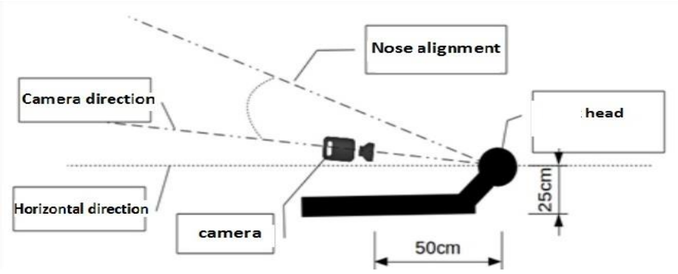

Figure 1. How to put the camera on the patient

A. First step

At first, the camera was linked to MATLAB software. Then, the image acquisition toolbox was called using the vid video command. Given that the image was taken in an RGB environment, it was optimized to improve the image quality.

B. Second step

Face and eye area was detected based on the facial features method using 'step' function. This eye and eyebrow locating technique is one of the fastest methods of image processing. It also has no sensitivity to head rotation up to 20-degree and to the camera distance. It should be noted that the rectangle frame moves along the image, and selects the area where both conditions are established. Fig. 2 shows the detected frame as the eyes zone.

C. Third step

In the next step, the area is divided into two zones, and one eye is selected. Then, the pupil is extracted using cavity processing. The center of pupil is found by central function shown in Fig. 3.

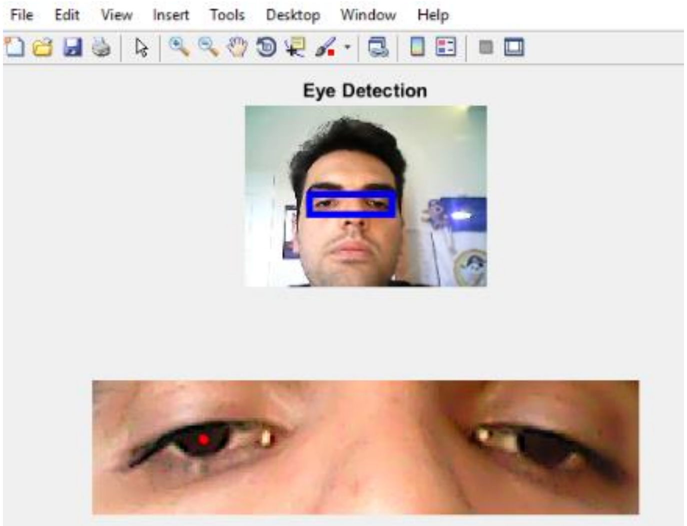

Figure 2. A frame in the image that includes the eyes

Figure 3. Center of the pupil is found by the central function

The distance of the detected center with the zero of coordinate system in the upper left corner of the rectangle is stored (one time per each frame). It is then stored as an array of x-y coordinates. Dispersion of the points detected in a 100 frame interval is shown in Fig. 4.

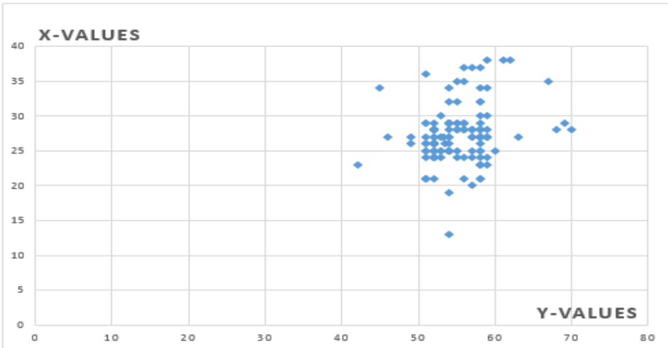

Figure 4. Dispersion of the detected coordinates in 100 consecutive frames.

According to the diagram, it is seen that the range of tolerance for detection of coordinates is very large. To determine the mean of these points, the method of statistical averaging is used. In this method, the frequency of each x and y value is found. Then the value with highest frequency is selected. It should be noted that all numbers are rounded before statistical averaging. Fig. 5 shows this frequency in a recording range.

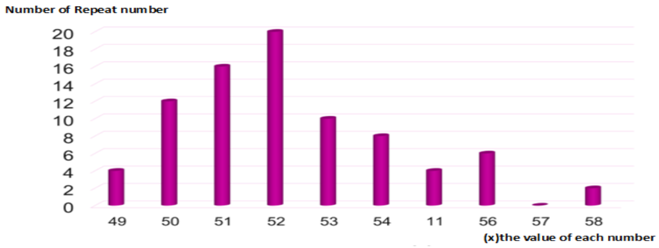

Figure 5. Frequency of identified coordinates in 82 frames.

First, all zero points resulting from non-recognized points on the face are removed. The average of these two sets calculated by statistical averaging method, and the point with the highest frequency on each axis is selected. If the number of points (the overall frequency of coordinates) is less than a specified limit, a command is set up to re-schedule the program. If the frequency of the detected coordinate is more than a minimum number, it is stored as the reference in the program. Since the program is written for five points, it stores five reference points in the calibration. Figs. 6 and 7 show the accuracy of data before and after the statistical averaging.

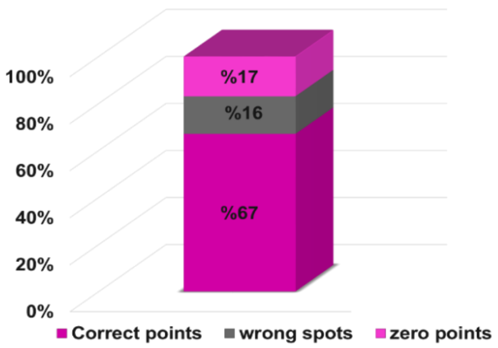

Figure 6. The accuracy chart of traced points before the statistical averaging.

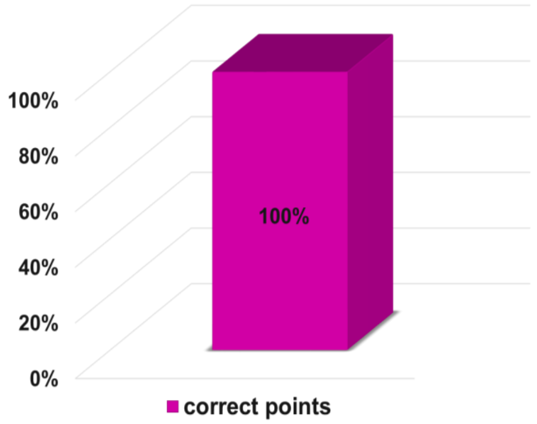

Figure 7. The accuracy chart of traced points after the statistical averaging.

Fig. 8 shows the flowchart of the program. After eye zone detection, the iris center points is found, and if this coordinate is compared with the coordinates stored in the calibration, the output is exported. In the comparison process there is a condition in which the differences between each detected point with five calibrated points are calculated, and the lowest value is declared as the result waiting for the confirmation command of the user. If the command is verified by looking at the fifth point, the command is sent to the output to be executed. If the user does not acknowledge the confirmation, the process of face recognition and point of view will be performed from the beginning. The front panel designed for the patient has five options: four options for issuing a command and an option for confirming the selected command. After looking at each option and detecting the command, the system announces the detected command and the patient can confirm the order by looking at the confirmation option.

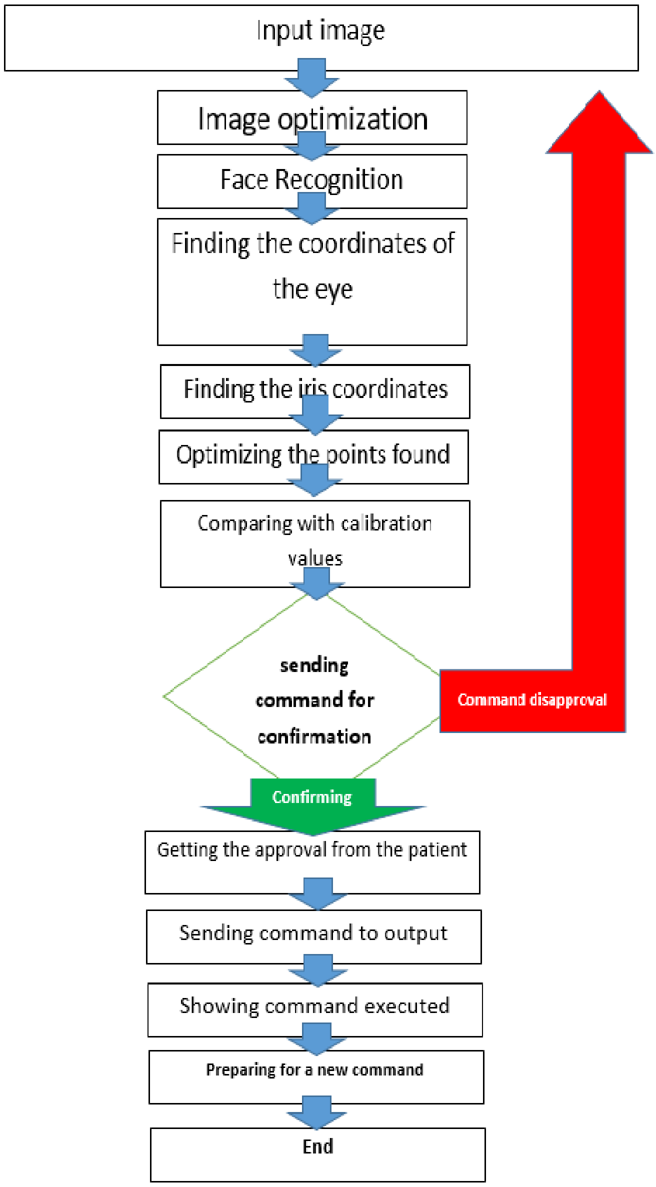

Figure 8. Flowchart of the program

III. Results and Discussion

In this study, due to the fact that there was no direct access to people with spinal cord injury, the tests were performed under three environments with light intensity of 50 lux 90 lux and 290 lux, using different individuals with different face features (beard, hair, eyebrows), ages and genders.

The data gathering process in this study was first to determine the angle of the camera and the best distance for each person (test samples). Then, each person was tested for ten times for each test point and the detection error percentage was recorded for each point. Fig. 9 shows the test setup.

Figure 9. Experimental setup with four command point (corners) and one confirmation command (center)

Fig. 10 shows a diagram for the mean accuracy of each detected points after test with all individuals.

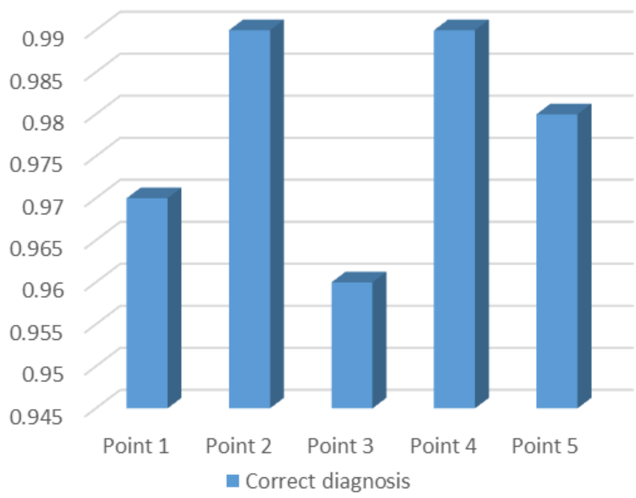

Figure 10. Correct detection percentage of algorithm detection at each command point for all individuals

The accuracy of the algorithm relative to the ambient light intensity is shown in Fig. 11. It is seen that the highest accuracy is obtained under 90 lux light intensity ambient. The best results were obtained when the patient wears no glasses. Wearing glasses reduces the accuracy up to 20%.

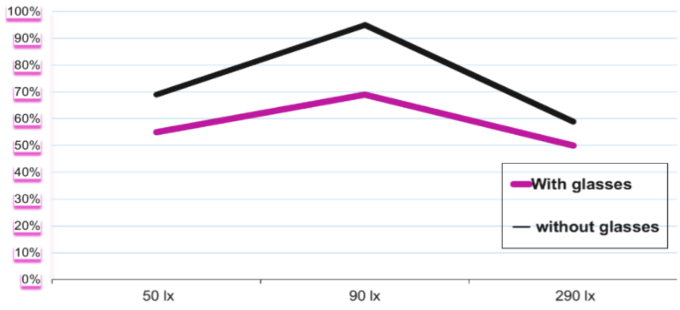

Figure 11. The response accuracy of the algorithm relative to the ambient light intensity

By performing multiple tests, it was found that the eyebrow width has a significant effect on the eye pupil detection. In Fig. 12, the relation between the eyebrow width and correct detection percentage of the algorithm are shown in two modes with glasses and without glasses. Also, this algorithm has no sensitivity to individuals with a different gender or beard shape and type.

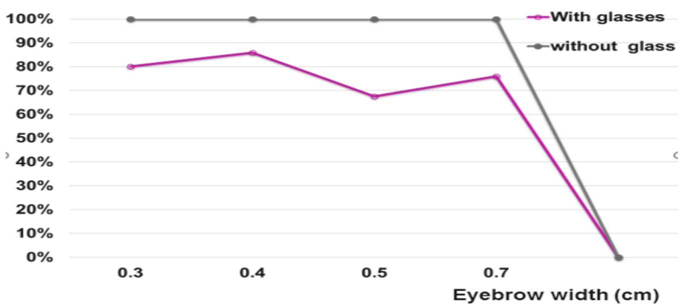

Figure 12. Characterization of the eyebrow width on the accuracy of command detection

IV. Conclusion

In this research, a non-invasive intelligent method is used to take and confirm the eye commands by people with spinal cord injuries. This eye movement tracking method is designed and programmed in MATLAB software. The center of patient's eye pupil is first detected; the related command is selected and then verified by patient looking at the confirmation command. The proposed method was tested for people with different gender/age/eyebrow type/beard type both wearing and not wearing glasses. The results showed that this technique is a simple and efficient method for eye tracking in normal light density (90 lux) for people not wearing glasses.

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