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Guiding Wheelchair Motion based on EOG Signals using Tangent Bug Algorithm

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***Abstract*— In this work, we propose new method beside the classic method, to control the motorized wheelchair using EOG signals. The new method allows the user to look around freely while the wheelchair navigates automatically to the desired goal point. Only EOG signals are used to control the wheelchair; eye gazing and blinking. The user can still choose to control the wheelchair using the classic manual method in case the environment and obstacles structure does not help with the auto navigation method. In the new auto navigation method the microcontroller can know the goal point direction and distance by calculating the gaze angle that the user is gazing at. Gaze angle and blinks are measured and used as inputs for the controlling method. Tangent Bug algorithm is used to navigate the wheelchair in Auto controlling method.**

Keywords-wheelchai, electrooculography, eye movement, gaze angle, blinking, Tangent bug.

I. INTRODUCTION *(HEADING 1)*

It is estimated by New Freedom Initiative Act that, disabled and elderly people who need a wheelchair are to be over 100 million worldwide. A lot of these disabled cannot use the traditional electrical wheelchairs, which are controlled by joystick, due to their limb movement restrictions. Hence, many alternative control methods have been developed to allow those disabled users to live more independently, e.g. voice recognition and guidance [1] and [2], vision based head gesture control [3]-[7], EMG signal based control [8] and [9], and EOG eye tracking control [10] and [11]. Even though, EOG eye tracking control offers a more natural mode to guide the wheelchair, it is omitted because users are normally not allowed to look around the surrounding environment during motion. Most researches tried to overcome this problem by using EMG along with EOG signals to control the wheelchair [12] and [13].

A. *Paper Scope and Contributions*

In this paper, we present EOG signals based control method of the wheelchair. A hands-free control system that uses only EOG signals for control of an electric powered wheelchair. New automatic controlling method is introduced besides the common manual method. The user can look around the surrounding environment freely during the navigation process in automatic mode.

B. *Paper Organization*

The paper is organized as follows. Section II presents the related works with Eye-movement recognition. Some typical eye-movement measurement methods for recording the electrical activity of eye-movement will be illustrated in this section. Section III shows the novelty of this project is .The proposed EOG-based Eye-movement HCI platform is given in section IV, and some proposed prototype applications for Eye-movement are shown as well. The various control tests and investigational results are given in section V. Finally, section VI draws the conclusion and future work.

II. RELATED WORK

A. *Wheelchair mation control metods*

A powered wheelchair is driven by electric motors, instead of the user's arms. It is normally controlled with a joystick. However, other input devices such as voice, EOG and EMG are used if the user has restricted limbs movements.

This work has proposed an eye tracking based on EOG signals to control the wheelchair. Wheelchair motion control using eye tracking has been applied in many research studies. For example, [12] and [13] used EMG to control the direction and EOG to control the speed of the wheelchair. While other researches has focused on Human Computer Interfaces (HCI) based on EOG signals, where the user will be allowed to perform other simple tasks beside wheelchair motion control [14]. Although, only few focused on using EOG signals solely to control the wheelchair [15] and [16].

On the other side, current studies describe the design approaches for gaze control, where the user controls the wheelchair by gazing directly at the physical target point [17] and [18]. However, the eye tracking method used was camera based which is more expensive, complex, and the camera must be mounted to the head of the user.

B. *Electrooculography Applications*

Electro-Oculography (EOG) observes the eye-movement by recording the corneal–retinal potential polarity from de-polarizations and hyper polarizations existing between the retina and cornea.

Fig. 1 shows the most commonly used configuration to measure the EOG signal and five electrodes are used to capture the potential fluctuating. The EOG signals are obtained by placing two electrodes to the right and left of the outer canthi (D, E) to detect horizontal movement and another pair above and below the eye (B, C) to detect vertical movement. A reference (Ground) electrode is place on the forehead (A) [15] (see Fig. 2).

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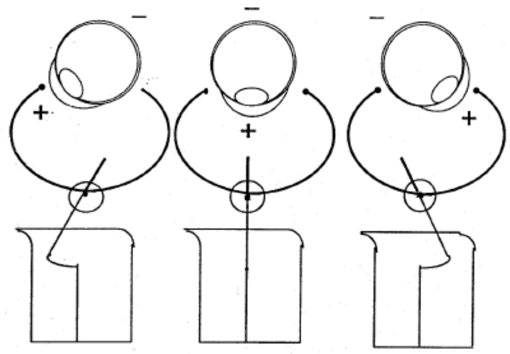

Figure 1. Dipole model of eye.

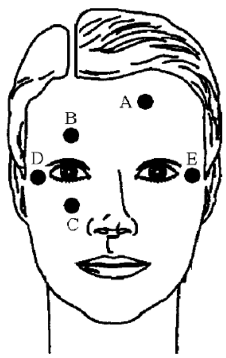

Figure 2. Electrodes placement.

III. PROPOSED NEW TECHNIQUES

Previous researches use classical manual method to control the wheelchair motion using EOG signals. In manual method, the user look up to move forward, right to turn right, left to turn left, and down to stop the wheelchair. This method exhausts the user due to the concentration needed during the navigation process. In addition to that, the user is not allowed to look around the surrounding environment while navigating the wheelchair to the desired destination. This research proposes to get rid of this drawback by introducing new controlling method, which takes advantage of the gaze angle detection. In the new method, the user only needs to look at the desired destination, and then blink to give the signal to the controlling unit to start navigation. After that, the wheelchair will calculate the desired goal position and distance from the measured gaze angle. Finally, the wheelchair will move toward the destination in straight line and go around obstacles when detected by sensors (see Fig. 3).

Even though the new controlling method is easier to use, there are cases where the manual method is more efficient to use such as environment with concave obstacles. Hence, the user can switch back to use the manual method to control the wheelchair, which gives more freedom and variety of motion paths, (see Fig. 3).

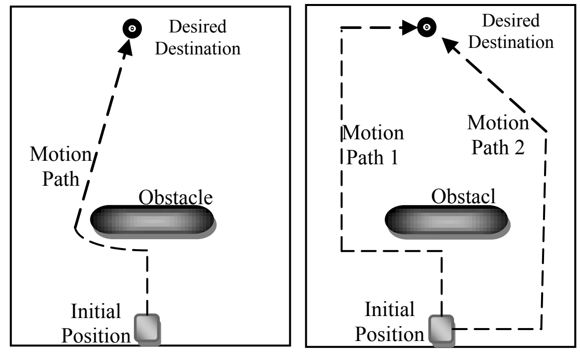

Figure 3. Motion path of the wheelchair controlled by Auto navigation method (left), and Motion path of the wheelchair controlled by Manual navigation method (right).

IV. METHODOLOGY

A. EOG Signal Measurement System

According to the literature [18], the eye-movement coils produces between 50 uV and 3500 uV with a frequency ranging from dc-100 Hz. BMA-400 multichannel bio amplifier is used to for amplification and filtering the signals. AC high-gain differential amplifier (1000–5000) is used. According to literature [18], the signal band-width of eye-movement was located in the range of 0.1–20 Hz, so signals more than 20 Hz would be regarded as noise which should be deleted using noise filters. The low pass filter cut-off frequency used is 30 Hz and the high pass filter cut-off frequency used is 0.1 Hz.

[15] has also shown that electro-oculography can be used to determine the eye position in its socket with good accuracy, and that Its behavior is almost linear for gaze angles of ±50° horizontally and ±30° vertically. Besides, monocular blinking (with one eye), differed from all other phenomena in having an anomalously high amplitude, i.e. 10–20 times greater than that in normal bilateral blinking and other phenomena, such that they could be identified easily [18].

According to the literature [15] a software program has been developed for calibrating the eye position. The communications between PC and wheelchair is made by means of PLCTA and LonWorks bus based on a Neuron-chip. When the eye position is calculated, the eye gaze is obtained and represented in this window in angles (Fig. 4).

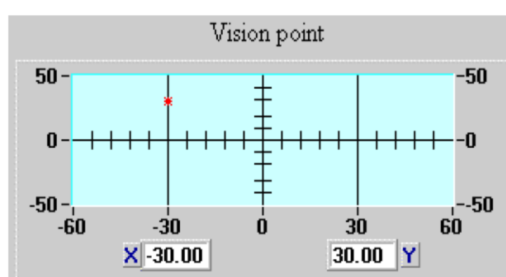

Figure 4. Gaze angle representation.

B. Navigation control method

In this research, the user can choose between two methods to control the wheelchair. The first method is the common manual method, where the user look up to go straight, look right to turn right, look left to turn left, and look down to stop. The user cannot look around the surroundings while controlling the wheelchair using this method.

However, the other method provides the freedom for the user to look around freely during the navigation process. The user only needs to blink after gazing at the desired destination. After that, the wheelchair will automatically navigate to the target position. The gaze angle can be measured by the EOG measurement system. Intentional blinks are used as input signals. They are commands to switch between the controlling methods and to execute navigation process.

B.1. Auto Navigation method (Tangent-Bug Algorithm)

Tangent Bug algorithm is used to control the navigation process of the wheelchair in automatic mode. The wheelchair has to find its way to the desired goal position that is specified by distance and direction relative to the user position; no other information about the environment is needed [19]. Tangent Bug uses two basic behaviors: motion toward the target and obstacle boundary-following. The wheelchair will move toward the target position following the shortest path. If an obstacle is detected by the range sensors, the wheelchair will go around it until the range sensors detect no obstacle. Then the wheelchair will recalculate and follow the new shortest path to the target position [20] (see Fig. 5).

Tangent-Bug is chosen over other bug algorithms, because it is based on range sensor. In other words, it is safer for the user and the wheelchair. Moreover it produces the shortest path in environments with wider spaces (convex obstacle) that allow it to make use of its range sensors [Performance Comparison of Bug Navigation Algorithms]. Hence, the user can choose to control the wheelchair manually in case of concave obstacle (see Fig. 5).

At every motion step, the current position of the wheelchair is stored, and the navigation algorithm assures the convergence of the wheelchair toward the target near obstacles (see Fig. 5). The algorithm is described as follows:

1- When the wheelchair detects an obstacle within its sensor range, it come near to the obstacle and begins to follow the obstacle's boundary. The wheelchair stores its location as the last hit point. Go to (3).

2- When the wheelchair does not detect an obstacle for the target direction, it moves straight to the goal direction with one step. If the point is the destination position, then stop the navigation, else go to (1).

3- The wheelchair continues to follow the current obstacle with one step. If the target path is obstacle free, then go to (1).

C. Authors and Affiliations

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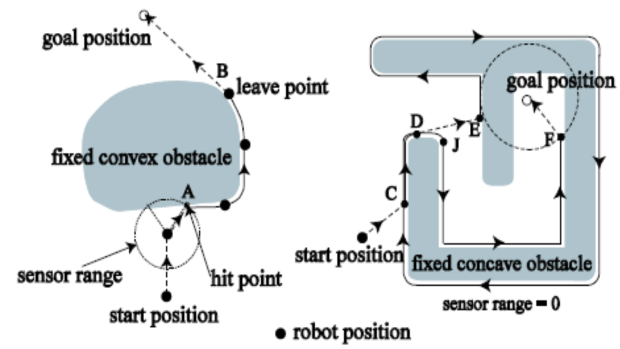

Figure 5. The behavior of a mobile robot for a fixed convex (left), and concave obstacle (right) by T-Bug.

Calibration has been done to calculate the distance and angle of the desired goal point based on the measured horizontal gaze angle (α) and vertical gaze angle (β). Firstly, the y-axis distance to the goal (Y) is measured; it depends on the height (h) of the user eye level and the vertical gaze angle (β). Then, the x-axis distance to the goal (X) is measured; it depends on the Y value and the horizontal gaze angle (α) (see Fig. 6 (a,b)). The distance and direction of the goal can be easily calculated from Y and X values. In addition, the maximum y-axis distance to the goal (Y) when vertical gaze angle (β = 0) should be set previously (15 meters in our case).

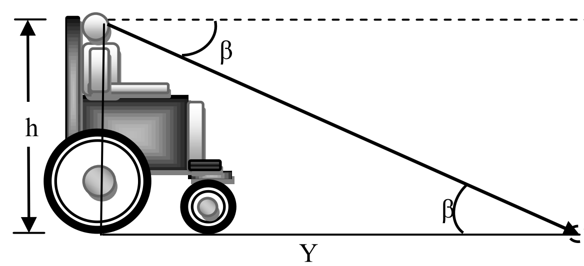

Figure 6. (A.). Calculation of distance and angle of the goal (side view).

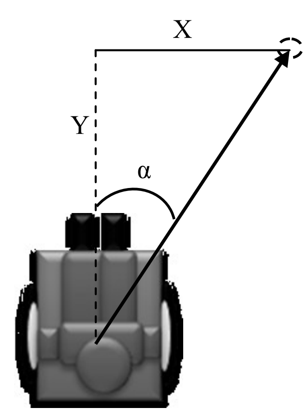

Figure 6. (B). Calculation of distance and angle of the goal (top view).

However, the number of the positions that can be targeted by the user is finite. Its limitation depends on how many different horizontal and vertical gaze angles that can be detected by the EOG signals measurement system (Fig.

7). Nine different horizontal and four vertical gaze angles are used in our case of study to avoid clashing errors between angles.

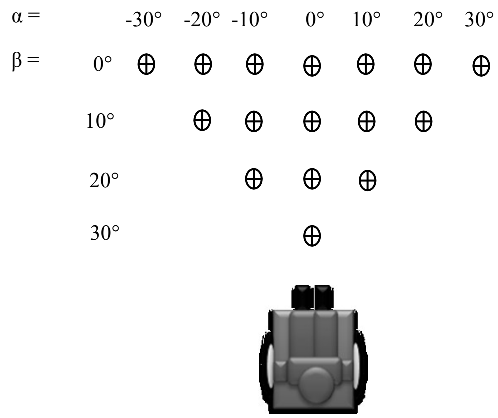

Figure 7. Possible goal points to be targeted by the user.

V. Results and Discussions

The EOG measurement system is able to detect eye movements to with no errors; all the needed gaze angles as inputs for controlling the wheelchair are easily distinguished Fig.8(a), making it possible to expand the possible selectable target points.

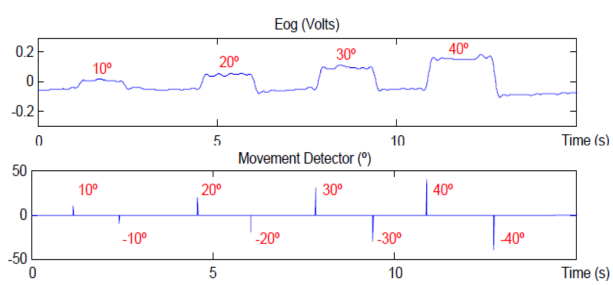

Figure 8. (A). Eye-movement detection with gaze angles (horizontal EOG).

In addition to that, eye blinks can be easily detected in the EOG vertical measurement system, as blinking have different characteristics from gazing (see Fig.8(b)). Hence blinks are used in the controlling method with no errors.

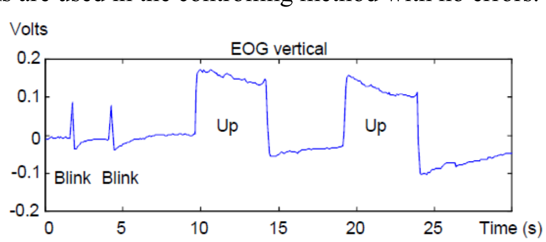

Figure 8. (B). Eye-movement and blinking detection (vertical EOG).

Due to sources limitations, MATLAB (simulation) and CamStudio (video capturing) are used to simulate and implement the tangent bug algorithm which is used to control the wheelchair.

The world I have chosen is a continuous world bounded with a closed box of 300×250 units (Decimeters). The wheelchair and the goal are denoted as points on this space as Wheelchair = [Wx,Wy] and goal = [Gx,Gy]. The movement factor is 2 for the wheelchair. The obstacles are denoted as polygonal shapes with differing sizes and locations. The maximum range of the sensors is 30 units and yields an infinite reaction for open spaces with a value of 400, which is set to be longer than the diagonal of the bounding box. The threshold is set to 20 units for detecting obstacles as a change between two angles.

Three maps are tested and simulated with same initial point for the wheelchair (0, 0), but with different goal points, and shapes and locations of the obstacles.

In map A, the obstacle does not interfere between the wheelchair and the goal, so the wheelchair will calculate the direction and distance of the goal. Hence, the wheelchair will turn to the direction of the goal and move in straight line toward the goal till it reaches it (see Fig. 9(a)).

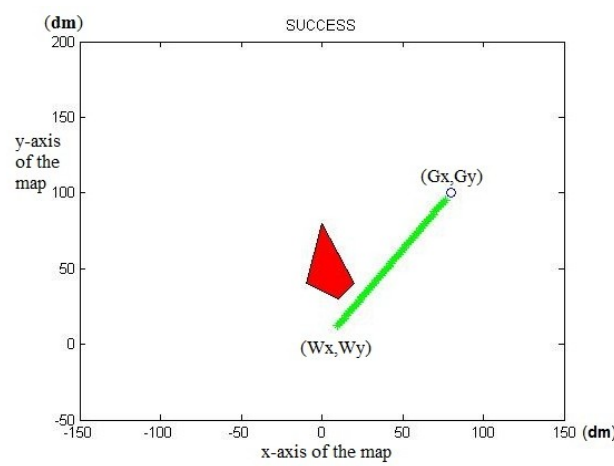

Figure 9. (A). Virtual map (a) with the navigation process.

In map B, the obstacle is placed between the wheelchair and the goal. The range sensor detects the obstacle so the wheelchair omits it by following its boundaries till the sensor sense no obstacle, then the wheelchair moves in straight line toward the goal till it reaches it. Map B shows the perfect case for using auto controlling method (see Fig. 9(b)).

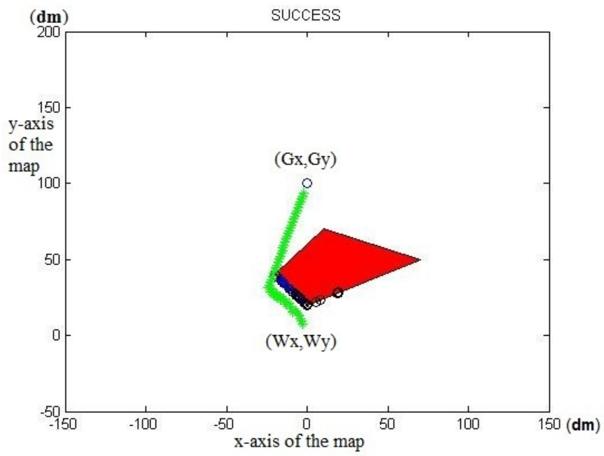

Figure 9. (B). Virtual map (b) with the navigation process.

In map C, the obstacle has same goal point with map B, but with different obstacle shape, size and location. It is shown in this map, that sensors are not always perfect to select the direction to omit and go around an obstacle, because it only sense within its range limit and react based on that information (see Fig. 9(c)).

The user has the advantage to overcome the sensors limitations, and select manual navigation method to navigate manually in such cases like map C. .

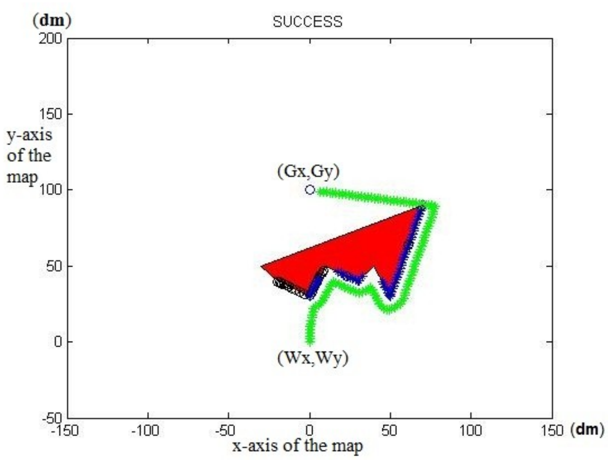

Figure 9. (C). Virtual map (c) with the navigation process.

VI. Conculsions And Recomendations

A. Conclusions

This paper presents EOG signals measurement system in order to control the wheelchair motion using only eye gazing and blinking. The main objectives of this project is to help disabled, who can only move their eyes to easily control the wheelchair, and yet look around the surrounding environments while navigation process is done automatically. Particular hardware has been developed to capture users' biopotentials.

Gaze angles between 0° and 40° with increment of 10° are easily measured and by measurement system and detected by controlling unit as inputs. Intentional blinks are also easily detected and used as input commands in the controlling method.

Tangent bug algorithm is implemented and used to control the wheelchair in auto navigation method. The simulation shows that the user can enjoy looking around while the auto controlling method navigate to the goal point with avoiding obstacles, however there are cases where manual controlling method is more efficient to use such as in map C case.

B. Future Work

System can be integrated with HCI to expand the selected options and tasks for the wheelchair and the EOG measurement system together. Moreover, the number of possible selected goal points can be increased by increasing the number of input gaze angles.

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