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Electric Wheelchair Control with Gaze Direction and Eye Blinking

Djoko Purwanto[1)], Ronny Mardiyanto[2)] and Kouhei Arai[3)]

[1),2)]*Department of Electrical Engineering ITS, Kampus ITS Sukolilo, Surabaya 60111, Indonesia*
Tel : 62-31-594-7302; Fax : 62-31-593-1237
djoko@ee.its.ac.id, ronny@ee.its.ac.id

[3)]*Department of Information Science, Saga University, 1 Honjo, Saga 840-8502, Japan*
Tel : 81-952-28-8567; Fax : 81-952-28-8650
arai@is.saga-u.ac.jp

Abstract: In this research, the electric wheelchair control with gaze direction and eye blinking is proposed. A camera is set up in front of wheelchair user to capture image information. The sequential captured image is interpreted to obtain the gaze direction and eye blinking properties. The gaze direction is expressed by horizontal angle of gaze, and it is derived from the triangle form formed by the centre positions of eyes and nose. The gaze direction and eye blinking are used to provide the direction and timing command, respectively. The direction command relates to the movement direction of electric wheelchair, and the timing command relates to the time condition when the wheelchair should move. The timing command with eye blinking mechanism is designed to generate ready, backward movement, and stop command for the electric wheelchair. Furthermore, to move in certain velocity, the electric wheelchair also receives the velocity command beside the direction and timing command. The disturbance observer based control system is used to control the direction and velocity. For safety purpose, the emergency stop is generated when electric wheelchair user do not focus the gaze direction consistently in specified time. A number of experiments conducted for the electric wheelchair in a laboratory environment. The simulation results indicate the effectiveness of the proposed electric wheelchair system.

Keywords: electric wheelchair control, gaze estimation, blinking measurement.

I. INTRODUCTION

The ability to move freely is highly value for all people. However, it is sometimes difficult for person with physical disabilities. Nowadays, the electric wheelchair is commercially available for the disable person. It is generally require considerable skill to operate. Moreover, some disabled person cannot drive the electric wheelchair manually, even with a joystick, because they lack the physical ability to control the movement. To enable the disable person to drive a wheelchair safely and easily so that they can enjoy a higher quality of life, researchers proposed some electric wheelchair system. The use of voice command to control an electric wheelchair is one of research results. A small number of command worlds and high performance voice recognition employed in this system. An electric wheelchair control with electrooculography (EOG) techniques proposed. In this case, the different commands for wheelchair derived from electrooculography (EOG) potential signals of eye movement.

A system for electric wheel chair control with human eyes has been proposed in 2007. Commercially available Web camera mounted on Head Mounted Display: HMD of which user wears is used to capture moving pictures of users' face. Computer mounted on the electric chair process the captured imagery data, detecting and tracking of user's eye, estimating line of sight vector and actuate electric wheel chair in the designated directions pointed by human eye. One of the keys of the proposed system is detection and tracking of eye movement so that this paper deals with the experimental results from the eyeball rotation angle estimation accuracy with the acquired eye and its surrounding image. Through the experiments almost 99% success rate was confirmed in terms of matching accuracy the electric wheel chair movement with the desired directions user intended to move[1].

In this research, the topic of electric wheelchair control with gaze direction and eye blinking properties is proposed. A camera is set up in front of wheelchair user to capture image information. The camera direction is focused to the face area of wheelchair user. The camera is connected to a computer with vision processing and electric wheelchair motion control capabilities. With vision processing, the sequential captured image is interpreted to obtain the gaze direction and eye blinking properties. The gaze direction is expressed by horizontal angle of user's gaze, and it is derived from the triangle form formed by the centre positions of eyes and nose. The eye blinking properties obtained from blinking time condition. The gaze direction and eye blinking are used to provide the direction and timing command, respectively, for the electric wheelchair. The direction command relates to the electric wheelchair movement direction, and the timing command relates to the time condition when the electric wheelchair should move. The eye blinking mechanism with blinking duration at least 400 ms is designed to generate timing command for moving action. Furthermore, the electric wheelchair also receives the velocity command to move in certain velocity beside the direction and timing command. The disturbance observer based control system is used to control the direction and velocity. For safety purpose, the emergency stop is generated when electric wheelchair user do not focus the gaze direction consistently in specified time.

II. PROPOSED SYSTEM

1. System overview

The electric wheelchair system equipped with a camera is shown in Figure 1. The electronic system for vision processing and control purpose is place on the bottom of wheelchair. The electric wheelchair adopts the differential streering mechanism. The wheelchair design considers 4 important factors as follows: safety, easy to operate, cheap, and convenience.

Fig. 1. The electric wheelchair system

There are 4 commands applied to the electric wheelchair, safety, timing, direction, and velocity command (see figure 2). Safety command is related to situation where wheelchair must stop immediately. The timing command is obtained from eye blinking mechanism and it is used to run and stop the motion. The direction command is derive from properties of triangle points from both eyes and nose of user. The velocity command is set independently and it does not depend on vision system. Both of direction and velocity command refer to wheelchair motion in cartesian space.

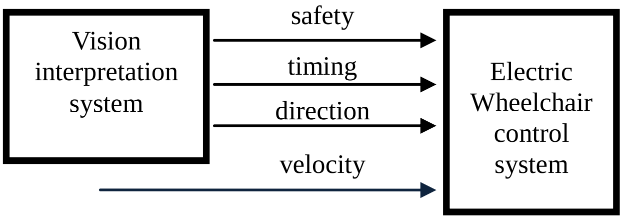

Fig. 2. Command for electric wheelchair

2. Electric wheelchair model

Figure 3 illustrates the differential steering type of electric wheelchair model. The desired wheelchair motion determined by the command value of direction θ and linear velocity v. The wheelchair motion depends on the electric signal applied to motor of each wheel. The angular velocity ω_l and ω_r represent the direct input signal to move the left and right wheel of electric wheelchair. The relation between direction-velocity (θ, v) and angular velocity of wheels (ω_l, ω_r) is written in equation (1), where R_w is radius of wheel, η is gear ratio, and l is distance between wheels.

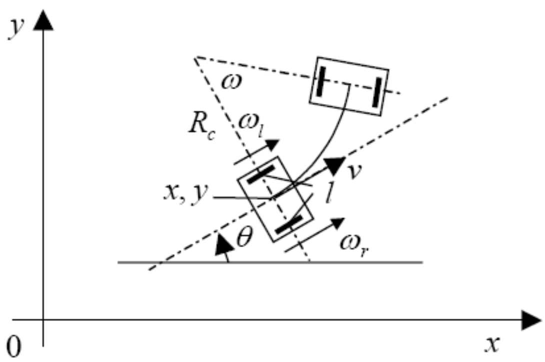

Fig. 3. Electric wheelchair model

$$\begin{bmatrix} v \\ \dot{\theta} \end{bmatrix} = \begin{bmatrix} \frac{R_w}{2\eta} & \frac{R_w}{2\eta} \\ \frac{R_w}{l\eta} & -\frac{R_w}{l\eta} \end{bmatrix} \begin{bmatrix} \omega_l \\ \omega_r \end{bmatrix} \quad (1)$$

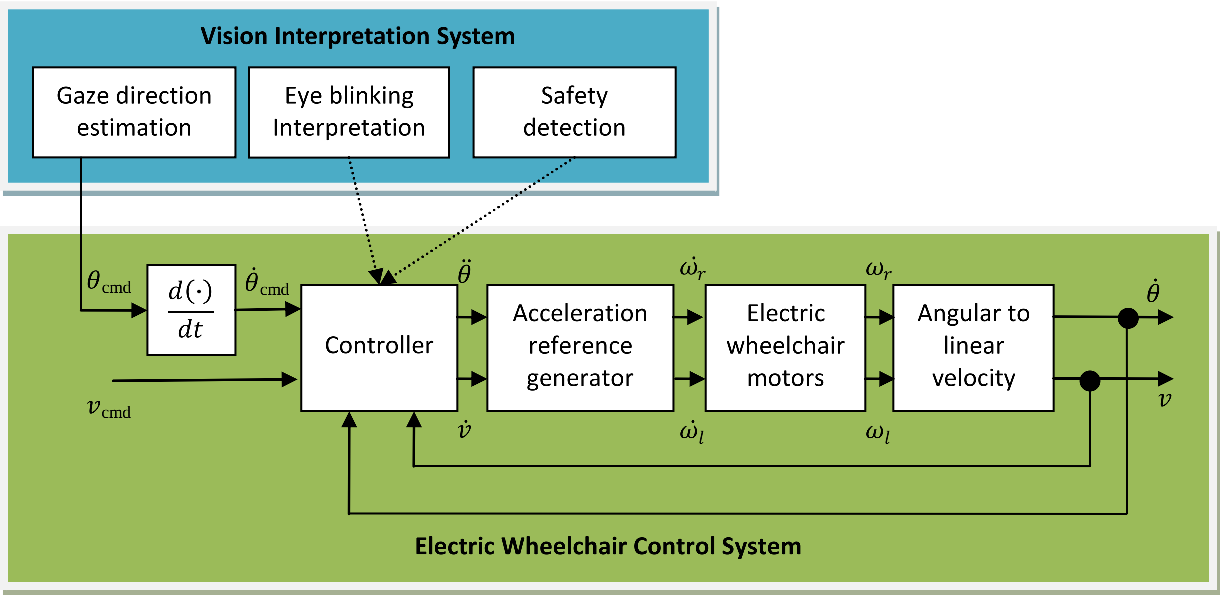

Fig. 3. Electric wheelchair system

3. Electric wheelchair system

The overall block diagram of electric wheelchair system is shown in figure 3. The system consist of vision interpretation system and electric wheelchair control system. All of visual information processing that include gaze direction estimation, eye blinking interpretation, and safety detection, are carried out in vision interpretation system. The gaze direction estimation generate the smooth-running direction command. The eye blinking interpretation and safety detection are generated commands signal directly to the controller. In the wheelchair control system, a disturbance observer based control strategy is applied to solve 2 inputs 2 outputs control problem.

4. Vision interpretation system

A. Gaze direction estimation

The gaze direction is interpreted from 3 positions of both 2 eyes and nose of wheelchair user. As show in figure 4, these 3 positions form a triangle shape that relates to gaze direction. With the parameters of triangle is shown in figure 5, the estimation of gaze direction is formulated as equation (2). The function of $f_1(\cdot)$ is determined during calibration procedure.

$$\hat{\theta} = f_1\left(\frac{a-b}{L}\right) \tag{2}$$

The direction command θ_{cmd} is derived from the gaze direction estimation $\hat{\theta}$ with smoothing function

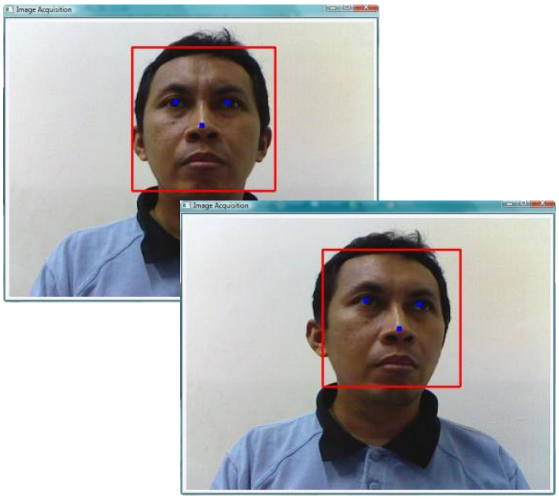

Fig. 4. Relation of triangle shape and gaze

formulation to yield natural change of command and to suppress measurement noise.

$$\theta_{cmd} = f_2(\hat{\theta}) \tag{3}$$

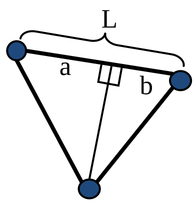

Fig. 5. Triangle shape from eyes and nose

B. Eye blinking interpretation

The interpretation of eye blinking is useful to generate the timing command applied directly to the controller. The eye blinking with duration at least 400 ms is used as timing command. The algorithm of timing command is as follows:

If <1 time blinking> **then** <disable controller>
If <2 times blinking> **then** <enable controller>
If <long blinking> **then** <set move backward>

C. Safety detection

The safety detection monitors the electric wheelchair user behavior and vision system performance. Bad behavior is defined when the user does not focus in wheelchair control. Failed vision system occurs when vision system fails to detect user face. The safety command algorithm is defined as follows:

If <bad user behavior> **or** <face detect failed>
then <disable controller>

5. Electric wheelchair control system

A. Electric wheelchair motors and controller

In both of wheelchair motors, the disturbance observer technique is applied. Disturbance observer is a technique to estimate the disturbance existing in a plant and to make the motion controller to be an acceleration controller [3]. With acceleration controller, the wheelchair motors can be modeled as ideal integrator, and the controller block diagram is realized by constant gain *K*.

$$\begin{bmatrix}\dot{v}\\ \ddot{\theta}\end{bmatrix} = \begin{bmatrix}K & 0\\ 0 & K\end{bmatrix}\begin{bmatrix}v_{\text{cmd}} - v\\ \dot{\theta}_{\text{cmd}} - \dot{\theta}\end{bmatrix} \qquad (4)$$

B. Angular to linear velocity conversion and acceleration reference generator

The conversion from angular to linear velocity is formulated in equation (1). Furthermore, the acceleration reference can be derived from equation (1) as follows :

$$\begin{bmatrix}\dot{\omega}_l\\ \dot{\omega}_r\end{bmatrix} = \begin{bmatrix}\frac{R_w}{2\eta} & \frac{R_w}{2\eta}\\ \frac{R_w}{l\eta} & -\frac{R_w}{l\eta}\end{bmatrix}^{-1}\begin{bmatrix}\dot{v}\\ \ddot{\theta}\end{bmatrix} \qquad (5)$$

III. RESULTS

To verify the effectiveness of proposed method, several simulations was carried out. Figure 6 shows that the actual response follows the command in specified settling time. Furthermore, the actual response of motor shows that there is difference angular velocity in left and right motor when direction command changes.

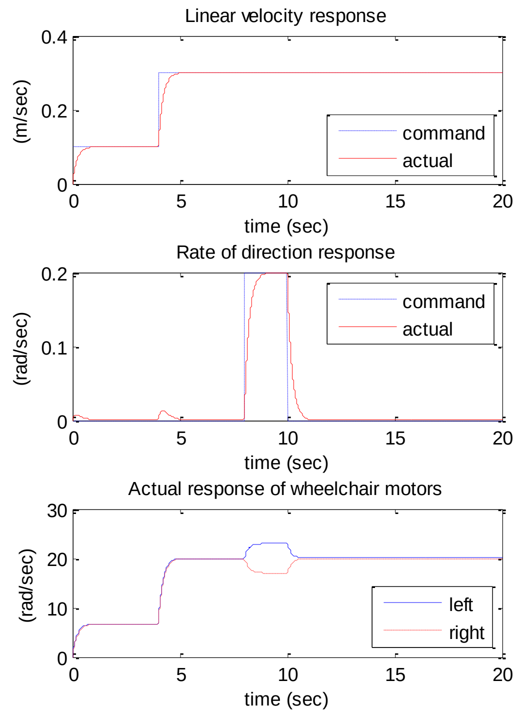

Fig. 6. Simulation results

IV. CONCLUSION

The feature points in triangle shape of eyes and nose positions can be formulated to generate direction command for electric wheelchair. Combining direction, velocity, timing, and safety command yields effective method to control electric wheelchair. With disturbance observer technique applied as control strategy, the design criteria of wheelchair control system can be satisfied easily.

V. ACKNOWLEDGEMENT

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