Improvement of Control Command Input Device Using Image Processing for FES System

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Abstract: In order to develop a control command input device for a functional electrical stimulation (FES) system, an image processing method was used in this paper. A healthy subject's eye movement was detected, the prototype control command input device was made, and we verified its performance in experiments. From the experimental results, it was found that a healthy subject could appropriately operate the control device to control his wrist joint by FES.

Keyword: control command input device, eye movement, functional electrical stimulation (FES), image processing

1. Introduction

There are persons who had lost motor functions in their hands and feet by spinal cord injury in traffic accidents. And they want to restore their motor functions. Functional Electrical Stimulation, FES, system is one of effective tools for them [1], [2]. There are some devices to input the control commands for FES system. For example, breath switch, voice switch, up-and-down movement of shoulder switch and so on. Breath switch becomes cumber when we take a meal. Voice switch has danger of doing false input from ambient noise. Up-and-down movement of shoulder switch can not be used by disabled persons. Thus, these switches still have some problems. In this research, the control command input device using eye movements was developed. Specifically, a control command input program was improved, and a camera to detect eye movements was fixed to the user's head.

2. System Configuration

The basic configuration of FES system is shown in Fig. 1. The system consists of a CMOS camera, PC, and stimulator. The eye movements are captured with the CMOS camera, and the image processing process is programmed into the PC to detect the iris and pupil of user's eye from images [3]. Surface electrodes are used to conduct electrical stimulation to the muscles.

The image processing processes used in this paper are the YIQ transformation, binarization, labeling processing, and opening processing to decrease noises such as eyelashes [4]. The RGB color system of an image is transformed into the YIQ color system using the transform matrix:

$$\begin{bmatrix} Y \\ I \\ Q \end{bmatrix} = \begin{bmatrix} 0.299 & 0.587 & 0.144 \\ 0.595 & -0.276 & -0.333 \\ 0.209 & -0.522 & 0.287 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix} \quad (1)$$

If the eye was opened, a cross-shape mark was plotted at the center of the iris and pupil. A detection of the eye closures during blinking was set to the condition when the area of the iris and pupil was smaller than a certain threshold.

Person's basic eye movements are shown in Fig. 2. As a control trigger of the system shown in Fig. 1, the eye movements such as the fixation, levoversion, dextroversion, and supraversion as well as the blinking were chosen. This is because these movements can be intentionally generated. Control commands for FES system are composed of three commands, such as a selection command, execution command and proportional control command. The selection command is a command to select one from the predefined restoring motor functions of the paralyzed extremities in the FES system. The execution command is a command to perform a selection command, such as "start," "stop," or "hold." Allocation between the eye movements and control commands for FES system is shown in Table 1. The stimulator we made outputs electrical stimulation according to the user's eye movements.

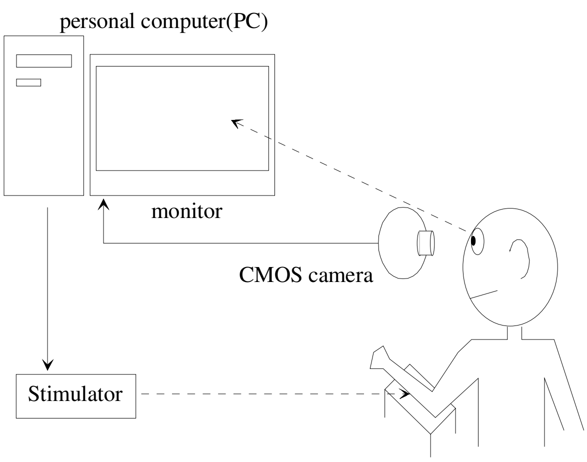


Fig. 1 Configuration of FES system.

An example of screenshots of the control command input is shown in Fig. 3. A stimulation level and the state of control command input are displayed in the image of captured with CMOS camera. The bullet-shaped regions are set as the regions to detect the levoversion, dextroversion, and supraversion of the eye movements, respectively.

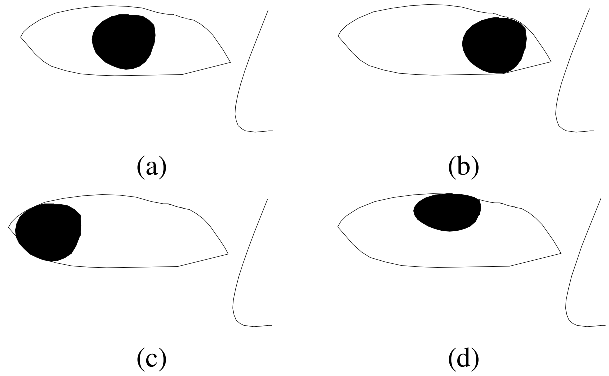


Fig. 2 Detected eye movements of (a) fixation, (b) levoversion, (c) dextroversion, and (d) supraversion.

Table 1 Allocation between eye movements and control commands.

Fixation	Wait
Levoversion, dextroversion	Increase or decrease in stimulation level
Supraversion	Selection mode
Blinking	Input

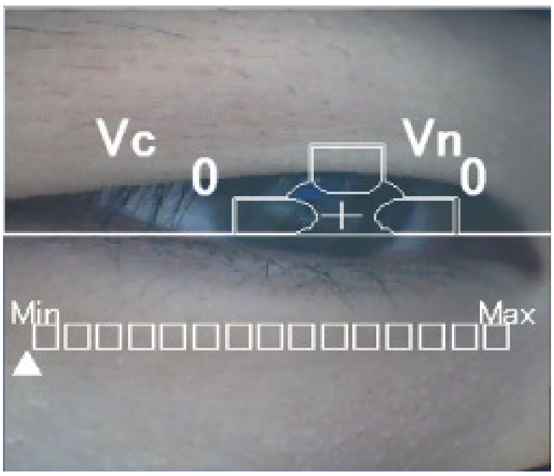


Fig. 3 Screenshot of control command input.

3. Method

Experimental setup is shown in Fig. 4. CMOS camera, USB-CAM30V, I/O DATA, was fixed to eyeglasses, and a healthy subject, 22-year old, male, put on them. The distance between the CMOS camera and his left eye was set to 7.0 cm. In the experiment, PC powered by the Pentium 4 processor of 2.8 GHz and RAM of 1 GB was utilized.

Surface electrodes, Vitrode M, Nihonkohden, were attached to his left arm, the stimulation level was changed while seeing the monitor display as shown in Fig. 3, and the changes of the angles of the left wrist joint caused by electrical stimulation were observed. Stimulus pulses with frequency of 20 Hz and pulse width of 200 us were applied to the muscle of the subject's left forearm through the surface electrodes. The stimulated left forearm was recorded by a digital video camera.

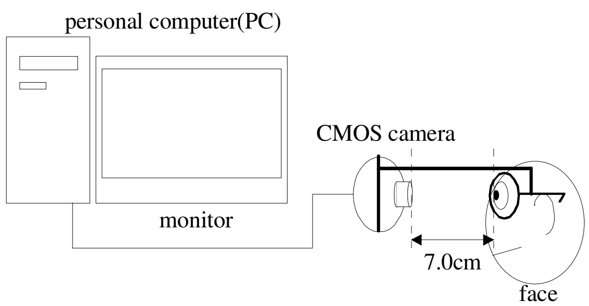
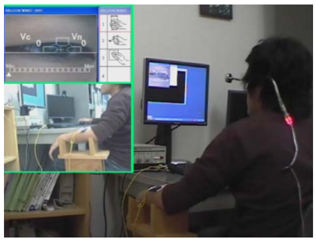


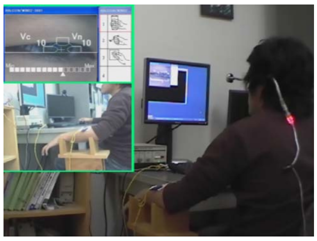
Fig. 4 Experimental setup.

4. Results and Discussion

An example of the experimental results is shown in Fig. 5. The images of the control command input on the screen and side view captured by the other video camera are also indicated. From the experimental result, we found that the left wrist joint began to go up when a certain constant stimulation level was exceeded, as shown in Fig. 5(b), and that the left hand could go up more than horizontal line of the subject's forearm, as shown in Fig. 5(f).

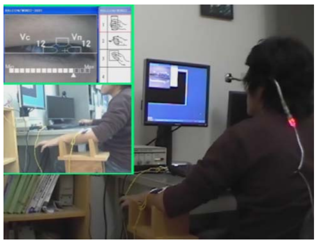


(a)

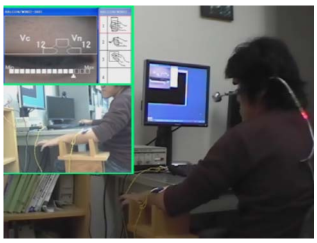


(b)

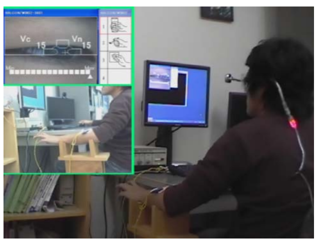
(c)



(d)



(e)



(f)

Fig. 5 Changes in angles of left wrist joint at (a) 0s, (b) 9s, (c) 11s, (d) 19s, (e) 21s, and (f) 29s, respectively.

5. Conclusion

It was confirmed from the experimental result that the experimental subject's tiredness was considerably decreased not only using the improved control command input program but also using the eyeglasses fixed the CMOS camera. We hope FES quadriplegic patients will be more comfortable to use FES system by using the control command input device we made. For our future work, some experiments with FES patients should be needed.

References

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