

# Man-Machine Interface Using Eyeball Movement

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**Abstracts** In this paper We propose one computer interface device for handicapped people. Input signals of the interface device are movements of eyeballs and head of handicapped. The movements of the eyeballs and head are detected by an image processing system. One feature of our system is that the operator is not obliged to wear any burdensome device like glasses and a helmet. The sensing performance of the image processing of the eyeballs and head is evaluated through experiments. Experimental results reveal the applicability of our system.

**Keywords** Human Interface, Eyeball Movement, Head Posture, Image Processing, Environmental Control System

## 1. INTRODUCTION

Nowadays, the increase of the aged people has become one of the notable social problems in Japan, and it should be noticed that many of them are handicapped in some meanings. Therefore, development of supporting devices and care equipments for the handicapped is desired. One difficult problem related with the development of such supporting devices is that the every handicapped people has various physical abilities. Therefore, supporting devices should be developed considering the ability of every handicapped people. One possible solution to cope with this problem is to develop interface devices between the handicapped people and the computer. Once it becomes possible for the handicapped people to communicate with the computer using some interface device friendly, the computer becomes a big help for them. Already some interface devices are developed for the handicapped people to communicate with the computer using some remaining physical abilities. Some devices use the simple breathing actions or patting actions of the handicapped as input signals. For the heavy handicapped people one interface device to use eyeball movements as input signals is proposed, considering that the eyeball movements are relatively easy to control even for the heavy handicapped people. Several techniques to measure the eyeball movements [1,2,5] are also reported. One technique is to use optical sensors those are mounted on a specialized helmet or glasses. However, wearing a helmet and glasses are not preferable and sometimes unacceptable for the handicapped because of some physical reason.

In this paper we propose an interface device to use eyeball movements as input signals. One feature of our system is that the image processing technique is employed to detect eyeball movements. Therefore, the camera is settled apart from the operator without forcing the operator to wear special glasses

or a helmet. The camera is used to detect the orientation of the eyeball and the blinking of the eyes. The information about eyes obtained by the image processor are used as input signals of the environmental control system for the handicapped people. This environmental control system can control the switching of the electrical devices like TV, radio, lights and so on. We named this system "Eye-Controller". Experiments to evaluate the accuracy of the detection of the eyeballs revealed enough performance to use for the handicapped people. Another feature of our system is that the 3-dimensional movements of the head is also used as input signals to the interface device. The information about head movement is useful to enhance the accuracy of detecting the eyeball movements and also simplify the input operation to the interface system. In case that the operator is able to move his head intentionally, the head movement simplify the input operation remarkably.

In order to enable stable 3-dimensional measurement of the head movement, two marking points are settled on the forehead of the operator. One camera obtains the image of the operator's face. Of course, both eyes of the operator and two marking points on the forehead need to be included in the image. Computer analyses the images and determines the 3-dimensional posture and position of the head.

We tested our interface device at a training facilities for the handicapped. Experimental results was satisfactory.

## 2. CONFIGURATION OF INTERFACE DEVICE

The interface between the handicapped people and the computer using the head and eyeball movements can be realized using an image processing technique. In Fig.1 the configuration of our interface device is shown, where a TV camera is settled in front of the operator to detect the image of

the operator. The operator can select the menu which is displayed on the TV monitor.

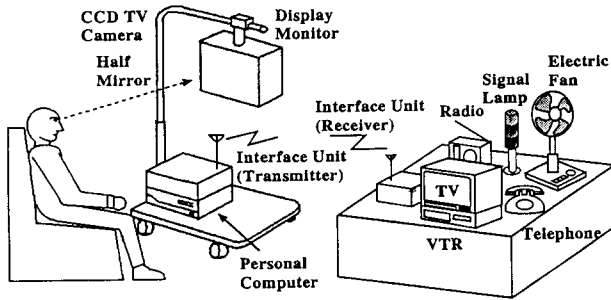


Fig.1 Configuration of interface device

One example of the menu on the TV monitor is shown in Fig.2, where five items are shown. A handicapped operator faces the display monitor and selects one menu item among menu items by gazing at it and by blinking his eyes for confirmation. Suppose the operator selects the third item (Telephone) in Fig.2, the next sub-menu is displayed on the display monitor as shown in Fig.3. Suppose the operator selects the second menu item (family), the interface device starts to connect the telephone line with his family automatically. Similarly every item on the menu has sub-menu if necessary.

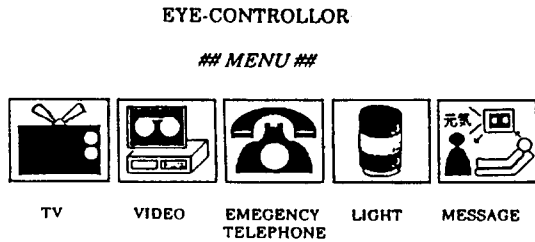


Fig.2 Main menu

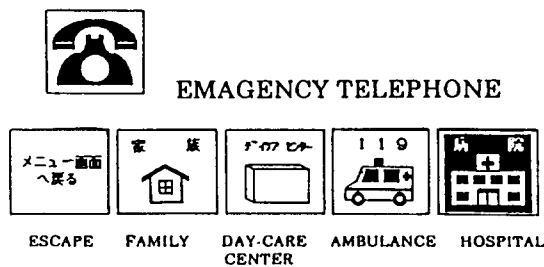


Fig.3 Sub menu(Telephone)

In Fig.4 the block diagram of our interface device is shown. In order to enable fast and tactful image processing, the image data are processed using a personal computer (NEC PC 9801 AN,90MHz Pentium processor) and a real-time image processor. The real-time image processor is composed of a FPGA (Field Programmable Gate Array) and its main function is real-time labeling operation (1/30 sec) on the binary image data (512h × 256v). Due to this function, fast detection of the eyeball movement and marking points on the forehead of the operator are simplified remarkably.

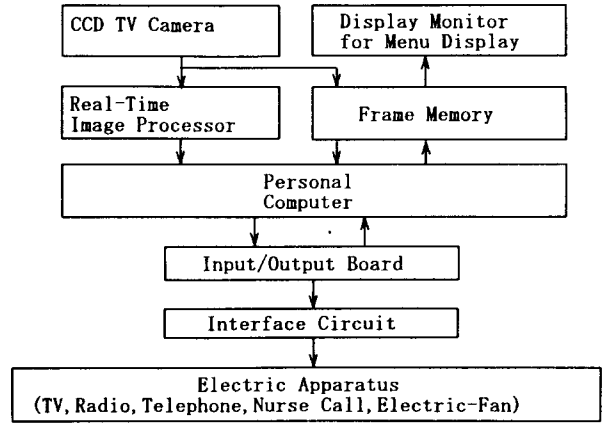


Fig.4 Block diagram

### 3.MEASUREMENT OF EYEBALL MOVEMENT

#### 3.1 Algorithm to detect eyeball movement

Two important image processings of our interface device are how to detect the position of the eyes in the image and how to detect the orientation of the eyes. Considering that the operator is apt to blink his eyes during the operation of the interface device, one simplified technique is introduced to detect the position of the eyes. At the beginning of the operation, the operator is requested to blink his eyes a couple of times. During the blinking, the real-time image processor performs the subtraction of two-sequential images. For the resultant image, conversion into binary image data and the labeling procedure is executed. Suppose head movements are negligible, position of the eyes can be detected easily using the above labeling procedure.

Once the position of the eyes in the image are detected, the image of the eyeball is analyzed in detail and orientation of the eyeball is measured. It should be noticed that detection of the eye position using eye-blinking needs not to be executed in the subsequent measurements. Because the image processing is executed quickly (1/30 sec) and the position of the eyes at the next measuring instant is easily estimated from the previous image analysis.

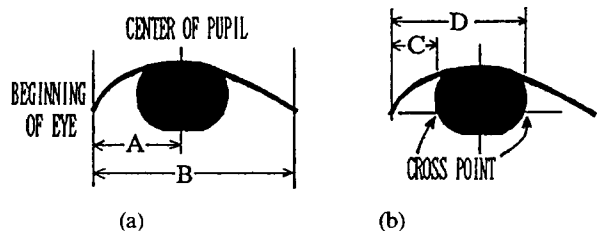


Fig.5 Definition of parameters

In order to detect the orientation of the eyeball, the parameter  $R$  defined as  $R = A / B$  is introduced, where  $A$  is the distance between the beginning of the eye and the center of the pupil and  $B$  is between the beginning of the eye and the tail of the eye. This definition is illustrated in Fig.5(a). The

positions of the pupils are detected as the midpoint of two cross points, which are explained in Fig.5(b).

### 3.2 Experiment of parameter R

Relation between the orientation of the eyeball and the parameter R is checked by experiments.

The display monitor was settled 50cm apart from the operator. Five menu items are horizontally arranged with 52mm interval on the display monitor (as is illustrated in Fig.6). Under the condition that an operator gazes at the center of menu items, the parameter R (orientation of eyeball) is measured by the image processing.

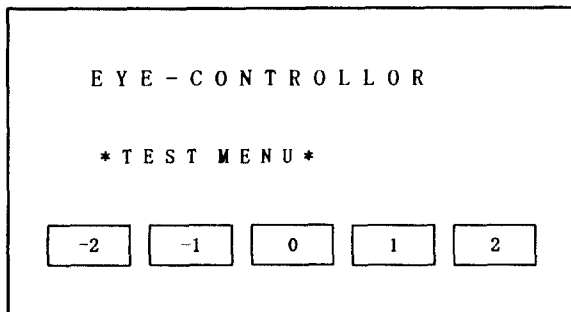
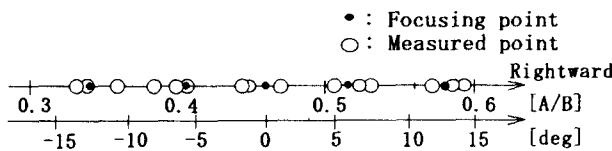


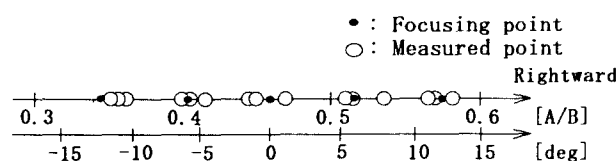
Fig.6 Test menu

In Fig.7(a) experimental results obtained by measuring only right eye are shown. In Fig.7(b) experimental results obtained by measuring both eyes are shown. These results mean that measuring one eye is enough to recognize which menu item is gazed at. The results also mean that the detecting performance increase if both eyes are measured.

Considering the experimental results, handicapped people tested our environmental control system. Only in the case that the head of the handicapped people was fixed enough, the performance was satisfactory.



(a) Focusing angle measured using right eye



(b) Focusing angle measured using both eyes  
Fig.7 Focusing angle measured using both eyes

### 4. MEASUREMENT OF HEAD MOVEMENT

From the experimental results, it became clear that orientation of the eyeball can be detected satisfactory only in the case that the movement of his head is negligible. However, movements of the head is inevitable. Practical interface device should deal with the movements of the head in order to enlarge the application field of this system. It is also important that if the movement of head can be used as the control signal of the interface device, the device becomes more friendly with the handicapped.

In the followings we explain how to detect the 3-dimensional position and posture of the head. Two marks are attached on the forehead of the operator so that these two marks and two eyeballs compose a parallelogram (see Fig.8). By measuring the direction of these two marks and two eyeballs using a TV camera, the 3-dimensional posture and position of this parallelogram can be readily determined as follows.

Suppose the position vectors of the four corners of the parallelogram are  $p_i (i=1,2,3,4)$ . The direction vector of these four corners can be measured as  $q_i (i=1,2,3,4)$  by the camera. From the geometric relation that  $p_1-p_2$  runs parallel with  $p_4-p_3$ ,  $p_i$  are determined as the  $p_i=k_i q_i$  where  $k_i$  are scalar numbers. Scalar numbers  $k_i$  can be readily obtained from the following relation and actual length of  $p_1-p_2$  and  $p_4-p_3$ .

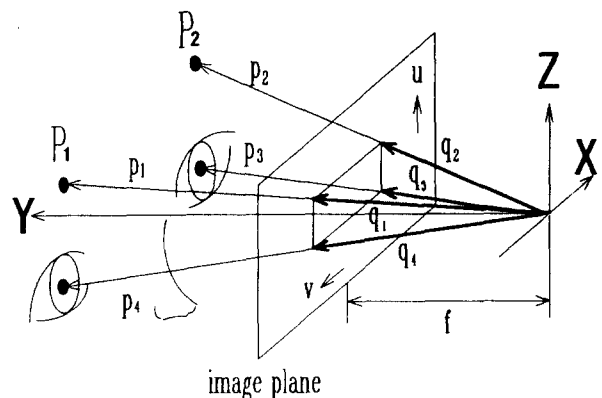


Fig.8 Geometry of two marking points

$$k_1/k_4 = (q_4 \times q_3) \cdot q_2 / (q_1 \times q_3) \cdot q_2$$

$$k_2/k_4 = (q_4 \times q_3) \cdot q_1 / (q_2 \times q_3) \cdot q_1$$

$$k_3/k_4 = (q_4 \times q_2) \cdot q_1 / (q_3 \times q_2) \cdot q_1$$

Since 3-dimensional positions of the marks on the forehead and eyes can be determined, the 3-dimensional position and posture of the head, and also distortion of the parallelogram are determined. It is important that the distortion of the parallelogram gives the information about orientation of the face.

We had experiments using a mannequin instead of an operator. The mannequin head was settled toward five different directions. Firstly, the head was settled rightward with

15 degree and the orientation was measured by the image processing. Similar experiments were executed with different orientation. The results are shown in Fig.9. While the results were obtained using a mannequin, the accurate to detect the orientation of the eyes was less than  $\pm 5$  degree.

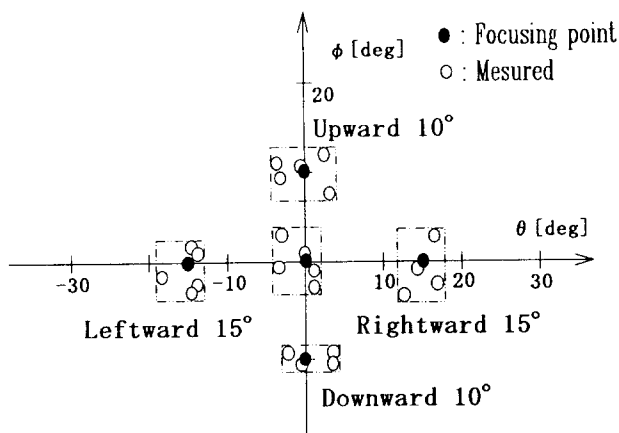


Fig.9 Experimental result to detect orientation of head

### 5.FIELD TEST

We built one Eye-Controllor. Considering the usage at the bedside, a thin liquid crystal display monitor, a TV camera and half mirror are united in a box.

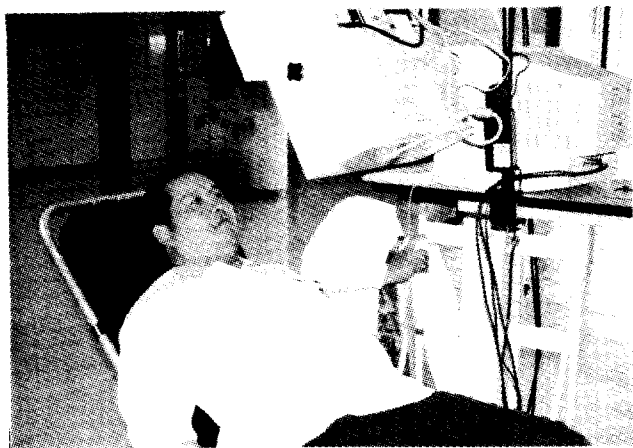


Photo.1 Test scene 1

Three heavy handicapped people tested the interface device. The first and the second people laid himself on the bed during the experiment (see Photo.1). Using the movements of eyeball, they succeeded to communicate with the computer without any trouble. The third woman on the wheel chair had some difficulty to communicate with computer (see Photo.2). One reason of this difficulty was that she was not able to gaze at one desired menu item because of convulsive movements. However, she could operate the system using head movements. She moved a cursor to a menu item on the display monitor by facing to the right and left and clicked the desired menu by nodding her head.



Photo.2 Test scene 2

### 6.CONCLUSIONS

A new environmental control system to use eyeball movement without wearing any device was developed. Detection of eyeball movements and the direction of the head became possible by the image processing. Even if an operator's face inclines or moves, it became possible to control personal apparatus by using eyeball movements. Moreover, it became possible to operate the system by using head movements. We built a test system in order to apply our environmental control system for the daily use. It was possible for handicapped people to operate our environmental control system in the bed side. The system needs to be adequately modified considering the physical abilities of the operator. Furthermore, the system needs to be more compact, cheap and reliable. This themes are now under study.

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