Computer Interface to Use Head Movement for Handicapped People

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Abstracts: *In this paper we propose one computer interface device for handicapped people, which enables the operator to communicate with the computer without typing on the computer keyboard. Input signals of the interface device are movements of the head and breathing of the handicapped operator. The movements of the head are detected by an image processing system.One feature of our system is that the operator is requested to wear a special glasses which has three LED marks. Due to the special geometry of the LED marks, the 3-dimensional posture and position of the glasses can be detected by a simple image processing algorithm. The movement of the head is used as a positioning signal of the computer cursor on the computer monitor. Breathing of the operator is used as a switching signal. Using this interface device, we built an environmental control system and also word processing system. Experimental results reveal the applicability of our system.*

1. INTRODUCTION

Nowadays, the increase of the aged people is one of the notable social problems in Japan, and it should be noticed that many of them are handicapped in some meanings. Therefore, developement of supporting devices and care equipments for the handicapped is desired. One difficult problem related with the development of such supporting devices is that handicapped people have various physical abilities. Therefore, supporting devices should be developed considering the remaining ability of the user who intends to use the supporting device. 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 friendly, it is sure that 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 interface devices use the simple breathing actions or patting actions of the handicapped as input signals. For the heavy handicapped people an interface device to use eyeball movements as input signals is proposed. In case that the operator is able to move his head intentionally, the head movement can be input signals of the interface device.

In this paper we propose an interface device to use head movements as input signals. One feature of our system is that the operator is requested to wear a special glasses which have three LED marks. Due to the special geometry of the LED marks, the 3-dimensional posture and position of the glasses can be detected by a simple image processing algorithm.

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Since the algorithm is simple, the algorithm can be realized on one chip field programmable gate array to realize the system in a compact body. The movement of the head is used as a positioning signal of the computer cursor on the computer monitor. Breathing action of the operator is used as a switching signal.

As one application of our interface device, we built an environmental control system for the handicapped people. This environmental control system can control the switching on and off of the electrical devices like TV, radio, lights and so on. Furthermore, we tested our interface device as character data input device, where alphabets are displayed on the computer monitor and the operator selects the desired alphabet using the head movement.

2. CONFIGURATION OF INTERFACE

The configuration of our interface device developed here is shown in Fig.1, where a TV camera is settled in front of the operator to detect the head movement of the operator. In order to enable stable and accurate operation of the interface device, three-dimensional posture and the position of the head movement is measured. Therefore, the operator is requested to

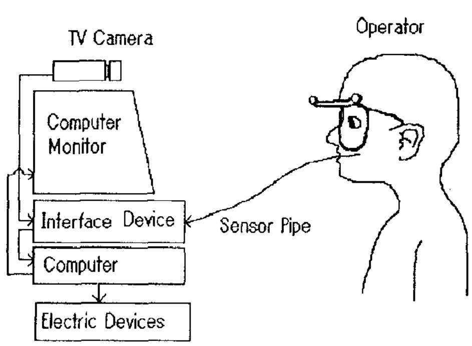

Fig.1 System Configuration

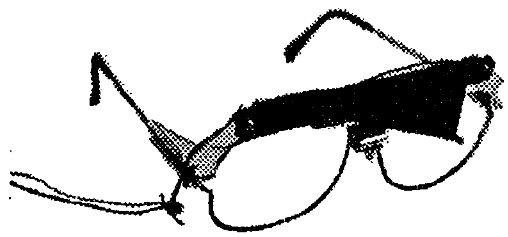

Fig.2 Glasses with three LED marks

wear special glasses. On top of the glasses three LEDs (light emitting diode) are mounted to compose a triangle as shown in Fig.2. Three LEDs to emit infrared red and the optical filter on the camera simplifies to detect the position of three LEDs on the image plane.

It is possible to calculate the three-dimensional position and posture of the glasses by the raster coordinates of three LEDs. From the three-dimensional position and the posture of the glasses, the focusing point on the TV monitor by the operator is estimated. From the estimated data, the position of the computer cursor on the TV monitor is determined. Therefore, the operator can specify the position of the computer cursor on the TV monitor only by moving his head, in stead of moving the computer mouse by hand. After positioning the computer cursor onto the desired menu item, the operator can activate the menu item by blowing action. The blowing signal is detected by a pressure sensor via a pipe.

One example of the menu on the TV monitor is shown in Fig.3, where five items are displayed. A handicapped operator faces the display monitor and selects one menu item among menu items by moving his head and by blowing action. Suppose the

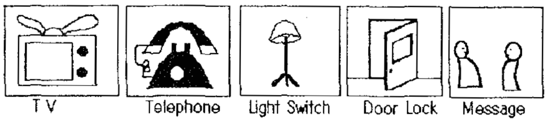

Fig.3 Menu items

operator selects the second item (Telephone) in Fig.3, the next sub-menu is displayed on the display monitor. Suppose the operator selects the one menu item (family) in the sub menu, the interface device starts to connect the telephone line with his family automatically. Similarly every item on the menu has sub-menu.

3. MEASUREMENT OF HEAD MOVEMENT

3.1 Detection of LED's marks

In order to build the interface device in a compact body and also realize real-time image processing, raster coordinates of three LED marks on the glasses are detected by one tip field programmable gate array (FPGA;Xilinx,XC4003A). This means that all image processing are executed only by one IC tip. The raster coordinates of three LED marks can be detected 30 times per one second. The FPGA detects the raster coordinates of mid-points of blinking spots , whose block functions are shown in Fig.4.

3.2 Determination of 3-D position and posture

Since the geometrical relation of three LED marks

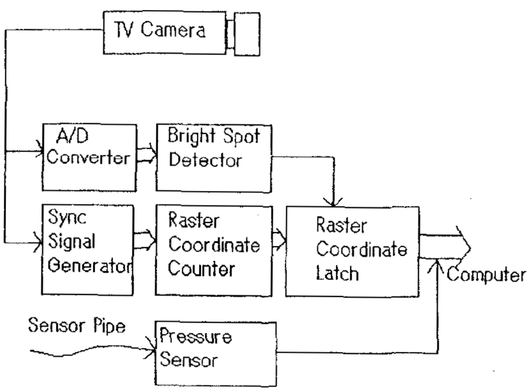

Fig.4 Block Function of Interface Device

on the glasses is known in advance, the three-dimensional position and the posture of the glasses can be determined by the raster coordinates of three LED marks analytically. The solution can be obtained as a solution of four-dimensional algebraic equation. We had an experiments to test the accuracy of pointing by using our specialized glasses. The glasses is located 600mm apart from the TV camera. And the azimuth and tilt angle of the glasses is specified from -30 degree to 30 degree with 15 degree step.

The result is shown in Fig.5. Absolute error was less than 4 degree. Repeatability is assured with error 0.5 degree.

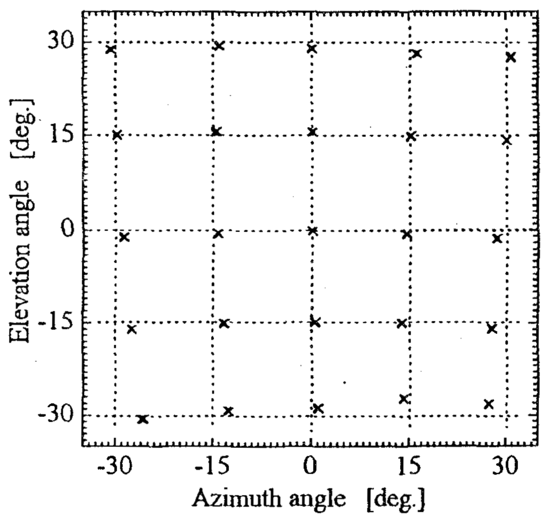

Fig.5 Accuracy of Pointing by Glasses

3.3 Algorithm to move computer cursor

In order to develop a system with simple hardware configuration, our system employed a simple heuristic algorithm. Considering the special geometry of the LED, the three-dimensional posture of the glasses can be estimated heuristically . In case the operator is facing toward the camera, the three LEDs are observed on the line as shown in Fig.6(e). In case the operator is facing upward, three LEDs are observed by the TV camera as shown in Fig.6(b). In case the operator is facing upward and leftward, three LEDs are observed by the TV camera as shown in Fig.6(a). Therefore, we

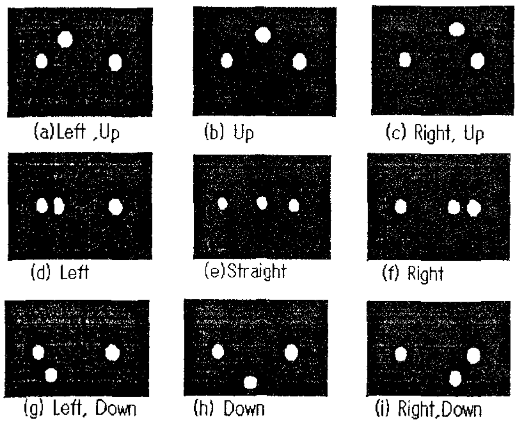

Fig.6 Images of LEDs

employed the following algorithm to move the computer cursor on the computer monitor.

(Proc.1) Obtain raster coordinates (ui,vi) i=1,2,3 of three LEDs .

(Proc.2) Calculate the raster coordinate of the middle point C of the right and left LEDs (i=1,3) and the length L1 and L2 on the image plane, those are defined in Fig.7.

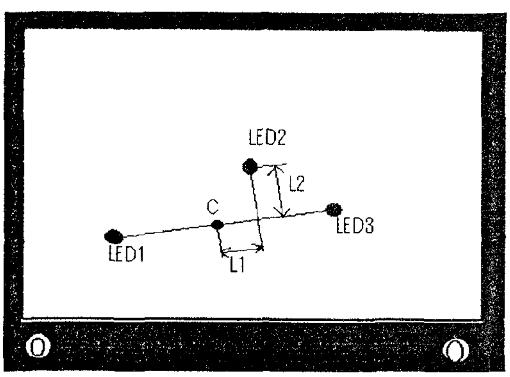

Fig.7 Parameters to determine 3-D posture

(Proc.3) The position of the computer cursor on the computer monitor is specified by the following equation.

$$U = L_2 * k_1 + U_c * k_2$$

$$V = L_1 * k_3 + V_c * k_4$$

where coefficients ki (I=1,2,3,4) are determined experimentally so that the movement of the computer cursor is reasonable to the operator.

5. FIELD TEST

We had tests using our interface system. Considering the usage beside the bed thin liquid crystal display monitor, a TV camera and half mirror are united in a box as shown in Fig8. This system is used as an environmental control system for heavy handicapped peoples. Three heavy handicapped people tested this system. All of them satisfied the performance of our system.

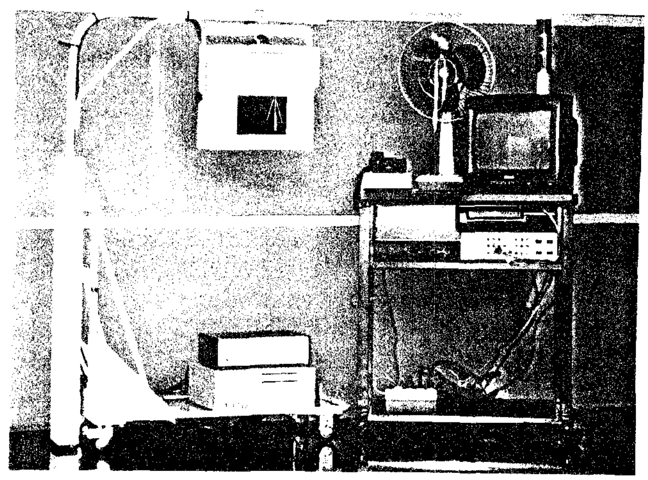

Fig.8 Environmental Control System

Furthermore, we applied interface device to select desired alphabets on the computer monitor as shown inFig.9.

Fig.9 Alphabet Input Test

One operator had some training for about twenty minutes. After the training , the operator had no difficulty to write some messages using our interface device.

6. CONCLUSIONS

A new environmental control system to use head movement was developed. While the operator is requested to wear specialized glasses, detection of three-dimensional head movements is readily realized by the image processing of three LED marks on the glasses. It was possible for handicapped people to operate our environmental control system in the bed side. Furthermore, it is important to note that the real time image processing system can be realized compact , cheap and reliable by employing a FPGA chip. Since our system requires the operator's ability to move his head intentionally, the system needs to be adequately modified considering the physical abilities of the operator.

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