Evaluation of Tooth-touch Sound and Expiration Based Mouse Device for Disabled Persons

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Abstract— **This paper presents an evaluation of a mouse interface device using tooth-touch sound and expiration signals, which we developed as a pointing device for disabled persons. Our device enabled disabled persons to operate a personal computer easily using a mouse driven by their tooth-touch and expiration. It also had superior features, being easy to handle, light weight, user-friendly and inexpensive to make. The performance of our device was evaluated using Fitts' law, which estimated the comparative usability of the pointing device against that of a conventional ball-type mouse. Finally, we designed a rounding-type menu to improve the input efficiency of the device and apply it in a TV controller. We then compared the input velocity of our device against that of a conventional mouse.**

Keywords — interface; Fitts' law; disabled persons; tooth-touch sound; expiration

I. INTRODUCTION

The Internet has become an important part of our daily lives. Personal computers can be used to easily get a lot of information and communicate between family and friends. Among users, disabled persons are interested in accessing multimedia on the Internet. Therefore, the Internet is essential technology for disable persons to improve their Quality Of Life (QOL). A mouse is usually used as a computer interface to select icons on a display and execute programs by clicking the mouse button. As a result, the ability to use a mouse is important to disabled persons. However, as hand operation is needed to control a conventional mouse, disabled persons may not use the mouse easily. It is necessary to develop new input devices instead of a hand-operated mouse. Several types of mouse for disabled persons have been devised. For example, Dmitry et.al. developed a mouse device using vision-based technology [1]. The mouse cursor position could be controlled by multiple eye blinks and nose movement was used for clicking operation. However, it was sensitive to external disturbance, such as the brightness of the room and users' movements.

Recently, we proposed a hands-free, man-machine interface device, utilizing expiration in conjunction with tooth-touch sound signals, which we had been developing [2,3]. This device utilized the bone conduction signal collected by a bone-conduction microphone for clicking operation of the mouse, and the expiration signal gathered by piezo-film sensors to control the mouse cursor position. The proposed device met the following conditions required by disabled persons: Low cost, good fitness, ease of handling. A prototype device was constructed and its usefulness as an input device for a character input system [2] tested. We designed the tooth-touch sound and expiration-based mouse device system using VHDL and applied it using an FPGA chip.

This paper presents a performance evaluation of our device for disabled persons. The well known model used for evaluation and prediction was Fitt's law [4]. Most research evaluating interface devices by Fitt's law was for hand-operated interface devices, such as a mouse, pen with small tablet, trackball or joystick. A tooth-touch sound and expiration based device had not been evaluated by Fitts' law. The objective of our research was to make obvious whether or not the pointing performance of our device adhered to Fitts' law and to devise a graphical user interface to improve input efficiency.

This paper is organized as follows: In section 2, we present the device architecture of a mouse driven by tooth-touch sound and expiration signals. In section 3, the performance of the mouse interface device is evaluated. First we investigate the characteristics of the velocity of the mouse driven by expiration. We then examine whether pointing operation of the device driven by expiration followed Fitt's law or not. In section 4, we apply our device in a TV controller and evaluate its performance. Section 5 outlines our conclusions and potential development.

II. DEVICE ARCHITECTURE

A schematic diagram of the tooth-touch sound and expiration based input device for disabled persons is shown in Figure 1. It consisted of several parts, namely the tooth-touch sound signal and expiration signal input/detection circuits and the USB interface circuit to connect with a PC. In this section we review its principal operation [3].

A. Tooth-touch sound detection

The bone conduction microphone picked up not only the tooth-touch sound, but also the user's voice and noise. The frequency spectrum of tooth-touch sound overlapped with that

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of the voice signal. Therefore it was difficult to detect only the tooth-touch. We developed a novel method for white noise suppression by dyadic wavelet transform in conjunction with the signal adaptive threshold technique. Figure 2 shows the output pulse signal, where even small tooth-touch sounds could be detected.

B. Expiration signal detection and pulse generator, depending upon expiration amplitude.

Figure 3 shows an example of an expiration signal and a pair of signals for moving the mouse cursor. To improve the usability of the input device, we modified the control method to adjust the mouse cursor position more intuitively, adapting to the amplitude of the expiration signal. When stronger expiration was applied to the sensor, more pulses were output and as a result the cursor moved more quickly.

III. DEVICE PERFORMANCE EVALUATION

The most well known model used for pointing task evaluation and prediction is Fitts' law, on which the following formula is based.

$$MT=a+bID \qquad (1).$$

MT denotes the time a subject takes to move a pointing device from one target to another. *a* and *b* are empirically determined constants. *ID* is the index of difficulty for the task, which can be presented as:

$$ID=\log_2(1+D/W) \qquad (2)$$

This model is called the ID model. Here, *W* is the target width and *D* is the distance between the two targets, as shown in Figure 4. The experiment to evaluate the pointing performance of our device was executed according to Fitts' law.

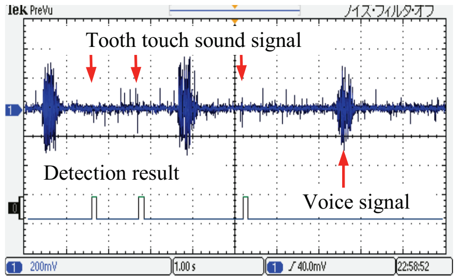

Figure 2. Resulting tooth-touch sound signal detection from bone-conduction signal corrupted by voice signal.

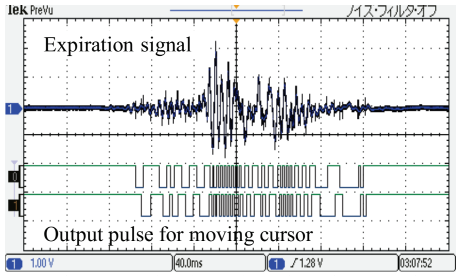

Figure 3. Example of expiration signal and control signals for moving mouse cursor.

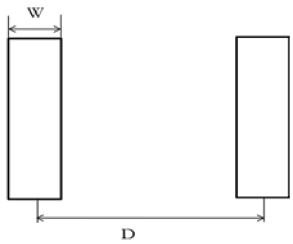

Figure 4. Two targets used in pointing task experiment.

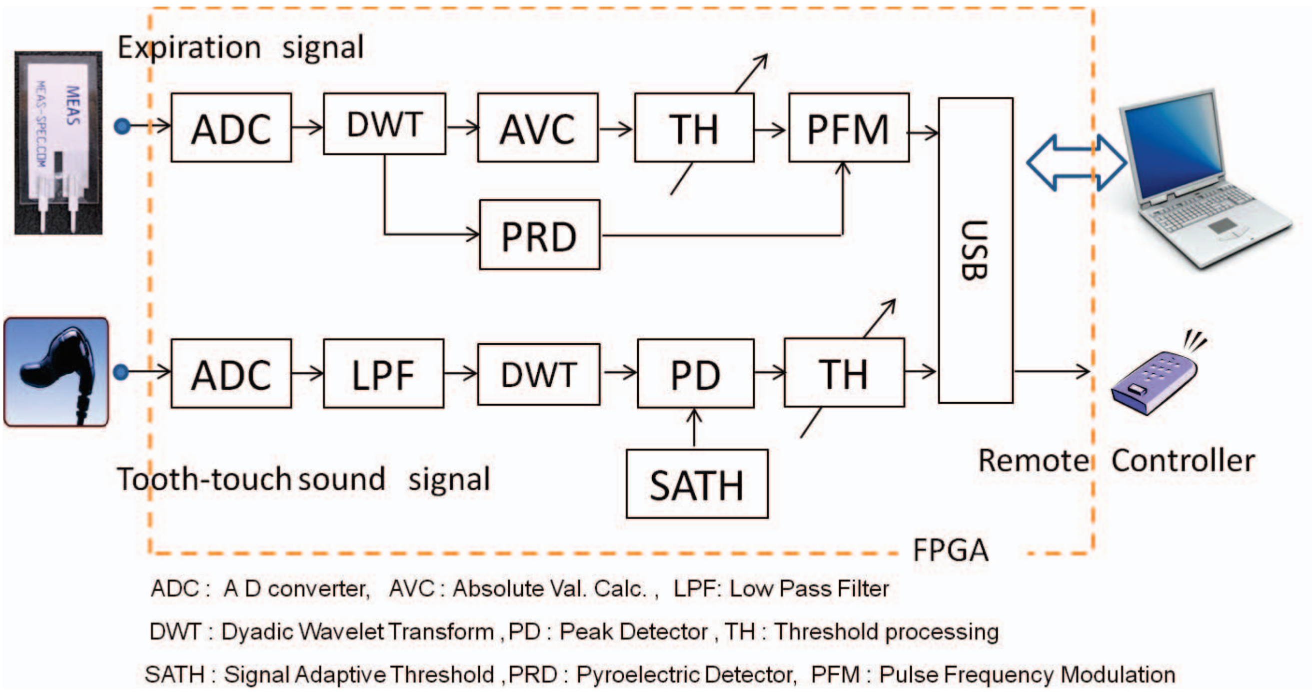

Figure 1. Schematic of tooth-touch sound and expiration based interface device.

A. Subjects

Six healthy, 20 year old students, 3 female and 3 male, participated in the experiment. All the subjects were right hand dominant.

B .Equipment

Equipment used in the experiment included a note-type personal computer (PCG-6V2N Sony Corp.), a tooth-touch sound and expiration-based device and a ball-type mouse device (M-M1UWH/RS Elecom EU Corp.) as a reference input device. The 13.3 inch screen size LCD display of the computer had a resolution of 1280×768 pixels.

C. Design

The combinations of different width (W) and distance (D) between the two targets were set at W = 45, 65, 75 pixels and D = 100, 240, 400, 540 pixels, as shown in Table 1. The order of the twelve width and distance combinations was randomized.

D. Test Procedure

Prior to the test, the participants reciprocally pointed with the device to a pair of rectangle targets which appeared on the screen of a PC for ten minutes to develop familiarity with the tooth-touch and expiration based device. After a left hand side target was clicked by tooth-touching, a cursor was moved to the right hand side target by expiration. When the cursor came into the target area, a pointer was clicked by the tooth-touching again. The interval time between the first and second tooth-touching was measured. Twelve tests, with varying width and distance, were executed and repeated three times each.

E. Results

The typical experimental characteristic of the velocity of the two devices is shown in Figure 5. The conventional ball-type mouse had one peak velocity, as shown in this figure. Users moved a cursor quickly at the beginning and before arriving in the target area the cursor was controlled carefully. The velocity of the proposed device did not have any peaks and the users' expiration for control of the cursor did not vary dramatically over time. Figure 6 shows the average movement time (MT) measured, corresponding with the distance between the targets, for various target widths (W). The MT increased with the distance (D) and as the target became narrower. The regression lines for the two devices were linear and correlation coefficients were R1=0.81 for the conventional mouse device and R2=0.67 for the proposed device. The coefficient for the proposed device was smaller because users spend time aligning the cursor due to the narrow width, resulting in variable MT between people. Conversely, it was easy for people to do the tasks with the conventional ball-type mouse, resulting in small variation in MT between people. In Figure 6, we can see the interval time for our device was 4 times longer than that for the conventional one.

$$MT1=3.24+0.37ID,\quad Cor.Coefficient\ R1=0.67$$

$$MT2=0.53+0.11ID,\quad Cor.Coefficient\ R2=0.81$$

The average movement time (MT) for each D and W combination is shown in Figure 7. In Figure 7, A1 to C4 indicate the twelve different combinations of D and W. The respective IDs of the twelve combinations (from A1 to C4) are listed in Table 1.

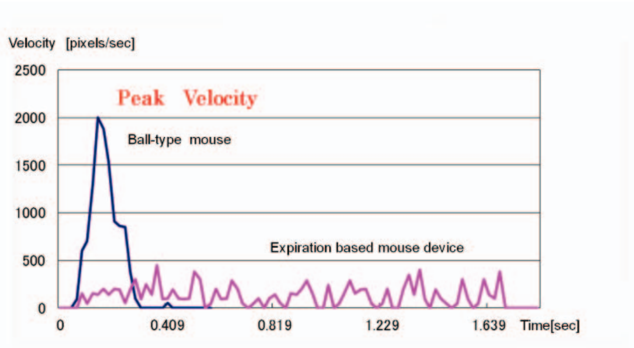

Figure 5.Typical characteristics of velocity of two input devices.

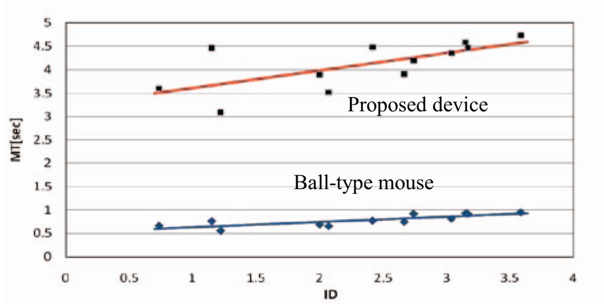

Figure 6. Regression lines for the two tasks using ID model.

Table 1. Different D-W combinations for performance evaluation.

Combinations	A1	A2	A3	A4	B1	B2	B3	B4	C1	C2	C3	C4
D(in pixels)	100	240	400	540	100	240	400	540	100	240	400	540
W(in pixels)	45	45	45	45	65	65	65	65	75	75	75	75

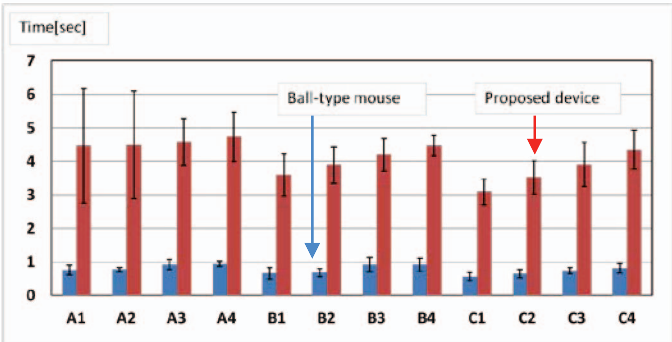

Figure 7. Average movement time of each combination for two input devices.

IV. Application in TV control and performance evaluation

To precisely align a mouse pointer in a target area using 3 sensors was difficult, especially right and left side sensors.

This was because the users had to input by changing the form of their mouths. Therefore, we designed a rounding-type menu to improve usability and input efficiency, using only one piezo film sensor and turning the channel menu in only one direction. Figure 8 shows the test image for evaluation of our device using the rounding-type menu. Users were requested to adjust the channel number displayed in a text box, called Input CH No., as shown in the image. They then selected a channel number from the rounding-menu using expiration, and finally clicked a mouse button by touching their teeth. The interval times between one click and the successive click were measured. Tests were carried out 20 times each, using the following four kinds of task: T1 was to select the successive channel number. T2 was to skip the next channel. T3 was to skip two channels. T4 was to input the channel number which randomly appeared in the Input CH No. box. The channel numbers went round in only one direction. Therefore, if the user failed to select the correct channel number, they had to continue blowing past a full circuit of numbers. Figure 9 shows the arrangement for TV control using our device.

Increasing the number of channel-skips, the interval time became larger. However, T1 showed the largest deviation in time. Conversely, T2 and T3 had smaller deviation. This was because the number of channel-skips was one for T1, making it difficult to control the cursor pointer and variable between people. T2 and T3 had enough channel-skips to control easily. For task T4, the random input test, it took some time to recognize which channel number to select. The interval time when using the proposed device was a little higher than when using the ball-type mouse device. From Figure 10 we can see it took about 3 to 11 seconds using our device, compared with 2 to 4 seconds using the ball-type mouse.

V. CONCLUSIONS AND POTENTIAL DEVELOPMENT

We evaluated the pointing performance of our device using tooth-touch sound and expiration, in comparison with that of a conventional mouse. First, the MT was measured experimentally using Fitts' law, and compared with the MT when using a ball-type mouse. The resulting MT for our device, used by health persons, was 4-times longer than that for a conventional mouse. To improve pointing efficiency we designed a rounding-type menu selection and evaluated its performance. The result showed that the rounding-menu selection input interface could improve the input efficiency and be adopted with our device. Further evaluation of the usefulness of the device for disabled persons and modification of Fitts' law for more accurate evaluation of the device is necessary.

ACKNOWLEDGMENT

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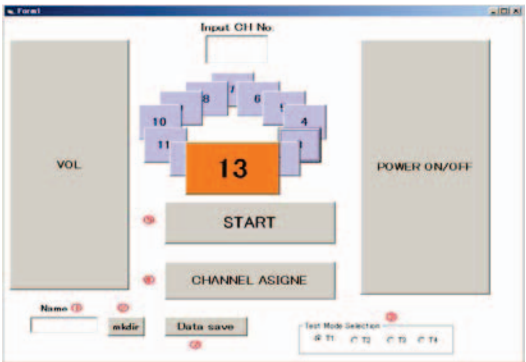

Figure 8. Rounding-type menu for TV control.

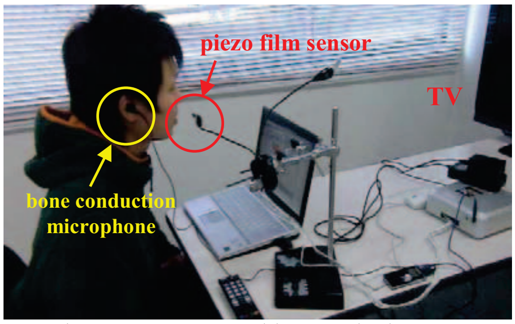

Figure 9. TV control by our device.

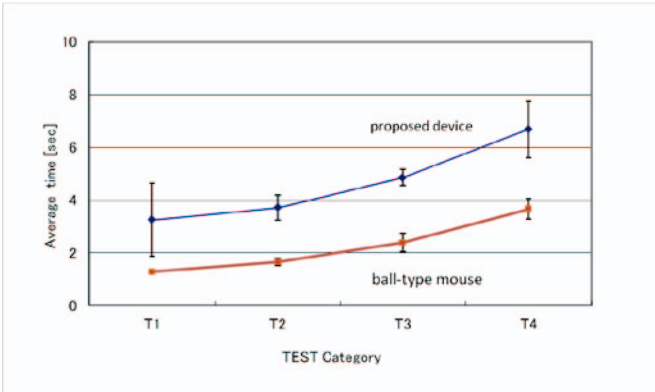

Figure 10. Average interval time for several kinds of tasks.

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