Head Mouse System Based on Gyro- and Opto-Sensors

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Abstract—**We proposed the mouse to control a computer mouse with head rotations and eye blinks so that the severe disabled person can use a computer. We compared the performance of the proposed mouse to that of a general computer mouse and to that of alternative mouses such as Quick glance using eye movements and a Camera mouse using face movements. The mouse positions were estimated using gyro sensors that can measure the angular velocity of head rotations, and mouse events such as clicks/double clicks were detected using opto-sensors that can detect blinking of the eyes. We could eliminate the need to perform the cumbersome task of periodically removing the accumulated error. We facilitated intuitive control of the mouse by using a nonlinear relative coordinates system with dead zones. We added circuitry to opto-sensors for event detection in order to reduce the influence of the ambient light changes. As a result, we could increase the mouse movements and events accuracy. The proposed mouse showed superior performance about 21% in the experiment of the 20 times clicks, about 25% of Dasher, and about 37% of on-screen keyboard, respectively. The mouse is also better than Camera Mouse, which is used along with a web cam.**

Keywords- Gyro-sensor; human computer interface; gaze tracker

I. INTRODUCTION

The development of the computer made human life more comfortable. Using computers and the Internet has become a part of our daily routine. People even use computers for shopping and banking. People with severe disabilities such as paralysis of their upper extremities cannot efficiently use computer input devices such as a keyboard or a mouse; meanwhile, the Internet is playing an important role in preventing such users from being isolated from the society by providing new information and serving as a communication channel [1, 2]. The development of a computer GUI (graphic user interface) that includes a touch screen and various alternative input devices whose operation is based on movements of the head or eyes has made it easier for users with the abovementioned disability to use computer input devices.

There are two types of alternative input devices. The first type of device functions by a direct method in which behavior information such as information on the movement of the head or eyes is used; many sensors such as tilt sensors, gyro sensors, incline, accelerometers, optical sensors, imaging sensors, magnetic sensors, or ultrasonic sensors can be used to directly obtain information on movements. The other type of device functions by an indirect method in which biosignals such as electroencephalograph (EEG), electrooculargraphy (EOG), and electromyography (EMG) signals are used [3, 4]. These methods require physical contact with electrodes, which is a very serious drawback.

The advantages and disadvantages of these methods have been mentioned in previous papers [2, 4-12]. A review of these papers reveals that for detecting mouse movements, the gyro sensor is more effective than sensors whose operation is based on the use of biological signals and for detecting mouse events, the opto-sensor is better than sensors whose operation is based on the use of the sip & puff method because of hygiene problems in the latter type of sensors. The rotation of the user's head is estimated using the gyro sensor and used to control mouse points. The information obtained from the sensor is converted from the angular velocity to an angle by integral operation. However, the cumulative error due to integration must be initialized by the user to prevent the error from increasing. The mouse events only using movement sensor (acceleration or gyro) method isn't easy to control the exact mouse position.

To solve these problems, we used a nonlinear relative coordinates system with dead zones so that the cumbersome task of periodically eliminating the accumulated error need not be carried out. An active light source and opto-sensors were used to reduce the effect of changes in ambient light and to solve the hygiene problem by using a noncontact method for detecting mouse events (e.g., clicks and double clicks), respectively.

II. EXPERIMENTAL METHODS

A. Mouse pointer control using the gyro sensors

There are several sensors that are used for measuring head movements, such as accelerometers, gyro sensors, tilt sensors, and digital goniometers. In the preliminary stages of this study, we compared the characteristics of each sensor according to head movements, and we chose the gyro sensor (ENV05G, Murata, Japan).

Signals generated by the gyro sensor because of head movements have to be converted to pixel information on the computer screen. There are two methods for this conversion. One is to use absolute coordinates not considering a current mouse pointer such as a tablet notebook and another is relative coordinates considering that such as a general computer mouse.

In the method based on absolute coordinates, the coordinate axes do not change when a program is running; the upper-left corner of the screen corresponds to the coordinate (0,0), and the lower-right corner of the screen corresponds to the coordinate (1023, 767). In the method based on relative coordinates, the current position of the cursor is always (0, 0); this relative coordinate corresponds to an absolute coordinate of (200, 200). Therefore, the position of the cursor along the x and y axes always ranges between 0 and 1023 and 0 and 767, respectively. However, the each coordinate ranges are adjustable from -1023 to 1023 and from -767 to 767, respectively, because in the system of relative coordinates, the coordinate is dependent on the current position of the cursor.

Because the gyro sensor outputs the angular velocity as obtained from the user's head movements, the angle information can be obtained through integration. In this process, errors due to DC offset and noise are also integrated along with the signals. This makes it difficult to control the mouse cursor by head movements [2]. To solve this problem, integration error can be eliminated by periodic initialization, but in order to do so, additional events are required.

In order to solve this problem, we used relative coordinates instead of absolute coordinates and used an exponential function with dead zone, as shown in Fig. 1. We neglected the movements within the dead zone and used an exponential function for the larger movements than dead zone, in order to increase the convenience in mouse control. This was done because the large movements made a larger signal and the small movements made a smaller signal.

B. Detection of mouse event using optical sensors

While mouse events include clicks, double clicks, and dragging, in this study, we considered only clicks and double clicks. Using an infrared light source (SFH485P, Osram, Germany) and an optical sensor (ST3311, AUK semiconductor, Japan), we detected the change of reflected light caused by blinking. When the user's eyes are closed, the optical sensors output a strong signal, and when the user's eyes are open, the sensors output a weak signal. We can detect clicks and double clicks on the basis of the signal amplitude and the time to close eyes.

The output of the optical sensor is strongly influenced by changes in the light source in the environment, such as a fluorescent lamp, or the brightness of the computer screen. We tried to minimize the artifacts by considering the difference between the strength of the output signal when the infrared light turns on and the strength when the light turns off [13]. Fig. 2 shows that the sensors are attached to a goggle.

C. Mouse pointer control

We obtained two channel signals from the gyro sensors and one channel signal from the optical sensor through a data acquisition board (USB-6009, National Instruments, USA). Mouse movements and events were calculated and detected, respectively, using LabVIEW (Ver 8.2, National Instruments, USA) on Windows XP.

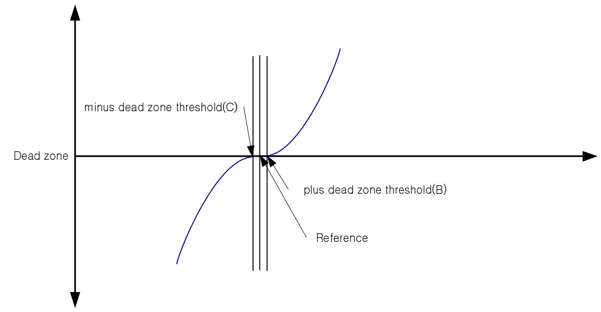


Figure 1. The method to control the mouse pointer by gyro sensors

Figure 2. Photograph wearing the goggle equipped with infrared sensors

D. System evaluation

The proposed mouse was compared with standard optical mouses, Camera Mouse (Ver 2009, Boston University, USA) and Eye Tracker (TM3, Eyetech, USA), in terms of the ability to detect movements and process events. In addition, we compared the keyboard typing speed to test the convenience of the proposed method.

The typical camera mouse whose operation is based on the use of facial images is Camera Mouse 2009, which can be downloaded for free from the Web. It can be used to control cursor movements through the point movements and to generate a click event by gazing at the point for a while; however, the mouse does not support double clicks.

Quick Glance estimates the mouse point and detects mouse events using eye images obtained by a video camera. The calibration method is simple, but it should be recalibrated whenever the camera position is changed [14]. Because eye images generally have low resolution, the spatial resolution is low. While Quick Glance is expensive, it is the most suitable method by which users with severe disabilities who cannot move their body and head can use computer input devices.

The typing speed achieved using the keyboard was compared with that achieved using an on-screen keyboard (Windows XP, Microsoft, USA) and Dasher (AEGIS project, United Kingdom). Dasher is an information-efficient text-entry interface that is driven by natural and continuous pointing gestures. Dasher is an effective text-entry system in cases where a full-size keyboard cannot be used [15].

III. Results & Disscussions

A. Evaluation of the mouse pointer control

In the proposed evaluation of mouses, the speed, accuracy, and precision of mouse movements should be considered simultaneously. Each experiment was repeated three times for ten computer users. In order to evaluate the movement speed, subjects controlled the mouse to sequentially pass over five points on the screen, i.e., from point A to B->C->D->E->A, as shown in Fig. 3; the time taken for this action was measured. The monitor resolution was 1280 × 1024. The time elapsed when the proposed mouse was used and the time elapsed when the general mouse was used were 6.9 ± 0.5 s and 4.3 ± 0.5 s, respectively. For 2.6 s, the subjects did not perceive a significant difference between the two mouses. The time elapsed for Camera Mouse and Quick Glance were 9 ± 0.7 s and 8±2.4 s, respectively. The proposed mouse was the second when we compared it with the alternative mouses.

B. Evaluation of the mouse event

The output of the optical sensor was affected by the change in the ambient light, as shown in Fig. 4(a), even though we used an active light source. We can completely eliminate the effect of ambient light using a different output of the optical sensor, as shown in Fig. 4(b). The different output was generated using the difference between the output of the sensor when the active light was turned on and that when the active light was turned off. In Fig. 4, ① and ② represent conditions in which a desk lamp is on and off, respectively. The output of the sensor was low when the user's eyes were open and high when the user's eyes were closed by the eyelids.

Click, double click and blink would be distinguishable by eyes-closing time which the sensor's output is maintained over 2.5 V. It took 0.08-0.12 seconds for natural blink and at least 0.15 seconds for clicks (intentional blink). On the basis of these data, we decided that an event will be identified as a click when the time is above 0.14 s and the amplitude of the sensor output is above 2.5 V. We decided that an event will be identified as a double click when the time elapsed between the first blink and the second blink is less than 0.2 s. The mentioned time and amplitude were based on data collected for the subjects who participated in this experiment. The decision criteria can be adjusted according to the user.

C. Evaluation of mouse usefulness

A square box (size: 50 × 50 pixels) was shown on the screen and was randomly moved to new position whenever a user clicked in this square. For the four different types of mouses (a general mouse, Camera Mouse, Quick Glance, and the proposed mouse), we measured the time required for clicking the box 20 times. The results were as follows: general mouse, 17.3 ± 3.0 s; proposed mouse, 47.4 ± 5.0 s; Quick Glance, 60 ± 7.25 s; and Camera Mouse 58 ± 3.0 s. The proposed mouse is slower than the general mouse but is faster than the other mouse, as shown in Fig. 5. When we consider

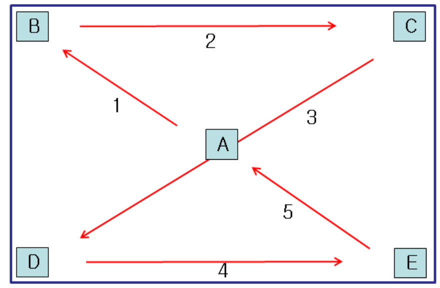
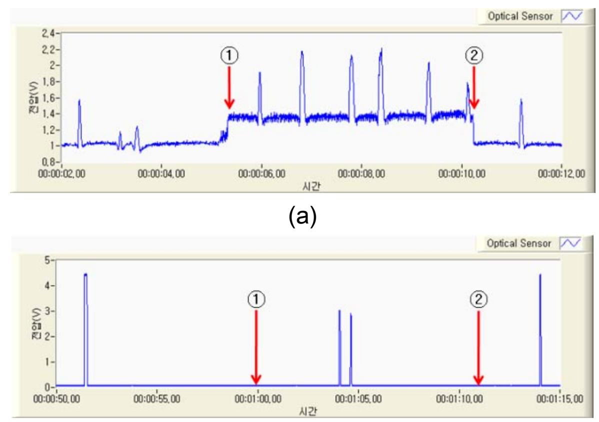


Figure 3. Pathway used to estimate the movements time of mouse point



(b)

Figure 4. (a) Output of a light sensor using a DC light source, (b) The processed output using the proposed method

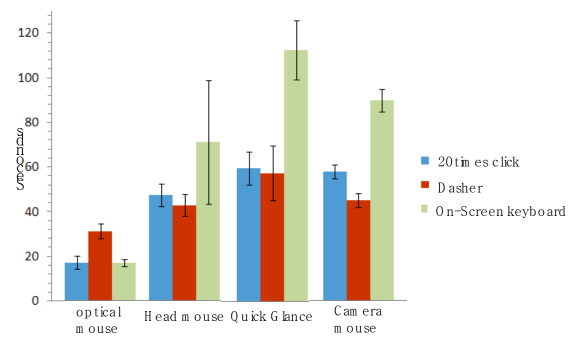


Figure 5. Experimental results of three kinds of mouse

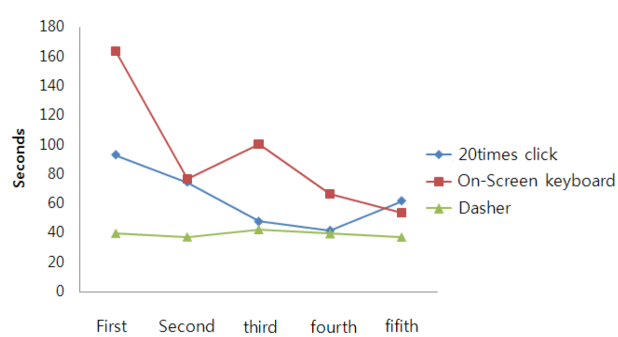


Figure 6. Reduction of mouse control time according to the number of trials for each test methods

that most users are familiar with the general mouse but are not familiar with the proposed mouse, we believe that the estimated time could be further reduced if users become familiar with the proposed mouse.

We measured input time using on-screen keyboard. The string used in the measurement was "This is a new head mouse." The times required for clicking by using the general mouse and the proposed mouse were about 17.2 ± 1.6 s and 71.1 ± 27.7 s, respectively. The time required in the case of the proposed mouse was around four times that in the case of the general mouse. This experiment required more time than previous experiments even though the numbers of clicks were not very different. For this reason, each key on the on-screen keyboard was smaller than the 50-pixel square. The times required in the case of Quick Glance and Camera Mouse were 230 ± 32.7 s and 90 ± 5.1 s, respectively. These times were greater than that in the case of the proposed mouse by factors of around 3 and 1.3, respectively.

We tested the proposed mouse using the Dasher program that did not involve the general method of keyboard input. When we entered text using Dasher, text-entry was excellent in terms of speed and accuracy compared to Quick Glance and Camera Mouse. Fig. 6 shows the estimated time according to each input method and each mouse. We cannot say that the performance of the proposed mouse is excellent compared with a general mouse , but the performance of the proposed mouse was better than the performance of other mouses such as Quick Glance and Camera Mouse.

IV. CONCLUSIONS

A comparison of accelerometers and gyro sensors revealed that the gyro sensor shows excellent responses to the pitch, yaw, and roll movements of the head. We proposed the head mouse using gyro sensors for head movements and optical sensors for mouse events.

In the experiment, there was no significant difference between a general mouse and the proposed mouse from the viewpoint of mouse movement and event detection (detection of clicks and double clicks), but it took more than about 3~4 times to control minutely the mouse position because its accuracy was low. Although the proposed mouse was less convenient to use than the general mouse, its performance was better than that of alternative mouses such as Quick Glance and Camera Mouse.

The integration error could be removed using nonlinear relative coordinates. The mouse point could be controlled intuitively on the basis of both the head rotation angle and velocity. The optical sensor circuit for detecting mouse events was designed to reduce the effects of ambient light, and the number of malfunctions caused by drastic changes in the ambient light in the environment could be reduced. However, it is inconvenient to use the proposed mouse since help from others is required while putting on and taking off the mouse.

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REFERENCES

[1] J. J. Magee, et al., "A Human-Computer Interface Using Symmetry Between Eyes to Detect Gaze Direction," Systems, Man and Cybernetics, Part A, IEEE Transactions on, vol. 38, pp. 1-1261, 2008.

[2] K.-S. K. Gwang-Moon Eom, Chul-Seung Kim, James Lee, Soon-Cheol Chung, and H. H. Bongsoo Lee, Norio Furuse, Ryoko Futami, and Takashi Watanabe, "Gyro-Mouse for the Disabled: 'Click' and 'Position'Control of the Mouse Cursor," International Journal of Control, Automation, and Systems, vol. 5, pp. 147-154, April, 2007 2007.

[3] R. Barea, et al., "System for assisted mobility using eye movements based on electrooculography," Neural Systems and Rehabilitation Engineering, IEEE Transactions on, vol. 10, pp. 209-218, 2002.

[4] S. H. Kwon and H. C. Kim, "EOG-based glasses-type wireless mouse for the disabled," in [Engineering in Medicine and Biology, 1999. 21st Annual Conf. and the 1999 Annual Fall Meeting of the Biomedical Engineering Soc.] BMES/EMBS Conference, 1999. Proceedings of the First Joint, 1999, p. 592 vol.1.

[5] C. Yu-Luen, "Application of tilt sensors in human-computer mouse interface for people with disabilities," Neural Systems and Rehabilitation Engineering, IEEE Transactions on, vol. 9, pp. 289-294, 2001.

[6] G. Schalk, et al., "BCI2000: a general-purpose brain-computer interface (BCI) system," Biomedical Engineering, IEEE Transactions on, vol. 51, pp. 1034-1043, 2004.

[7] M. Betke, et al., "The Camera Mouse: visual tracking of body features to provide computer access for people with severe disabilities," Neural Systems and Rehabilitation Engineering, IEEE Transactions on, vol. 10, pp. 1-10, 2002.

[8] D. Kumar and E. Poole, "Classification of EOG for human computer interface," in [Engineering in Medicine and Biology, 2002. 24th Annual Conference and the Annual Fall Meeting of the Biomedical Engineering Society] EMBS/BMES Conference, 2002. Proceedings of the Second Joint, 2002, pp. 64-67 vol.1.

[9] K. Young Wook, "Development of headset-type computer mouse using gyro sensors for the handicapped," Electronics Letters, vol. 38, pp. 1313-1314, 2002.

[10] I. Virtual Realities. GyroTrack. Available: http://www.vrealities.com/gyrotrack.html

[11] I. Virtual Realities. Head tracker. Available: http://www.vrealities.com/headtrackers.html

[12] O. Instruments. HeadMouse® Extreme. Available: http://www.orin.com/access/headmouse/

[13] M. Park, et al., "Head Mouse System Based on A gyro and Opto sesors," The Transactions of the Korean Institute of Electrical Engineers-SC, vol. 46, pp. 70-76, 2009.

[14] EyeTech. Quick glance. Available: http://www.eyetechds.com/

[15] D. Project. Dasher. Available: http://www.inference.phy.cam.ac.uk/dasher/