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Developing Handheld and Lower-Cost Eye-tracking System for Smart Devices Using Gaming Eye Tracker

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Abstract: Recently inexpensive eye-gaze input devices are available and easy to buy for only tens of thousands of yen. The device is attached to the bottom of the monitor and detects the user's gaze point while the user is tackling console games in front of the monitor. With this device, we can track eye movement instead of using previously existing input devices. We have developed our eye-gaze recording method for use with smart devices (i.e. smartphone/tablet PC) based on the original concept at about one tenth the cost of the currently existing one.

Keywords: Eye-tracker, Tablet device, Lower-cost, Gaming device

1. Introduction

Recently, eye-gaze input devices are for sale on the market at low and affordable prices, such as the SteelSeries Sentry Gaming Eye Tracker. It is priced at between 25,000 and 30,000 Japanese yen. The price is rather high compared to those of ready-made gamepads such as a computer mouse or a game console, but it is reasonably priced for a new game controller which deals with biological information. The device is attached to the bottom of the monitor (Fig.1). When we use it, we need to perform a calibration for each participant. The application which corresponds to this device — because of its characteristics, corresponding applications are mostly games — can use a user's line of sight instead of a computer mouse or a keyboard.

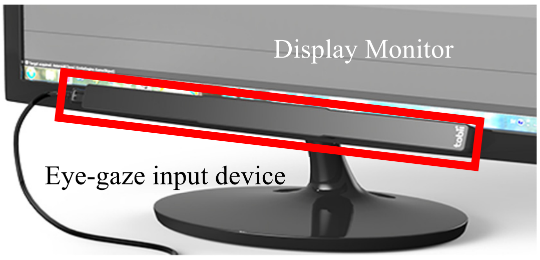

Fig.1 Location of an eye-gaze input device

These eye-tracking devices detect gaze motion using the reflection of infrared rays from eyes[1]. Thus, the sensor must be located in such a way that the user's hands would not obstruct the infrared rays (Fig. 2).

Fig. 2 Hand obstruction over the sensor

Locating a sensor at the top of a monitor is not always a good solution, because of the interruption of the infrared rays by the user's hands and arms. Therefore, eye trackers should be attached to the bottom of a monitor.

Tobii technology offers a stand for mobile devices which creates an attractive environment with a mounted scene camera, configuration file and calibration board[2]. However, the system has the following shortcomings: 1) it is made only for Tobii devices 2) it is prohibitively expensive, and 3) it is large and heavy (Fig. 3).

Fig.3 Tobii mobile stand for eye-gazing

On the other hand, the Tobii eye-gaze input device has its own SDK, including the software for data analysis, in order to develop corresponding applications stated above. Using SDK enables it to detect which point on the monitor the user stares at simultaneously in digital, numerical format.

To solve these difficulties — the interruption of the infrared rays by the user's hands and arms, exclusiveness, high cost, and the size — we have developed our own inexpensive eye-gaze recording method based on the ready-made one in order to evaluate the interface for the digital picture book system, which we have been creating for the last couple of years. Our handheld

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[1] For detailed overview of the existing eye-tracking methods, see [1].
[2] https://www.tobiipro.com/product-listing/mobile-device-stand/

and lower-cost eye-tracking system for smart devices consists of a stand for a smart device, an eye tracker and a PC for sampling/monitoring gaze motion.

Previous studies, [2] and [3] among others, also aimed to build a lower-cost eye-tracking system. Both studies used a web camera and developed their own eye-tracking software while our study adopts the existing eye-tracker and its SDK considering development cost. In addition, both studies, [2] and [3], chose a laptop PC as the user's device instead of a smart device.

2. System Overview

2.1 Overview

Most existing eye-tracking systems work properly under the condition that the distance between the user's eyes and the sensor is approximately 45 cm or more. At this distance, however, it is not easy for users to reach the device with a touch screen. In addition, the closer the sensor is to a user, the more easily the infrared rays are obstructed by his or her hands.

To solve these problems, we located a sensor and a smart device at different distances from the user, in the current experiment 60 cm and 40 cm, respectively (Fig. 4). When the smart device is located at the closer distance, the recorded data should be multiplied by 2/3. In this way, the sensor is located 20 cm behind the smart device and the user's hands do not obstruct the infrared rays (Fig. 5, cf. Fig. 2). Using this method, a four-year-old, the 100-cm-tall user with a length of 43-cm-right-arm, can reach the smart device comfortably without obstructing the infrared rays, as also taller (both child and adult) users. It was not possible for another four-year-old, the-97-cm-tall, with a length of 41-cm-right-arm to reach it.

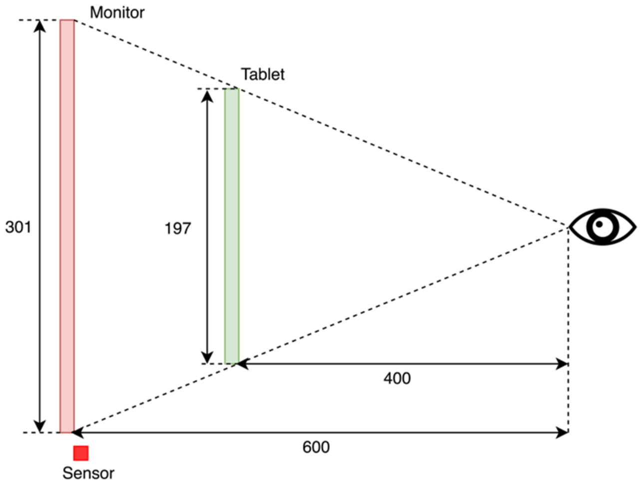

Fig. 4 Monitor and smart device

Fig. 5 The sensor attached 20 cm behind the tablet

2.2 Stand for Eye tracker and Smart Device

We have developed a stand with arm to fix the sensor and a smart device at the required position. A board for the smart device is connected to steel bars with holes, and they are fixed together to the pan head of the tripod (Fig. 6 and 7).

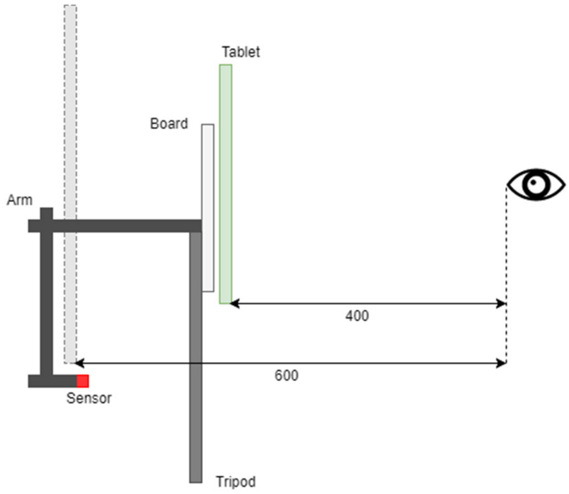

Fig. 6 Tablet, arm and tripod

The relative location of the sensor and the smart device is kept (40 cm distance in this study), so the height and angle of the smart device can be easily adjusted to the user with the tripod stand.

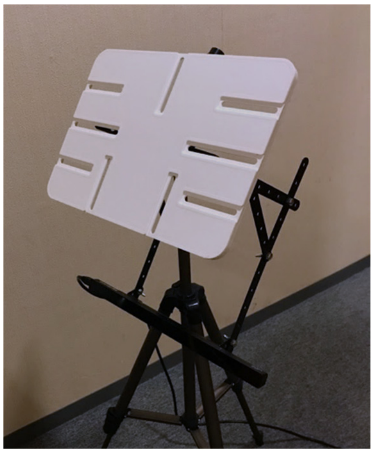

Fig. 7 Stand with a sensor attached

The size of the stand is 20 cm × 30 cm × 5 cm, when folded and the weight, including the tripod and the sensor, is less than 1kg. (Fig. 8).

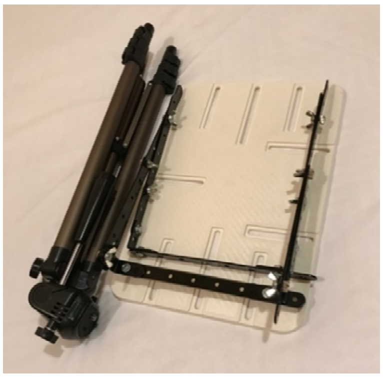

Fig. 8 Stand and tripod folded

2.3 Hardware

Our system consists of the following hardware.

- Eye-tracker device
- Stand for eye-tracker and smart device
- Laptop PC
- Monitor
- Smart device
- Wi-Fi router

Eye-tracker device in this experiment must use the optical (contactless) method. We adopted a device with PCCR (Pupil Center Corneal Reflection).

Stand with arm is to fix the sensor and a smart device at the required position (see 2.2).

Laptop PC is to control the sensor and record data including the monitor image. Because it must have average or slightly higher specifications than those of PCs for everyday use, we used a PC with Core i7 processor/8GB RAM to ensure the real-time screen mirroring and recording.

Monitor was used for calibration of the eye tracker, recording screen and real-time monitoring of the smart device. The screen of the smart device is mirrored on this monitor, so the physical size of the monitor must be larger than the mirrored screen of the smart device. In this study, we used a 1280 px × 1080 px, 30 cm height monitor.

Smart device in the experiment requires mirroring function and Air Play (iOS) or Miracast (Android/Windows). Here we used Apple iPad Air 2.

Wi-Fi router was used to build a local area network sending screen data from the smart device to the PC described above.

Other Peripheral Devices included mouse, display cables, etc.

2.4 Software

Our system consists of the following software:

- Data sampling and visualization
- Device mirroring
- Screen recording

This system gets X-Y axis of gaze position data at a given point in time. Using the data, we can create a heat-map or a real time monitoring of the gaze position.

Device Screen Mirroring is needed for monitoring and recording the current situation of the smart device. We used Reflector2[3] for this purpose since it is supported via a wireless network connection.

We also adopted ShareX[4] for screen recording, to record whole steps of the experiment, including real-time monitoring of the gaze movement which is overlaid in the mirrored smart device's screen.

3. Setup, calibration and measurement

3.1 Device setting

We located the PC, the eye tracker and the smart device as shown in Fig. 11. The entire scene of the experiment is recorded by a video camera.

The following settings must be made before starting the measurement.

PC and Monitor:

- Set an image for calibration as wall paper. (Fig.9)
- Connect the monitor to a PC.
- Execute a mirroring software program and a gaze tracing software program
- Mirror the screen of the smart device on the external monitor and magnify it by 3/2 times.

Wi-Fi network:

- Connect a PC and a smart device to the same network.
- Connect to the Internet if the tested application or system on the smart device needs it during the experiment.

Smart Device:

- Start mirroring the screen image to the PC.
- Set an image for calibration as wall paper (Fig.9).
- Execute an application for examination.

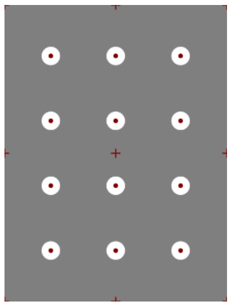

Fig. 9 Calibration wallpaper

3.2 Calibration and Measurement

The calibration of the eye-tracking device takes place in a standard way; the eye-tracking device is set to the bottom of the monitor. A participant sits in front of the monitor. The distance between the monitor and the eyes should be 60cm.

After the calibration, the eye tracker is removed from the monitor and attached to the arm of the stand, then a participant is

3 http://www.airsquirrels.com/reflector/

4 https://getsharex.com/

asked to move to the stand. The distance between the screen of the smart device and the eyes should be now 40cm.

The screen of the smart device is mirrored to the PC monitor, being magnified by 2/3 times, so we can overlay the real-time gaze movement on the PC monitor during the experiment (A captured screen picture shown in Fig. 10). At the same time, the whole screen shown on the monitor and the screen of the smart device is recorded, so we can examine later the participant's operation on the smart device and the timeline of the experiment.

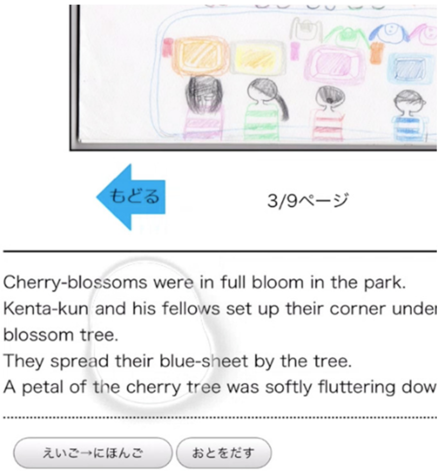

Fig.10 Overlaid gaze motion

Note that length in recorded gaze motion data is 3/2 of the actual size of the screen, as explained above.

4. Experiment and Result

We have been creating the digital picture book system for tablets appropriate for children to enjoy stories written in different languages [4]. We conducted trials of the system by children in the intended age group. We conducted the trials twice: the first was on August 16th, 2017; the second was on August 22nd, 2017. Table 1 shows the summary of the participants for each trial. The participants A through D were in the first group. The participants E through H were in the second group.

Table. 1 Age and Sex of Participants (Experiment 1)

Participant	Age	Sex
A	12	Female
B	10	Female
C	8	Female
D	6	Female

Table. 2 Age and Sex of Participants (Experiment 2)

Participant	Age	Sex
E	12	Male
F	10	Male
G	10	Male
H	12	Male

The trials were conducted in the following order.

1. Tell the children the purpose of the trial and gain a consent from each child and their parents.
2. Perform a calibration for each child.
3. Move to the tablet stand and adjust the position.
4. Use the tablet in the actual experiment.

It takes 40 minutes at a maximum for each trial by one child. At step 4, stated above, the child reads the same digital picture book story, first, with the sound in English followed by English subtitle, and second, with the sound in English followed by Japanese subtitle. It takes around 10 minutes to read through the story in both conditions. Fig. 11 shows how it was during the trial.

Fig. 11 Experiment scene

None of the participants had negative impressions of the trial. On the other hand, they were amazed at the system showing their eye-tracking on the screen and enjoyed the trials.

After conducting the trials, we found that the height of the child who tries the system should be over one meter. As they used the system in the sitting position on a chair, at least one meter height is the necessary condition. A child who was almost one meter tall could manage to manipulate the system, but the child below the height could not reach the touch screen and was not able to manipulate the system.

5. Summary and Future Plan

In our experiment, we used an inexpensive gaming device, a tripod, and a tablet stand to develop an eye-gaze recording method. This handheld and lower-cost eye-tracking system for smart devices showed the possibilities of recording eye-tracking data in numerical format on a PC, of making a real-time gaze tracing, and of creating heat maps. The total cost of developing our present method was 10,000 Japanese yen, which is lower than one tenth of the cost of using a device like the Tobii mobile stand. Moreover, it is more convenient when conducting experiments in different locations because of its portability: its weight is lower than 1kg, making it easy to carry.

In the present study, we have explored the only aspect of the viewing screen for our digital picture book application which we have already developed. We also have developed an original composition screen for children on the same application system to create their own short English story on the Web. We intend to conduct experiments to evaluate the composition screen as well as the viewing screen by using our eye-tracking system.

In so doing, we will collect more extensive eye-tracking data from different angles to elucidate the best positioning of eye tracking device in order to explore the users' inclination and needs. Thus, we will improve our eye-gaze recording method and make the portability of the device better.

Reference

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