Implementation of Application by Gaze Interaction on a Tablet Computer for Challenged People

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Abstract

The Japanese government conducted measures for persons with disabilities in 2013 and they reported that about 2.2 million of challenged children aged 17 or younger live in Japan. Those children cannot communicate with others without somebody's help because of severe physical disabilities and they are wholeheartedly keen to become a member of a society and crave a device/application to communicate with other people.

Indeed, there are many models of computer and tablet produced in Japan, however, quite small number of products are designed for the challenged children because difficulties of the children are unique and each assistive device should be designed individually. Therefore it's not easy to produce common-use devices or applications, and it's not easy for company to gain a profit from such special devices/applications. Finally, few types of assistive product are available even though a lot of challenged children desire such assistive device and application to be produced.

In this paper, application by gaze interaction on a tablet computer was proposed and examined the performance and effectiveness of this application through trial classes in special-needs school. Results of experiment through trial classes suggested that the proposed application gained high appreciation from teachers of special-need school.

I. Introduction

According to the annual report on government measures for persons with disabilities conducted in 2013, the number of persons with physical and/or intellectual disabilities is about 4,210,000 (33 in 1,000 in the general population). The number of persons with disabilities aged 17 or younger is about 223,000. For several years, Ministry of Health, Labor and Welfare also has conducted similar survey and issued "Actual Condition Survey on Persons/Children with Physical Disabilities". Looking at the transition of the number of person with disabilities aged 17 or younger, it is almost-constant.

It is obvious that the fine-tuned education should be provided for the degree of each disability for children with disabilities to become independent, and participate in a society. Therefore Japanese government set up special-needs school and special-needs classes in elementary school and junior high school. And many special trained teachers are assigned to the special-needs schools and the special-needs classes.

One of the special-needs schools managed by Japanese Government is near our college, named Kuroishibaru special-needs school [1]. Our college has kept good relationship with Kuroishibaru special-needs school since 2013 and been collaborating with each other. 112 students with severe disabilities study in the school and teachers have to be with the students at any time because most of the children cannot move their hands or legs voluntarily. Some of them cannot move even fingers or shake their head. The children can communicate with teachers only in the school because all of the teachers try to communicate with them positively and actively. Moreover the teachers are extremely sensitive to children's facial expression so that teachers can guess what/how the children think/feel, meanwhile the children cannot communicate with others outside of the school. Therefore the teachers desire assistive communication tools for the children to communicate with others in order to foster the ability of children with disabilities to participate in a society. At the same time, assistive communication tools may play an important role of a device expressing emotion for the children with disabilities, and the children can really feel that each of them is a member of a society.

As mentioned above, most of Kuroishibaru special-needs school's students cannot move their limbs or head, however, some of them actually can gaze at what they are interested in. Therefore only eye movement can be a channel to communicate with others for them. In Japan, some tools to detect and track eye movement are sold and a few papers proposed how to develop application to detect and track eye movement for the children with severe disabilities. Mr. Ito at el proposed an eye gaze communication system for people with severe physical disabilities in 2000 [2]. This paper describes a computer

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interface for the people with severe physical disabilities that people can input Japanese characters by gazing. The study achieved high recognition of gazing estimation, however, in order to detect eye movement they needed special devices and experimental calibration, and it was not easy to use the system at home in terms of both cost and inconvenience. In terms of eye tracking, Ono at el proposed gaze estimation system [3]. They proposed an appearance-based method for estimating gaze directions from low resolution images. They succeeded to improve gaze direction recognition, but, computational load of their algorithm to detect gaze direction was heavy and the system was not suitable for portable devices. Also, they used special designed cameras to estimate gaze direction. In terms of the system configuration, it was not convenient for people with severe physical disabilities to use at home.

Under actual environment, communication tools which do not need special setting to use is prefer for people with disabilities to use at home. Nowadays computer technology, especially in mobile computer field, has been advancing rapidly and many kinds of high-spec tablets and smart phone embed a high resolution camera are available. With attention paid on this fact, it may be possible to introduce a tablet computer to help children with disabilities to communicate with others by gazing.

This paper proposes an application by gaze interaction and algorithm to sense eye movement. Objective of this study is not only implementation of the application but also enhancement of utilization of the application by teachers in special-needs school who are not good at IT or computers, hence concept of this application is ”simple, user friendly but effective”. Therefore a tablet is adopted to use for communication. In order to realize high gaze direction estimation, the proposed application detects not only eyes but also whole face of user, then estimate eye position and gaze direction, however, the algorithm is simpler comparing to conventional gaze detecting algorithm and it is suitable to install on a tablet such as Surface 3 produced by Microsoft. In order to figure out of applicability of the proposed application, some trial classes were conducted in Kuroishibaru special-needs school and summarized feedback from the teachers.

II. Scenario to Utilize the Proposed Application by Gaze Interaction

Targeted children with severe disabilities cannot sit on a chair and keep their posture for a long time, and they usually lie down during a class. In order to adapt to this situation, each child takes private-tutorial classes and teachers usually use small and portable board instead of ordinary size of black/white board in a class room. Teachers always use the portable board in order to communicate with the children by displaying a question to ask the children; today’s weather, day, date and so forth. Sometimes teachers ask the children their feelings by writing a question on the board. Most of children answer the question by moving eye right or left. Their eye movements sometimes express their agreement or disagreement.

Figure 1 shows a scenario how to utilize the proposed application. First, a teacher talk to a child and show a question to the child. Second, the child express his/her feeling

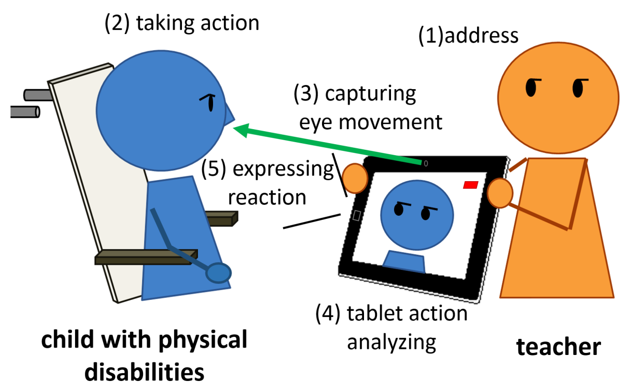

Fig. 1. Scenario how to use the proposed application.

with facial expression. Third, a tablet captures images and detects eye movement with embedded camera, then analyzes the movement. Finally, the tablet play sounds or synthesized speech for the child so that the child can feel that he/she can participant in a society.

III. Estimation of Eye Movement

In this study, OpenCV [4] is adopted for image processing because OpenCV is released under a BSD license and hence it’s free for both academic and commercial use. Furthermore, OpenCV is platform independent because it supports Windows, Linux, Mac OS, iOS and Android and it is easy for users to install OpenCV to any computer system. Originally, OpenCV was designed for computational efficiency and with a strong focus on real-time applications so that OpenCV is suitable to realize our proposed application.

In this section, a flow to detect eye movement is described. Figure 2 shows a flowchart of proposed algorithm to estimate eye movement, and details of each process is described in the following subsection.

A. Detecting face and eyes

Usually, positions of each eye and nose have positional relations with each other; Each eye and top of nose are usually located in an area corresponding to apexes of a triangle and the each eye locates symmetrically in the location of nose. Based of this assumption, our system detects face from captured image, then estimate region of both of eyes in the image. Some kinds of interference, e.g. reflection of light by glasses and shade of hat, should be taken into account to detect face from images, but such interference is reduced in this study because this application should be adjusted corresponding to individual child’s difficulties. In other word, this application has to be stable against environmental influences, however it can be easy to get rid off the interference because this application is designed for very personal use.

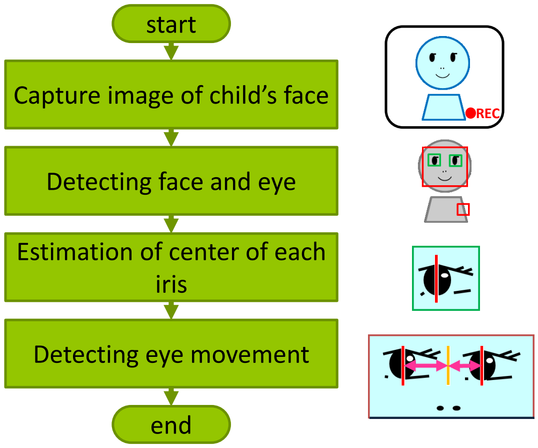

Fig. 2. Flowchart to detect eye movement

B. Estimation of center of iris

In order to reduce affection of contrast of images, each of captured image is converted from RGB domain to HSV domain, then each of average of saturation and value is calculated. Adjustment of contrast is done based on the equation (1). In this equation, *base* means average value of saturation and value of the captured image, meanwhile *dst* means a contrast adjusted image.

$$dst(x,y) = src(x,y) - \frac{1}{n}\left(\sum_{i=1}^{n} src_i(x,y) - \sum_{i=1}^{n} base_i(x,y)\right) \quad (1)$$
$$where \quad n : size\ of\ image$$

Finally, *dst* is converted from HSV domain to RGB domain, and the adjusted image is binarized in order to emphasize of the region of eyes and it helps to estimate of center of iris. Then, region of iris should be classified into black because the color of iris is darker than the color of sclera. After binarization, *dst* is divided into 5 regions in the direction of y (vertical) axis. Among these regions, the most black one is regarded as the center of iris as shown in Figure 3.

C. Estimation of eye movement

Before estimating eye movement, position of nose is defined as an orientation of child's face. According to the estimated positions of each iris, the movement of eyes is calculated based on the following equation.

$$D = \left|\frac{x_o - x_L}{x_o - x_R}\right| \quad (2)$$

In this equation, x_o means the orientation of the face, and x_L and x_R means the position of estimated center of left iris and the one of right iris, respectively. Parameter D should become greater when child move eye to the right, conversely, D should become smaller when child look to the left. Figure 4 shows relation of these parameters. To suppress rapid switching by

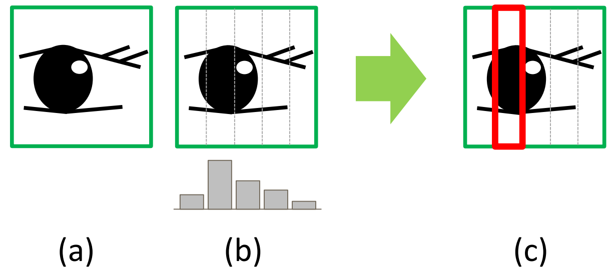

Fig. 3. Detection of center of iris (a):binarized image (b):divide the image to 5 regions (c):estimated center of iris

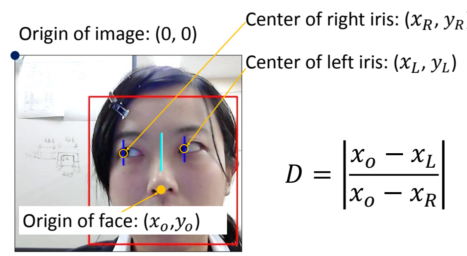

Fig. 4. Defining facial feature points and detecting eye movement

false detection of eye movements, our system recognizes gaze direction when user keeps looking in one direction for a while.

IV. Implementation and Evaluation

A. Experiment conditions

In this experiment, we shot video and divided and saved it to 400 still picture files. All pictures were taken using tablet and frame rate was 10 FPS. Two examples of captured image are shown in figure 5. In this figure, (a) is an image captured at 10 am and (b) was taken at 7 pm. There were some windows on the left side in the room where the image was captured so that the left side of the image, especially in the image (a), is lighter than the right side in the image.

B. Face recognition rate under variable distance between face and tablet

At first, accuracy of face recognition was examined under variable distance between face and tablet. In this experiment, the distance varied as shown in Table I. As shown in Table I, recognition rate at 60 cm was highest so that we set a tablet at a distance 60 cm from subject's face in the following experiments.

C. Light stability

Some experiments to check light stability of the proposed application were carried out in a room because most of classes in Kuroishibaru special-needs school were conducted in rooms. In this experiment, a distance between user and a tablet was 60 cm. Furthermore, the proposed application

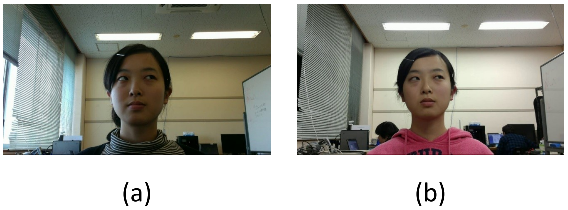

Fig. 5. Examples of captured image (a):captured in the morning (b):captured in the night

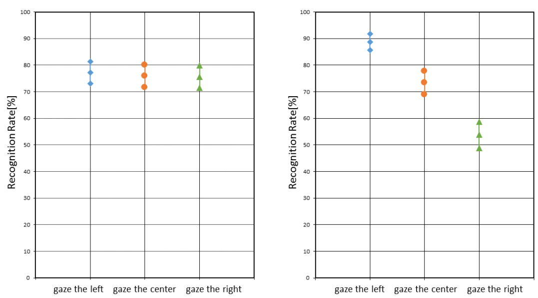

Fig. 6. Recognition rate of gaze direction (left):Without sunlight (b):With sunlight

recognized subject's gaze direction when the subject looked in one direction for 3 frames. Duration for gaze detection was 300 msec because frame rate was 10 FPS.

Figure 6 shows direction of gaze recognition rate. In this figure, left figure shows the performance of proposed application in a room without sunlight, on the other hand, right figure shows one in a room with sunlight. This result implies that the proposed application is very sensitive to influence of light.

D. Evaluation in trial classes

In order to evaluate the proposed application, trial classes were conducted in Kuroishibaru special-needs school. This trial classes had been conducted 13 times from November 2014 to February 2015 and two children with severe physical disabilities contributed to this trial classes. Both of these children could not concentrate on classes for long time so that duration of each class was limited up to 20 minutes.

In Japan, people usually say "Itadaki-masu" before a meal and "Gochisou-sama" after a meal. These phrases mean thanks for the food and also indicate the beginning and the ending of a meal. Theses phrases are simple, but they bring a sense of oneness to people because all of the persons being there take same action simultaneously. Therefore we selected these phrases to synthesize by our application in this experiment. Figure 7 shows the image captured by proposed application in

TABLE I. FACE RECOGNITION RATE ON DISTANCE BETWEEN FACE AND TABLET

Distance [cm]	Recognition rate[%]
30	88.74
45	93.47
60	94.69
75	93.77
90	88.74
120	40.62
150	33.73

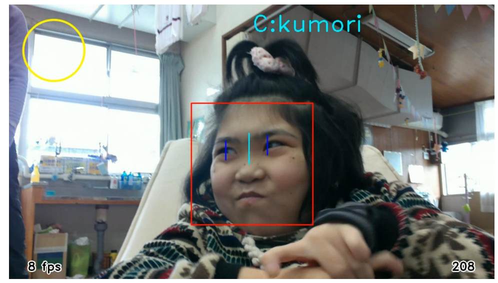

Fig. 7. Captured image in Kuroishibaru special-needs school

Kuroishibaru special-needs school. In this figure, each blue lines indicates position of iris of right eye and left eye, respectively. Also, red square shows the region of the subject's face. Light blue line is estimated nose line.

The proposed application could detect face and eyes, estimate eye movement correctly and synthesize "Itadaki-masu" for the child. The child sometimes gave a nice smile when she heard the synthesized phrase. According to a questionnaire conducted after trial classes, teachers in Kuroishibaru special-needs school gave feedback on the application as follows;

- Teachers found that children reacted quickly to teachers voice when they used this application.
- This application might have encouraged those who wanted to say something to try to say something.
- They expected the same kind of this application to be developed, which was easier for teachers to use.

V. CONCLUSION

In this paper, an application by gaze interaction on a tablet computer for challenged people was proposed. This application detect face of user and estimate eye movement using simple image processing. Result of experiments carried in special-needs school showed that this application could help challenged children to take part in a society by synthesizing special phrases such as greeting to start a meal, however, it's very sensitive to influence of light. Therefore we have to develop image processing techniques to improve stability to the influence of light in order use this application under various environment.

In this study, we did not evaluate our proposed application in terms of effectiveness comparing to other assistive devices for challenged children. Because difficulties of challenged children were unique and it was not easy to find a suitable device for each of child. Furthermore aim of this study is to realize a simple assistive application for challenged children without extra devices such as cameras and microphones. In terms of this point, we could show possibility to introduce our application to classes in special-needs school.

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