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Remote Learning Support System Using a Mobile Robot Operated by Eye-gaze Input for Long Time School Non-attendance Students

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Abstract. It is difficult for children or students under hospital care by the reasons of severe disease or injury to attend school classes. In this paper, we propose a system which enables them to join classes and communicate with friends and teachers by controlling an alter ego robot from a distant place. As the interface between the children or students and the avatar robot, we pay attention to eye movement because its function remains to the last. Using eye-gaze input, we construct a system to acquire environmental information by controlling the orientation of the robot and camera attached at the robot. The robot used in this system sends images acquired from the camera to the monitor in front of the operator in order for the operator to get environmental information of the surrounding area. Then the operator confirms the target inside the image by the control of the orientation of the camera and the robot.

1. Introduction

Presently, there exist many students who are absent from school for long time due to heavy illness or bullying, who cannot receive education by commuting or visiting due to health problem such as medical care, and who are not provided enough opportunity for learning because he or she resides in depopulated or devastated areas [1]. Hospital school and education through home visits are provided for such students. However, it takes much time to establish hospital school, and the number of medical institutions that have hospital school is not so many. The time for hospital school is limited to six hours per week, which does not complement enough opportunity for learning. In addition, both the hospital school and education through home visits do not provide enough overall learning time, which has possibility to delay his or her learning situation.

In this research, we propose a system in which a student living in hospital far from school can participate in class and communicate with friends or teachers through an alter ego robot operated by the student. Eye gaze input is used as interface in this system so that the student with serious disability in moving his or her hand or uttering a voice can operate the robot [2]. As a method to estimate eye gaze direction in eye gaze input system, EOG method [3][4], Limbus Tracking Method [5], Corneal Reflection method [6], etc., have been reported. However, there exist problems in these methods such that the methods are not invasive, there is possibility of illness caused by projecting infra-red radiation on eye ball for long time, and the commercially available eye gaze input system using infra-red radiation is expensive. Therefore, we proposed an eye gaze input method based on image processing by a USB camera and monitor under natural light, which is cheap and safe.

The alter ego robot takes image inside the classroom with a camera mounted at the end effector with two degree of freedom and shows it on the monitor in front of the student to provide the situation inside the classroom to the student. The student can control the orientation of the camera mounted on the alter ego robot so that he or she can get information of the noticed point in the image more in detail [7]. By realizing this, it can be expected that user can get wider information in the classroom, and that the teacher can guess the user's attention or concentration to the class by recognizing the movement of the camera.

2. System Configuration

Figure 1 shows the configuration of the system in which a human on the bed in a hospital checks the image of a classroom sent from an alter ego robot with a monitor in front of the human. The alter ego robot takes image of the classroom with a camera mounted at the end effector with two degree of freedom and sends it to the monitor in front of the student so that the student can watch the image. The student can control the orientation of the camera mounted on the alter ego robot using eye gaze input so that he or she can get information of the noticed point in the image more in detail.

This system is divided into two parts: eye-gaze input section and robot operation section. Eye-gaze input section is composed of a monitor, a web camera and an image processing PC. The operator uses the monitor to check image sent from the alter ego robot. The web camera is used to acquire the face image of the operator. The image processing PC estimates the line of sight direction from the face image acquired by the web camera and judges where the user gazes on the image of the monitor.

Robot operation section is composed of a Robot PC, a web camera and a notebook PC. The eye-gaze information estimated in the image processing PC is sent to the robot operation section by TCP/IP communication. In the robot operation section, the robot and motors on which camera is attached are controlled based on the sent information from the image processing PC. This control is conducted so that the point gazed by the operator on the monitor moves to the direction of the screen center.

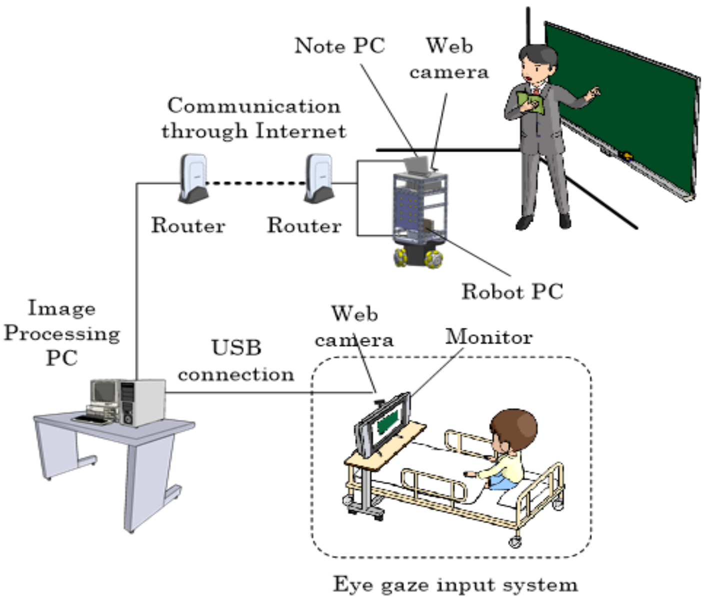


Fig. 1. Configuration of the System

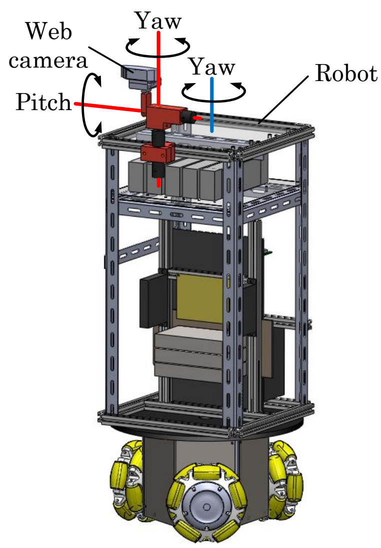


Fig. 2. Construction of the Robot

The robot used in this research is omni-directional robot with two degree-of-freedom in translation motion and rotational degree-of-freedom in yaw angle as shown in Fig.2. A camera is installed at the top of the robot to acquire information of circumstance in class. The camera is attached at two motors through an attachment to generate rotational degree-of-freedom in the direction of pitch and yaw. The user controls the robot and two motors with gaze input to change the orientation of the camera. The user can see the camera image of the class displayed on the monitor in the front.

3. Eye Gaze Estimation by Image Processing

In this study, a computer and a USB camera are used to estimate eye gaze direction to cut costs and for easy setting up. The eye gaze direction can be estimated by associating the location of black eye (iris and pupil) with the gazing position on the monitor. The image processing necessary for estimating the location of black eye is as follows. At first, images are captured by USB camera. Secondly, face and eyes are detected from the images. Next, medial canthus and lateral canthus are detected, and the location of black eye is estimated by particle filter processing and neural network.

3.1 Detection of Face and Eyes

At first, a color image from the waist up of user is captured by USB camera. The size of the color image is 640 pixels wide and 480 pixels height. User's face is detected from the color image. This processing is performed by the software of OpenCV library. OpenCV library is a type of image editing tool. An example of the detected face is shown by rectangle in Fig. 3.

For later processing, area of rectangle is trimmed and normalized into the image of 400×400 pixels. User's eyes are detected from the normalized image by OpenCV library. Detected results are shown by small rectangles in Fig.4. Size of rectangle is 100 pixels wide and 50 pixels height. This size is determined not to contain eyebrows and hairs.

Fig. 3. Detection of Face

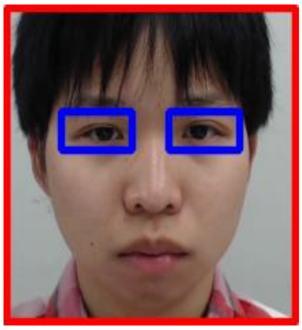
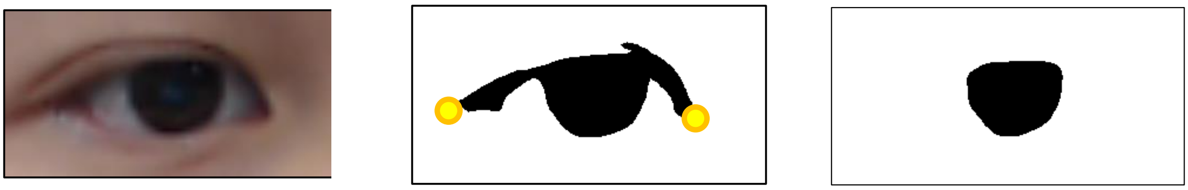


Fig. 4. Detection of Eyes

3.2 Detection of Black Eye, Medial Canthus and Lateral Canthus

The color image of the eye (shown in Fig.5(a)) is transformed into 2 binarized images by OpenCV library. The first image includes pupil, outer canthus and inner canthus. This image is used for the processing which distinguishes opened eye and closed eye. The Second image includes only pupil. This image is used for former processing and eye gaze estimation processing. These images are shown in Fig.5.

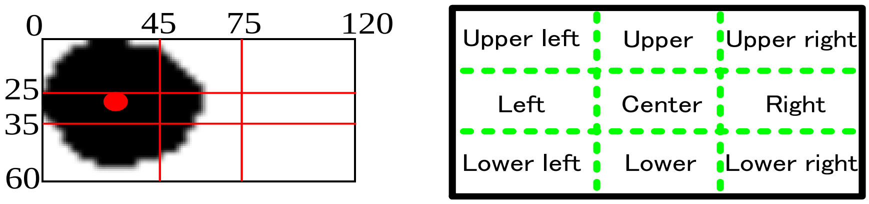


(a) Color Image (b) Detected Canthus (c) Detected Black Eye

Fig. 5. Detection of Characteristics of Eye

3.3 Change of Orientation of Camera Using the Estimated Position of Black Eye

In this research, the orientation of camera on the alter ego robot is changed by the estimated position of black eye. The area of the eye is divided into nine regions as shown in Fig.6(a) and the change of the orientation of the camera to be done is describe in each region as shown in Fig.6(b). For example, if the estimated position of black is in the region between (0,25), (45,35), the orientation of the camera changes to left direction with certain speed. The coordinates of each region are determined by trial and error through the experiments by 30 human subjects. The speed of the change of camera orientation is determined considering human sense toward the speed of changing image on the monitor, which is described in chapter 5.



(a) Regions of the Eye Area to Change Orientation of the Camera

(b) Expected Change of Orientation for Each Region

Fig. 6. Division of the Area of Eye and Expected Change of Orientation of the Camera

4. Psychological Evaluation of Moving Speed of Image on the Monitor when Changing Eye Gaze Direction

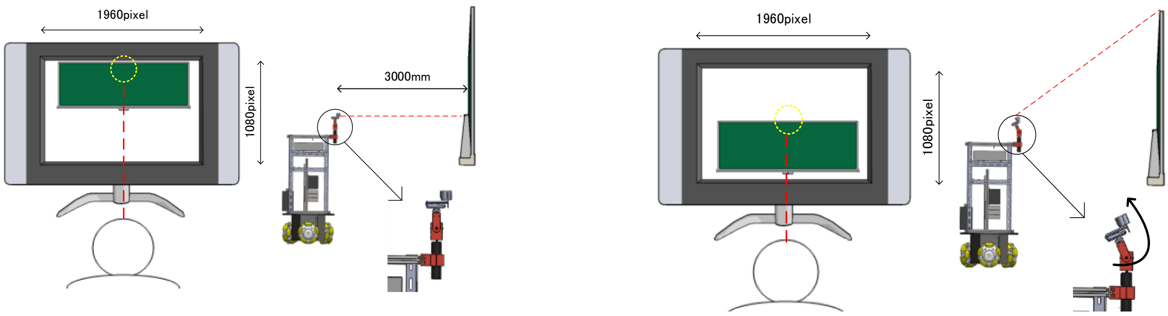
In this system, the user can take a class by controlling the orientation of the camera using eye-gaze input and getting information in classroom through the image sent from the camera. It is desired that the moving speed of image on the monitor should be appropriate for the user to follow the movement of the teacher or the character written on the blackboard. The desirable moving speed of the target object in the image displayed on the monitor is evaluated through experiments of psychological evaluations.

4.1 Experimental Method

To determine desirable moving speed of the image in vertical direction and horizontal direction, we conduct the experiment in which human subjects check the movement of the image of target (blackboard in a classroom) under different movement speeds and evaluate it psychologically. Rating scale method is used for psychological evaluation to determine desirable movement speed of the image.

The target of the experiment is a blackboard of 1200[mm]×3600[mm], which is displayed with a size of 550[pixel]×1650[pixel] on the screen. The distance between a robot and the blackboard is set to 3000[mm] assuming that the class is taken in the classroom.

The experiments to evaluate moving speed of image in vertical direction are conducted as follows. At first, the orientation of the camera on the alter ego robot is set so that the image of the bottom edge of the black be displayed at the center of the monitor in front of the user at the beginning or the experiments. The user starts to change the orientation of the camera attached at the alter ego robot in upper direction using eye gaze input. As the result, the image moves in lower direction. This operation continues until the image of the top edge of the blackboard is displayed at the center of the monitor. After that, the user changes the orientation of the camera in lower direction using eye gaze input. As the result, the image moves in upper direction. This operation continues until the image of the lower edge of the blackboard is displayed at the center of the monitor. The experiments are conducted under the condition that the moving speeds of image Pp = 10,130,250,370pixel/s.



(a) The user gazes the image of the top edge of the black board which cause movement of the image in lower direction

(b) The movement of the image stops when the image of the top edge is near the center of the monitor

Fig. 7. Experiment to Evaluate the Movement Speed of the Image in Lower Direction

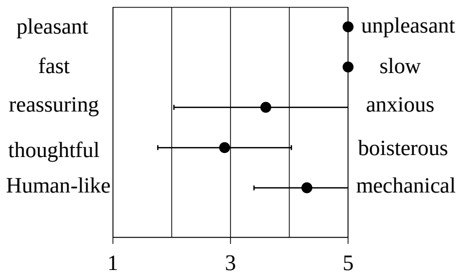
In order to evaluate the movement speed of the image when users change the orientation of the camera using eye gaze input, the rating scale method is used. In the rating scale method, several adjective pairs which represent human psychology to the movement speed of the image are selected.

4.2 Experimental Results to Evaluate Movement Speed of Image in Vertical Direction

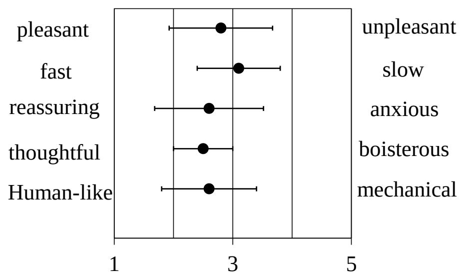
The results of the rating scale method are shown in Fig.8. In the figure, the average and variance when the point of one to five is given to each step of measure of adjective pairs are shown.

The following observations are taking into consideration from the results (here, “positive” is defined as the average value located in the left position in the five steps, and “negative” is defined as the average value located in the right). When the movement speed is 10 pixel/s, the results of measure 1 and measure 2 show the worst, and the results of the measure 3 and measure 5 show negative. This is because the movement speed is too small and humans show unacceptable feelings. When the movement speed is 130 pixel/s, the result of measure 2 is located at mean position, which shows that the speed is adequate. The results of the other measures show positive. When the movement speed is 250 pixel/sec, the results of all the measures show positive. When the movement speed is 370 pixel/sec, the result of measure 2 shows fairly positive and the results of measure 3 and

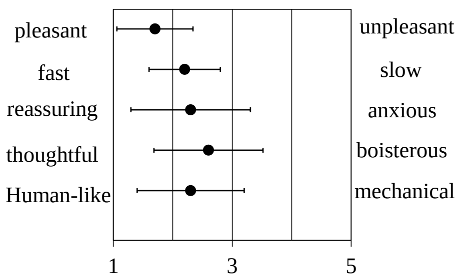
4 shows negative. This is because the movement speed is larger than appropriate value. Judging from these results, it can be said that the movement speed from 130 pixel/s to 250 pixel/s is recommended for the users.



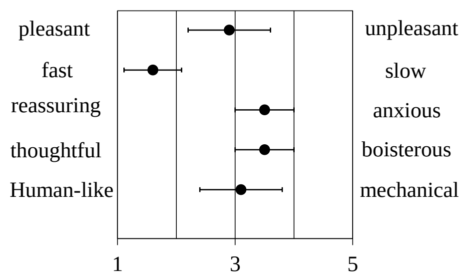
(a) Results when movement speed is 10 [pixel/s]



(b) Results when movement speed is 130 [pixel/s]



(C) Results when movement speed is 250 [pixel/s]



(d) Results when movement speed is 370 [pixel/s]

Fig. 8. The Results of the Rating Scale Method

5. Conclusion

In this research, we propose a system in which a student with severe disabilities living in hospital far from school can participate in class and communicate with friends or teachers through an alter ego robot operated with eye-gaze input by the student. The alter ego robot takes image of the classroom with a camera mounted at the end effector with two degree of freedom and sends it to the monitor in front of the student so that the student can watch the image. The student can control the orientation of the camera mounted on the alter ego robot using eye gaze input so that he or she can get information of the noticed point in the image more in detail.

A computer and a USB camera are used to realize eye gaze input to cut costs and for easy setting up. Image processing of face detection, eye detection, and estimation of the center of black eye is conducted. By coordinating the center of black eye with the eye gaze point of on the monitor, accurate estimation of eye gaze direction can be realized.

The desirable moving speed of the target object in the image displayed on the monitor for users is evaluated through experiments by the rating scale method. Judging from the results of the rating scale method, it can be said that the movement speed from 130 pixel/s to 250 pixel/s is recommended for the users.

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