Development of Eye-Blink Controlled Application for Physically Handicapped Children

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Abstract. In this paper, we describe a new application operated with eye-blink for physically handicapped children who cannot speak to communicate with others. Process of detecting blinks is performed in the following steps. 1) To detect an eye area 2) To distinguish opening and closing of eyes 3) To add the method using saturation to detect blink 4) To decide by a conscious blink 5) To improve the accuracy of detection of a blink We reduce the error to detect a blink and pursue the high precision of the eye chasing program. The degree of disablement is varied in children. So we develop the system to be able to be customizes depends on the situation of users. And also, we develop the method into a communication application that has the accurate and high-precision blink determination system to detect letters and put them into sound.

Keywords: VOCA (Voice Output Communication Aid), Phsically handicapped children, OpenCv, Haar-like eye detection.

1 Introduction

Special support schools in Japan need some communication assistant tools especially for physically handicapped children. In this study, physically handicapped children are defined as children with permanent disablements of their trunks and limbs because of cerebral palsy, muscular dystrophy, spina bifida and so on. Their body movements are very limited and many of them also have mental disorders, so they cannot communicate with their families or caregivers. It prevents helpers from understanding what they really need or think.

Taking the situation into consideration, we develop a communication support tool operated by eye-blink for physically handicapped children. We use front cameras on tablets (iPad, iPad mini of Apple Inc. iOS5.0). After several verifications and examination, we have developed a contactless communication assistant application "Eye Talk". The application does not malfunction by surroundings, such as brightness or differences of eye shapes.

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2 Purpose of the Study

The most common way to communicate with physically handicapped children is using “Yes=○” or “No=×” cards. (Figure 1) For example, if a caregiver wants to ask a child whether he/she wants to drink water, the caregiver will ask him/her “Do you want to drink water?” and show him/her cards with ○ and × by turns. If the child takes a look at ○ card or put his/her eye on it longer than the other one, the caregiver will know he/she may want to drink water.

Fig. 1. Using “Yes=○” or “No=×” cards to communicate with a physically handicapped child

But caregivers have to predict what patients need or want to say by their experiences or circumstances in this method. So the questions made by caregivers can be totally different from what patients really want to say. And also, it is difficult to figure out the movement of eyes of patients. Sometimes caregivers have to just guess the answer.

Some communication support tools using movements of eyes for these physically handicapped people have been released already, such as TalkEye[1] or Let’s Chat[2] . Most of them are relatively expensive because they require some special equipment. For example, TalkEye requires the executive head set to measure the movement of eyes.

3 Structure of the System

Process of detecting blinks is performed in the following steps,

1. To detect an eye area（By using Opencv Haar-like eye-detection）
2. To distinguish opening and closing of eyes（By using the complexity of binarized image）
3. To add the method using saturation to detect blink（Aiming more accurate detection）
4. To decide by a conscious blink（To define what is a “conscious blink”）
5. To improve the accuracy of detection of a blink

3.1 Detection of an Eye Area

There are many methods to detect an object. We choose OpenCv that is a library of programming functions for real time computer vision for image processing in this study. OpenCV's face detector uses a method that Viola, P. [3] developed first and Lienhart, R. [4] improved.

We use differences of brightness to figure out a face area and to remove other areas. Next, we detect an eye-area. Since an eye-area is inside a face area, we use data of a face area obtained by the method to obtain the average brightness of upper and lower part of eyes to define an eye-area.

3.2 Detection of Eye Opening and Closing

There are two methods to detect a blink of eyes. First one is calculating the size of the black area of eyes by using spiral labeling [5] and considering it as a blink when the size becomes smaller than the threshold. The second one is using the difference of the value of brightness of images to determine a blink. Figure 2 shows the image of spiral labeling. In spiral labeling, we search pixels from the starting pixel (1 in a square in Figure 5), calculate the medial level of the difference, and count the pixels within the threshold. In this method, we can reduce the time of processing if we can get the starting pixel because the area of processing is limited.

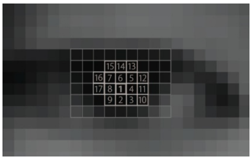

Fig. 2. Image of spiral labeling

But many physically handicapped children tend not to be able to open their eyes wide enough and their iris of the eye is relatively small, so it is difficult to detect the center of iris of the eye. So we use Value in HSV (Hue, Saturation, Value) in color space [6] to determine a blink. In this method, we cut an eye area based on the coordinate data obtained by Haar-like classifier and size it to reduce the load to a devise.

Then we obtain the average of brightness of the eye area. When someone closes his/her eyes, the average rises. We determine it as eye closing. Figure 3 shows the image of eye opening and closing.

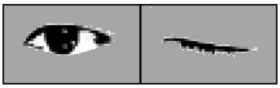

Fig. 3. Image of eye opening and closing

Usually, the classrooms of the most of special support schools are relatively dark to avoid giving extra impetuses to children, so we cannot get enough amount of light. So it is difficult to determine a blink, because there is no difference of darkness around the eye area and the average of brightness of white and black part of eyes that is close to the brightness of skin.

3.3 Detecting Method by Saturation in Color Space

Here we develop the method using saturation in color space. In this method, we calculate the average of saturation (0 to 255 in saturation of HSV) of area C (the center of the iris) and W (white part of the eye) in Figure 4. If the measured value is lower than the average of saturation, we determine it as eye closing. We collect many numbers of eye area data to calculate the average of saturation for eye opening.

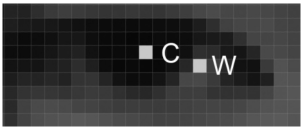

Fig. 3. To Obtain the average of saturation

When a user starts the system, it calibrates the picture of eye opening. Based on this picture, the system determines it as eye closing when the saturation of eye area is lower than the threshold. We use the threshold (the average of saturation) between 5 flames to 14 flames before of the present flame. But on the other hand, it detects a small movement such as an unconscious blink or moving of the face. So we add complexity of image of the eye in last 3 flames including the present flame to exclude the error to determine a blink.

3.4 Detection of Eye Opening and Closing

We use the difference of the outlines between eye opening and closing. We determine it as eye closing when the pixel of the difference of amount of edge in the picture becomes flat. The threshold is based on the average value of the amount of edges of 10 flames (5 to 14 flames before of the present flame). We determine a blink with the difference between the threshold and the present flame. Figure5 shows the utilization to each frame of the process complexity and saturation of blink detection.

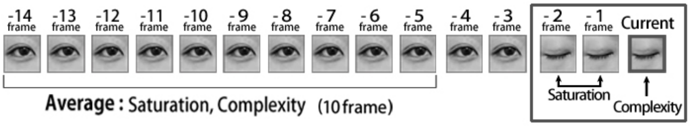

Fig. 5. Complexity of the image of the eye

The purpose of adding this method is to stop to detect an unconscious blink or a movement of the face. First, we try to find the most optimum value of combination of the saturation and complexity to determine eye closing. The setting that has less error is LP=0.75, DP=0.86. We set this number as the threshold.

Figure 6 shows the image when the application starts. ABC shows the correlation values of complexity and DEF shows the correlation value of saturation. A is the value of complexity of the present flame. B is the average value of complexity of 5 to 14 flames before of the present flame. C is the value of complexity multiplying the threshold LP (0.75) to the value of the present flame. D is the value of saturation of the present flame. E is the average value of saturation of 5 to 14 flames before of the present flame. F is the value of saturation multiplying the threshold DP (0.86) to the value of the present flame. When B is larger than A, and E is larger than D, we determine it as eye closing.

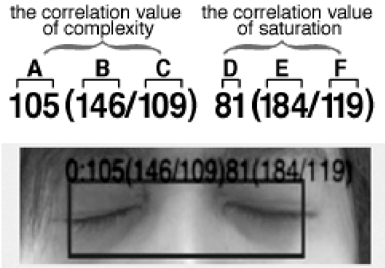

Fig. 6. Image and value of eye area

3.5 Developing Afterimage Method

After we developed the basic model of the system, we carried on a clinical experiment in the school for handicapped children. A subject suffering from spinal muscular atrophy has very weak muscle strength and cannot blink longer enough. So we need to improve the system to determine blinks even situations of users are different.

For users who can blink strongly enough, the method to determine blinks by the complexity and saturation is appropriate, but another detection method is required for users who do not have enough muscle strength. So we need to increase the sensitivity to detect blinks. Therefore, it is necessary to increase the processing power for detection of blinks. Since the tablet is fixed to the bed, we detect the position of eyes using OpenCV only when we start the system. It reduces the processing load and we can use 4 to 25 frames per second to determine blinks.

We use afterimages to determine weak and fast blinks instead of complexity and saturation.

By the method of using the afterimage, the number of the past frames to compare increases and we can capture changes with high accuracy. As a result, we can quantify the changes of series of movements "eye-opening → eye-closing → eye-opening". And it is possible to determine the situation of eyes as short blink, long blink, closing eyes continuously, except the malfunction due to fine movement of eyes. If a user opens and closes eyes within 50 flames, it is considered a blink. Figure 7 shows the determination of blinks by afterimage. The black area represents the current frame and the shaded area shows the afterimage. In the afterimage method, we determine the conscious blink and the unconscious blink using two thresholds. When we increase the sensitivity of the blink detector, the first threshold is defused to 1 frame maximum. The second threshold is set to 50 frames (approximately 2 seconds).

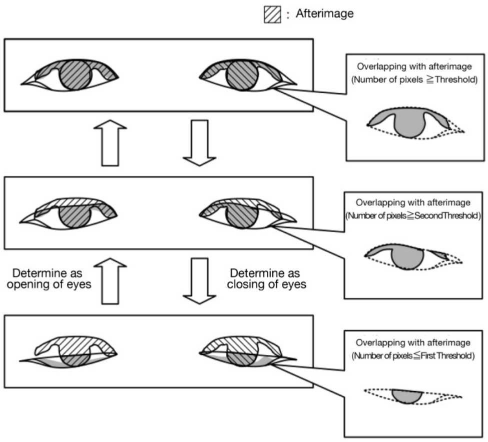

Fig. 7. Detection of unconscious blink by afterimages

In order to handle with face color and brightness of light, calibration is automatically activated when the black part in the image is doubled. Calibration means to detect the position of eyes and to set a threshold for binarizing. If the value of binarization threshold is too high or too low, it cannot detect blinks. We perform calibration to obtain the correct value for blink determination and set the threshold. As a result, it is possible to automatically capture the position of eyes in both a dark and a bright place or even if a user moves his/her face. It is possible to detect blinks using the value of the current frame, but if a user has long eyelashes, the outline becomes complicated because it acquires the contour of eyelashes. Therefore, we designed the method of using the afterimage to correspond to blinks of any user.

Table 1. List of errata of blinks

Acquisition of blinks from 30 healthy subjects			
Determination of eye-opening to eye-closing by complexity and intensity	Correct judgment 44.3%	Determination of eye-opening → eye-closing → eye-opening by afterimage sensitivity 80	Correct judgment 93%

Acquisition of blinks from 4 physically handicapped children (1 spina bifida, 1 cerebral palsy, 2 muscular dystrophy)														
	A	B	C	D		A	B	C	D		A	B	C	D
Determination of eye-opening to eye-closing by complexity and intensity	○				Determination of eye-opening → eye-closing → eye-opening by afterimage Sensitivity 80	○	○	○	×	Determination of eye-opening → eye-closing → eye-opening by afterimage sensitivity 93	○	○		○
				○			○	○	○		○		○	○
						○			○		○	○	○	
						○	○	○	×		○	○	○	○
						○			○		○	○	○	○
						○	○	○	×		○	○	○	
						○		○	×		○	○	○	○
						○	○	○	○		○		○	○
						○	○		○		○	○	○	○
							○		○		○	○	○	○
Correct judgment 5%					Correct judgment 72.5%					Correct judgment 87%				

We describe the comparison of the detection accuracy of two determination methods; by saturation and complexity and by the rate of change of characteristics with afterimage. For 30 healthy subjects, errata rate by saturation and complexity was around 40%, but error-free amount was more than 90% by afterimage. When we carried out clinical study with 4 physically handicapped children (1 spina bifida, 1 cerebral palsy, 2 muscular dystrophy), their blinks were too weak to react. It is considered that their blinks were determined as unconscious blinks that we had excluded. When we used the determination method by afterimage, the rate of accurate judgments was 70% with the initial value and it increased nearly 90% by raising the sensitivity (Table 1).

4 Developing Communication Applications

We developed the blink determination system into new communication applications "Eye Talk" and "Eye Tell" for physically handicapped children.

4.1 Eye Talk, Eye Tell

In Eye Talk, a user can select a character in the least number of times. Figure 8 shows the image of the application. A user chooses a consonant in "column" first and a vowel in "row" next from the character table of Japanese of this application.

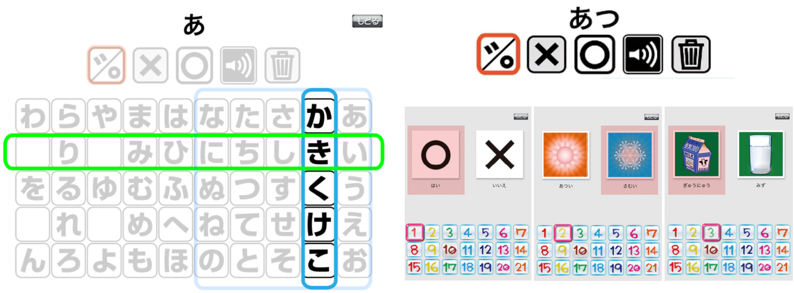

Fig. 8. Character table of Japanese of Eye Talk and Eye Tell

After choosing a letter, the frame cursor is moving along "Command" items (Fig. 8), which includes Voiced/Semivoiced sound symbols, Delite a letter, Select, Sound and Delite All, on the top of the screen. If a user blinks when the frame cursor is on Select, the letter is chosen. By continuing this operation, a user can create a sentence as long as he/she needs. Then the voice sound comes out when a user choose Sound button. Eye Tell is a modified communication application to indicate needs simply by "Yes = ○" and "No = ×" by blinks (Fig. 8). A user can make original symbols suitable for the level of handicap. First, a helper makes 2 symbols that are suitable for the situation of a user. (Up to 21 sets.) Then the symbols on right and left sides of the screen turn on and off reciprocally. A user chooses the symbol when it turns on by a blink. The application judges the blink and put the sentence into voice sound.

Even a user who has weak muscle strength, the conscious blink is slower than the unconscious blink and speed of blink is different among individuals. In Eye Talk and Eye Tell, a user can adjust the sensitivity of determining blinks from 0 to 100.

A user can customize the following settings of the applications.

1) To show the picture of eyes (On or Off)
2) Sensitivity of detecting blinks (low 0 to high 100)
3) Speed of moving the frame cursor on the character table of Japanese (slow 0 to fast 100)
4) Speed of moving the frame cursor on Command items (slow 0 to fast 100)

The cursor moves 0 = 100 frames and 100 = 10 frames. About 24 frames of pictures are processed per a second, so the speed of movement of the cursor is 0 = about 4.16 seconds and 100 = about 0.41 seconds.

5 Conclusion

We are on the process of filing a patent for the high quality blink detection system and distributing it free of charge in Japan. For further development of this system, we research and develop the method of determination of gazing directions by analyzing the eye movement. If we can detect the gazing direction accurately on the tablet, burden on a user is reduced. It is applicable to any application by limiting the processing range to achieve higher speed and simplifying the process and high detection accuracy. To determine gazing directions, we use the afterimage method we have developed in this study. To determine gazing directions, we measure the rate of increase or decrease of the area of the white part of eyes by the afterimage method for processing an image of the eyes. In this way, we can determine gazing directions with high accuracy and less error. By combined the method to determine gazing directions with the blink detection system, a user will be able to get more unfettered communication.

The support applications are living necessities for handicapped people. They should be practical and easy to use. Those applications encourage physically handicapped people to communicate with others and lead the society to support each other regardless of handicap.

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