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Automated cover-uncover test system using active LCD shutter glasses

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Abstract: The diagnosis of ocular malalignment is difficult and need examinations from ophthalmologists and orthoptists which are chronically insufficient. Part of the process of eye position check is systemized. With this check system, not only the symptom but also the angle and the extent of strabismus is detected. However, this method only useful for detecting one kind of strabismus which is divergent strabismus. The purpose of this study is to develop a simplified check system to screen at least the presence of strabismus apart from the type of strabismus or amount of ocular deviation. Digitalization of the check process was conducted. Specifically, the digitalization of element technology, "Cover-Uncover function ", was conducted necessary for the automation of the typical "Cover Test" for eye position check.

Keywords:. Abnormality of eye position, cover-uncover test, digitalization of check process, 3D glass

1 INTRODUCTION

Ocular malalignment such as strabismus and heterophoria are factors that cause defective stereopsis and asthenopia. Especially strabismus is a risk factor that cause amblyopia. Thus, the method for early detection and treatment of strabismus is a significant research theme for pediatric ophthalmology[1]. The diagnosis of ocular malalignment is difficult and examinations by ophthalmologists and orthoptists are required. However, there are chronic shortages of licensed clinical staff. This is obvious from the fact that licensed staffs are not present for the 3-year checkup at more than half of the venues in Japan, where vision checks are conducted[2]. From the above, even though temporary, there is a great significant in developing a simplified system to conduct an ocular position examination without a qualified staff in presence.

Part of the process of eye position check is systematized[3] With this check system, not only the symptom itself but the also the angle and degree can be detected. However, this method is effective for only exotropia, which is one of the many types of strabismus. It is to use the existing gaze measurement technology to measure ocular deviation quantitatively. The issue is the difficulty of quantitative measurements due to the unstableness of the eye position of strabismus (esotropia, hypertropia and hypotropia) with the exception of exotropia. Therefore, the development of ocular position examination system to detect every type of strabismus is considered to be difficult.

The purpose of this study is to develop a simplified check system to screen at least the presence of strabismus apart from the various types and amount of ocular deviation. Specifically, the digitalization of element technology, "Cover-Uncover function" necessary for the automation of the typical "Cover Test"(Fig.1(1)) for eye position check was conducted. (Fig. 1-(2),(3)) We solved the following two technology issues by digitalizing this function.

1. We materialized the shield function to conduct a specific timely cover-uncover test for one eye with the

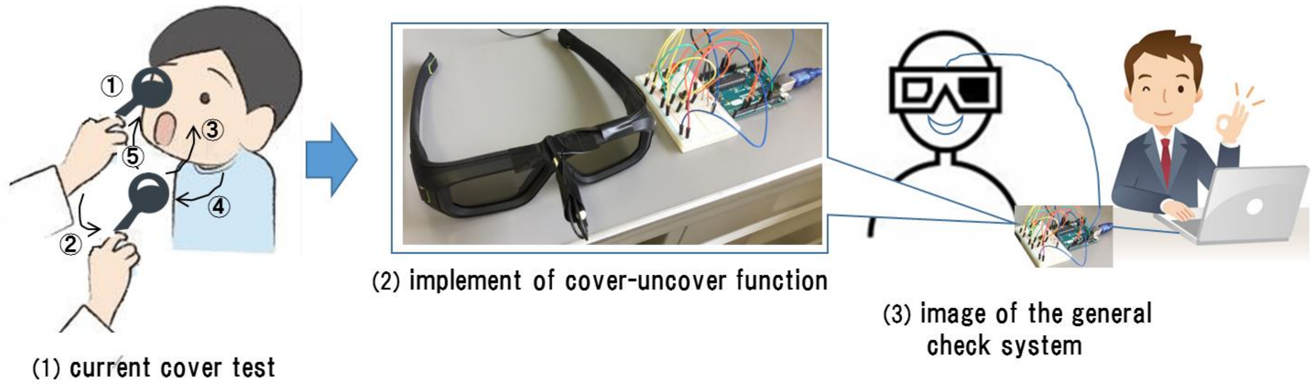

Fig. 1. development of eye position check system

use of a liquid crystal shutter function of wireless glassess(Nvidia 3DVision2:3D glass) supported with 3DVision. The issue is that the shutter of the 3D glasses open and close by the infrared light trigger signal which is radiated automatically from the correspondent display. Originally it cannot be controlled freely. In order to simulate the infrared radiation which controls the switch of the 3D glasses, the required function was realized by programming this signal into the microcomputer, Arduino. Futhermore, we used this information as reference since the signal spec of this shutter is analyzed per product of 3D environment and went public online as "White Paper" [4].

2. The issue is whether the LC shutter indicates the required level of it's shielding performance due to the high-transparent pale colored LC shutter compared with the conventional cover appliance (occluder). Therefore, in order to obtain accurate results, experiments were repeated to test the performance and set up the timing and number of times of cover-undercover test. Moreover, the confirmatory performance test was strictly conducted by presenter himself, a qualified orthoptist.

After explaining about the conventional cover test in section 2, digitalization of the cover Test will be indicated in section 3. First, we will show the necessary technique factors for the degitalization of examination process. Concretely, we set forth the solution of the technical issues 1,2 mentioned above which is the main proposal details. Furthermore, methods to continuously gain images of the ocular movements during the test as well as visualization methods of the ocular movements based on the image will be indicated to obtain test results. Section 4 indicates the contents and results of the verification experiment to verify the validity of the proposed method. The content of the identify issues for the purpose of the Cover Test systematization will also be shown. Section 5 covers the summary.

2 Cover Test

A cover test is to determine the ocular deviation by covering the fixating eye of the patient focusing on fixation targets, far (5m) or near (30cm). If the uncovered eye moves when the other eye is covered it is determined strabismus. On the other hand, it is determined heterophoria if there are movements in the eye when it is uncovered. Furthermore, the normal equilibrium of the eye muscles is called orthophoria. Although the timing and duration of each occlusion is determined at some extent, the practitioner decides the proper timing and duration by observing the examinee.

This test has two methods, CUT (cover-uncover test) which one eye is covered and after a few seconds, uncovered, and ACT (alternating cover test) which one eye is covered alternately repeatedly. The character of CUT is that it distinguish not only the presence of strabismus and heterophoria but also binocular function including fusion abilities. Since ACT detects the amount of the total deviation, it can detect the symptom of misalignment of the eye better than CUT. Generally, the conventional tests are performed in the order of CUT, ACT[1].

3 . Implementation method of cover test

3.1 Implementation of cover/uncover function

3.1.1 Implementation of the signal for the switch gear shutter

We implemented four types of signals in total based on the specification of infrared light pulse[4]. Figure 2 is a waveform graph which shows the signal of the opening of the right eye shutter. Based on this, we implemented a program that appropriately repeat the pattern, "ON (23μs) → OFF(46μs) → ON(31μs) → OFF(400μs)" which opens the right eye shutter. We equally implemented the other three signals based on the specifications. When we actually sent the implemented signal, some cases had unintentional

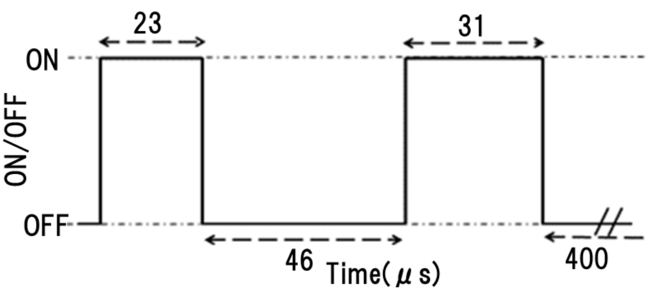

Fig. 2. The Timing Diagram (Open Right Eye)

Fig. 3. various conditions of the LC shutters

movements with the sent signals. However, with minor changes to each specification improved the shutter movements to our satisfaction. For example, in order to close the right eye shutter, we sent a signal to open the left shutter before sending the signal to close the right shutter.

Figure 3 is the various conditions of the LC shutters after receiving each implemented signals. That is to say, (b) is the initial state in which both shutters are opened, (a) is the state after receiving the signal for shutting the right eye shutter, (c) is the state after receiving signals for shutting the left eye shutter.

3.1.2 implementation of the shutter control pattern

We arranged four types of practice patterns of the sequential shutter switching action for the cover test and prepared two switches on a device to change the patterns. The light on the device starts blinking at regular intervals after a long press of switch 1 and stops when releasing the switch. The lighting frequency determines the shutter's open and close pattern of 1~4. By pressing switch 2, the shutter starts to open and close according to the previously determined pattern.

The four types of the shutter control patterns are as shown in table 1. Pattern 1~3 is the basic operation necessary to implement the test method CUT, and pattern 4 for ACT. Moreover, (b) is the initial state of all the patterns with both shutters opened.

3.2 Detection method of eye motion tracking

In order to detect the eye movements during tests, firstly we set a miniature USB web camera (hereinafter called "web camera") （Delock USB 2.0 Kameramodul 1,92 Megapixel 55 °Fixfokus, Art.-Nr.95950）inside the lenses of the 3D glasses to film the eye movements. Moreover, we mounted functions to acquire images in 63(ms) intervals repeatedly with C++ programming language. The movements indicating symptoms of strabismus or heterophoria appears a second or two, right after the shutter closes (or opens). Therefore, the filming starts immediately after the 3D glasses shuts (or opens). The length of time is about 6 seconds until the movement of the ocular stabilizes. 100 images are acquired continuously.

We considered the possibilities of using the optical flow to detect the movements of the eye[5], [6]. Optical flow is a technique indicating movements of objects in digital images with "vector" and for detecting motion vector and motion analysis. However, it is difficult to seek the optical flow uniquely (movement vector of objects). Therefore, the motion vector is obtained generally from estimation. The main methods to estimate this optical flow is "LucasKanade method" [7] and "Horn-Schunk method." In this study, we adopted the LucasKanade method. Moreover, the presence of the eye movement could be determined intuitively by visualizing the optical flow. We examined whether it was possible to distinguish tropia / phoria / orthophoria with the proposed method. In addition, we used the optical flow library implemented in OpenCV.

3.3 Methods to visualize eye movements

There are two methods in visualizing the optical flow, one is direction and size of the vector, the other is difference of color and its tint. In this study, we carried out the latter method. Specifically, we implemented a program to convert the color according to the direction of the movements and create a heat map with vectors showing the directions in gradation. The hue range in OpenCV is from 0 to 190, 0,180 is red, 30 yellow, 50 green, 90 cyan, 120 blue and 150 magenta . (refer to figure 4) [8]. Moreover, in this study, we created a program to give colors to only motion vectors over a certain length in order to create a heat map ignoring any small movements becoming noises.

3.4 Inspection methods

We implemented the serial communication program in order to operate the program of active shutter 3D glasses incorporated into Arduino (called the shutter unit) and the program to acquire sequential images with web camera (called photographing unit), according to the inspection procedure. The following is the inspection procedure.

(1) Give instructions to the subject to put on the 3D glasses and look at a target at far (5m) or near (30cm)

(2) Execute the program of the photographing unit, connect the serial port and be ready to receive the data from the shutter unit.

(3)After confirming that subject is looking at the target, choose the switching action pattern of the shutter (refer to table 1)

(4) Camera of the photographing unit starts filming after receiving instructions from the shutter unit by serial communication. Communication of the serial port is automatically disconnected after the images are acquired. The acquired images are stored in the designated file.

Table. 1. control pattern of LC shutter

No	Control Pattern
①	right close ⇒ right open ⇒ （1 second） ⇒ left close ⇒ left open
②	right close ⇒ right open
③	left close ⇒ left open
④	right close ⇒ right open/left close ⇒ left open

(5) Choose two images from the acquired images appropriate for detecting the presence of motion.(note) Carefully detect and visualize the optical flow (motion vector) about the filming order, confirm the presence of the optical movement and estimate tropia / phoria / orthophoria.

We consider that the validity of our proposed method can be confirmed by comparing the result of the estimation of exam procedure (5) with the orthoptist's decision done by the conventional method.

(note)Since the aim of this study is to ascertain the possibility of detecting the eye movement, we chose two images with possibilities of the maximum angle of deviation. (refer to section 4)

4 Verification experiment

We performed experiments to verify the validity of our proposed method. First, we verified the implemented cover-uncover function. First of all, we confirmed that the opening and closing of LC shutter's for both eyes are freely controllable. Orthoptist visually confirmed the ability of the 3D LC shutter for its screening ability to detect strabismus/ heterophoria sufficiently. As a result, sufficient screening ability was confirmed.

After the confirmation of the basic items, we followed the procedure indicated in section 3.4 and examined the detection possibilities of strabismus with a subject, diagnosed with internal strabismus by an ophthalmologist.

As a result, we confirmed the detection possibility of strabismus with the proposed method.

Specifically, a movement suspecting strabismus was detected from the images of the optical flow (figure5-(a)) obtained from the movement of the right eye on pattern 3 of table 1. Figure 5-(a) are the two chosen images. That is, they are the visualized flow vector obtained from figure 5-(b) and figure5-(c) with the method of section 3.3. Figure 5-(b) is the image immediately after the shutter starts action. In short, it is the image of the subject's eye position under normal conditions. Figure 5-(c) is the 30th image, 2 seconds after the shutter close to cover the left eye.

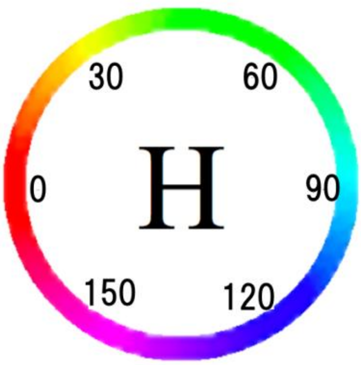

Fig. 4. correspondence of hue and value in Open CV[8]

In figure 5-(a), it is clear that the percentage of cyan, blue and green around the pupil is high. Comparing this to figure 4, we assume that the test subject's right eye moved to the temporal immediately after the left eye is covered which matches the fact that the test subject has internal strabismus.

In other words, the pupil of the test subject with internal strabismus (right eye) normally face the nasal and fixate the target only when the fixing eye (right eye) is covered which match with the eye movement of the conventional cover test of "suspected case of internal strabismus."

Figure 5 shows the yellowish color on the temporal, which is the flow distribution in the direction opposite to the eye movement. We considered that this indicates the minor movements of the eyelids and the wrinkles around the eye. It is necessary to consider a solution not to confound with these type of movements with the eye movements for the systematization of this method.

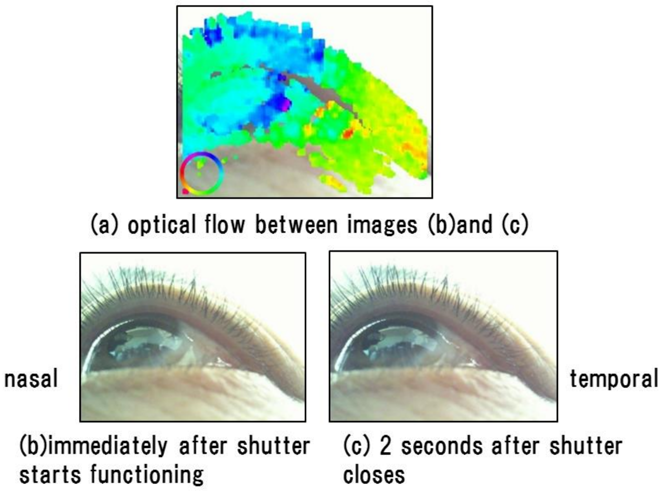

Fig.5. visualization of the eye movement during the examination

5 CONCLUSION

We digitalized the cover uncover function in order to automate the typical cover test of the eye position examination method. The basic device for the development are wireless glasses (3D glasses) provided with 3D vision active LC shutter glasses which reacts to infrared light.

The development procedure is, first, install infrared LED to the 3D glasses infrared receiver and create a program to simulate the infrared light signal with microcomputer Arduino. Implement the shutter control pattern to open and close the shutter freely. Next, install a web camera to the 3D glasses and create a control program to film the movements of the eye continuously during the examination in an arbitrary timing. Moreover, we created a program to visualize the optical flow (motion vector) of the two images chosen from the examination. Lastly, we performed an inspection experiment to a subject with internal strabismus based on the proposed method. We confirmed the validity of our method in conjunction with identifying issues for systematization. Specifically, we conclude that further studies are necessary in order to develop a system not to confound the irrelevant movements of the eyelids and wrinkles with the eye movements. As prospects for the future, we consider this study of developing technology for detecting minor eye movements is expected for application to person authentication technology with the use of gaze tracking and will continue research and development from this standpoint.

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