Visual Field Examination Technology Based on Semi-transparent Elliptical Mirror

Chao-Kai Chang
Department of Optometry
Yuanpei University of Medical Technology
Hsinchu, Taiwan
chaokai@ms17.hinet.net

Chun-Yu Chiang
Ph.D. Program of Electrical and Communications Engineering
Feng Chia University
Taichung, Taiwan
hank4681898@gmail.com

Feng-Ming Yeh
Department of Optometry
Yuanpei University of Medica Technology
Hsinchu, Taiwan
optfmy@yahoo.com.tw

Chi-Hung Lee
Department of Electrical Engineering
Feng Chia University
Taichung, Taiwan
chihlee@fcu.edu.tw

Chuen-Lin Tien
Department of Electrical Engineering
Feng Chia University
Taichung, Taiwan
cltien@fcu.edu.tw

Der-Chin Chen
Department of Optometry
Yuanpei University of Medical Technology
Hsinchu, Taiwan
kanatasan.tw@yahoo.com.tw

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***Abstract*—In this study, the human visual field test technology is established by using an optoelectrical system consisting of a translucent ellipsoid, an area light source, and a landscape scene with an indicator. During the test, the subjects stared at the indicator directly in front of them with one eye and kept their eyeballs still, scanning the light strip with peripheral vision and using the mouse button plus the playback program to record the start and end positions of the scanning light strip in the landscape scene. This method is tested subjectively, and the subject needs to respond during the test. Therefore, before the test, the subject needs to understand the test process and be trained in advance to improve the exam accuracy. In the experiment, fifteen subjects with normal vision and no eye disease were selected. Their visual fields were confirmed normal after a preliminary assessment. The test results showed that the subjects' eyes were within the normal visual field, indicating that this method was feasible. In this research, a digital optical platform for the near visual field is proposed to establish an optoelectric visual field measurement technology. The proposed method is characterized by small size, rapid operation, and easy portability. With the digital LCD and visual imaging technology, both dynamic and static visual fields can be tested. The test data on the eyes' upper, lower, nasal, and temporal sides were consistent with the normal visual field. This shows that this method is feasible and worthy of promotion in the optometry industry.**

Keywords—visual field, elliptical mirror, landscape scene

I. INTRODUCTION

The visual field refers to the range of visual perception when the eyes are gazing at a stationary landscape scene in one direction with the head and body of an observer kept in a fixed position. The binocular visual field is the combined visual perception of both eyes under the same movement with scene constraints. The standard unit of test in the visual field is differential light sensitivity (DLS), which is defined as the perception threshold of the indicator relative to the extent of the landscape scene [1−6]. The background brightness remains unchanged during the actual test, while the targets of different sizes, brightness, and positions are presented in the landscape scene. The target is introduced by movement while its size and brightness remain the same, known as a dynamic visual field or a static visual field that changes its size and brightness while staying in a fixed position. The visual field is often represented as a "vision island," which corresponds to the light perception field of the steady eye. There is a blind spot in these ranges, located 15° from the fixation point on the temporal side. The interest in perimetry comes from the anatomical organization of the visual system, particularly from the pathways and vascularization of nerve fibers. In normal subjects, the fovea has the best sensitivity to light. It regularly decreases as it develops away from the center toward the periphery, and the absolute limits of head morphology define the visual field of 60° for the nasal, 95° for the temporal, 60° up, and 70°down. For a general visual field test, the subject sits and looks at a bowl-shaped device called the perimeter. Until peripheral vision loss is detected, a map of the loss is provided to diagnose the cause of the loss in central vision testing. Perimetry can employ various techniques, such as static, dynamic, hybrid, and mobile perimetry.

II. PRINCIPLE

An ellipse has two focal points, which are located on the long axis, distributed on both sides of the ellipse's center point, and the distance is equal. If the interior of the ellipse is a mirror, any optical ray emitted from the focus always passes through the other focus, such as ray 1 and ray 2 shown in Fig. 1. Every optical ray that leaves F1 is reflected from the inside of the elliptical mirror and then passes through another focal point, F2. At any point on the ellipse, the sum of the distances from this point to the two foci is constant. The ellipse's center is at the origin O, the x-axis is the long-axis direction, the y-axis is the short-axis direction, c is the focal length, and the two focus are the points F1(c,0) and F2(-c,0). where V is the right vertex of the ellipse and the distance from O to V is a. For an arbitrary point P(x,y) the distance to the focus (c,0) is [(x-c)2+y2]1/2 and to the other focus [(x+c)2+y2]1\2. Hence, the point (x,y) is on the ellipse whenever

$$[(x-c)^2+y^2]1/2 + [(x+c)^2+y^2]1/2=2a \quad (1)$$

Equation (1) is used to deduce the angle between Ray1 and Ray2 on F2, which is the range of the opening angle of the two rays on F2. Using the principle of triangular geometry and Fig. 1, θ1 and θ2 can be obtained individually as follows.

$$\text{Tan}\theta 1=y/(x1+c1) \quad (2)$$

$$\text{Tan}\theta 2=y/(-x1-c1) \quad (3)$$

As shown in Fig. 1 and using Eqs. (2) and (3), θ is obtained as

$$\theta=\pi-\theta 1-\theta 2 \quad (4)$$

Assuming that the range of the light strip is from the rightmost point P to the leftmost Q point, which is also the viewing angle range that the eye can see, θ is the human eye that uses the elliptical mirror to transmit the light strip from the F1 point to the F2 point. Assuming that the width of the light strip is from the rightmost point P to the leftmost Q point, which is also the viewing angle range that the eye can see, then θ is the elliptical mirror to transmit the light strip from the F1 point to the human eye at the F2 point. The visual field is an essential parameter in the human eye, and diseases affect the visual field.

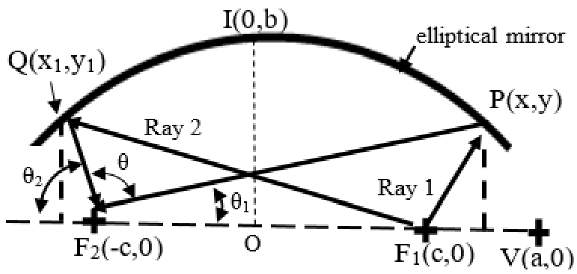

Fig. 1. Ray Tracing of an Ellipse.

III. Experiment Results

The system consists of a semi-transparent elliptical mirror [7], an area light source module, a landscape scene, and the computer as shown in Fig. 2. The semi-transparent elliptical mirror system provides a test platform, and the area light source module and the subject's eye are located at their respective focal points. The subject's eye can see the landscape scene and the scanning light strip through the elliptical mirror. The LCD is placed behind the semi-transparent elliptical mirror, providing the landscape scene with a significant indicator, as shown in Fig. 3. The content of the landscape scene can be replaced, and the indicator is used for the subject to stare during the test. The mini-CCD camera is embedded in the upper part of the LCD to monitor that the eyes of the subject look at the indicator during the test. The brightness and contrast of the LCD can be adjusted. Different brightness landscape scenes are used as a test of visual field sensitivity.

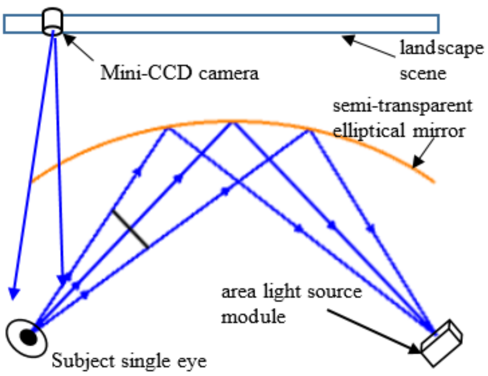

Fig. 2. System Structure.

The mini-CCD camera with a zoom lens is used to capture the appearance of the eye and cornea. The area light source module is composed of a negative cylindrical lens, an LED collimated light beam, and a rotating device. The brightness of the LED is modulated by the pulse width modulation method, and the brightness is controlled by adjusting the duty cycle of the pulse wave to meet the needs of the subjects with different eye sensitivity. The LED collimated light beam with diameter r is placed at the focus of the cylindrical lens with focal length f to form a one-dimensional light strip with length Las as shown in Fig. 4. The one-dimensional light strip scans using the rotating device to form an area light source. The length L of the one-dimensional light strip is equal to 2 x (r/f) x (z+f). When the scanning light strip of the area light source module placed on the first focus of the semi-transparent elliptical mirror is reflected by it and projected on the subject eye at the second focus, the dynamic response of the eyeball is captured through the mini-camera. When both the playback software of the landscape scene and the mouse's button are controlled by the computer, the subject can confirm the starting and ending positions of the light strip on the landscape scene by pressing the buttons during the test. In the monocular visual field test. The shielding device is used to shield the other eye during the monocular visual field test. To complement the monocular test and shield the other eye, the system is designed to rotate 180°.

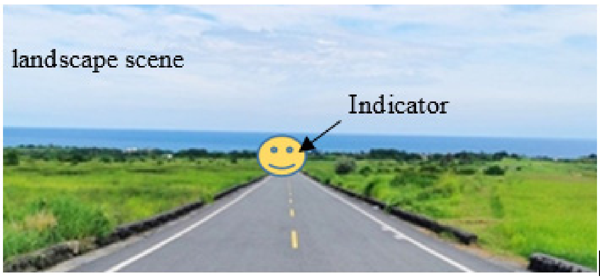

Fig. 3. Landscape Scene and Indicators.

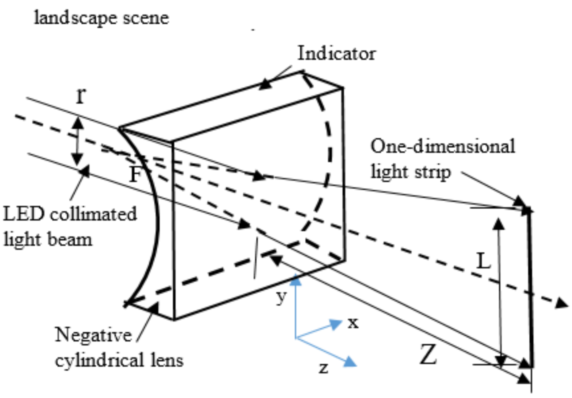

Fig. 4. One-dimensional Light Strip.

The experimental operation process includes the following eight steps: (a) System setup and functional connection test, (b) covering the left eye, measuring the right eye, and playing the landscape scene, (c) the right eye looks at the indicator of the landscape scene ahead, and the peripheral vision looks at the position where the horizontal light strip appears and disappears and records it, (d) the horizontal light strip scans from top to bottom to form an area light source, and its scanning speed should be suitable for the response speed of the subject, (e) the subject senses and reads the starting and ending positions above the scan line of the horizontal light strip, and for example, the subject automatically uses the mouse button and the playback program to perform the visual field test, (f) the vertical light strip is scanned from right to left to form an area light source, and its scanning speed should be suitable for the reaction speed of the subject, (g) the subject senses and reads the position of the right start and left end of the light strip scan strip, and for example, the subject automatically uses the mouse button plus the playback program to perform the visual field test, (h) rotating the system 180°, covering the right eye, measure the left eye, and repeating steps (d) to (g), and (i) statistics and analysis of test data. Figure 5 shows the visual field test flow chart of one eye. In this study, participants were required to have normal eye vision, no eye diseases, symmetrical faces, and the same pupil distance, and were trained before the test. A total of fifteen subjects participated in the experiment, and each subject took the test five times, taking the average value. The measured data are listed in Table I. The test results were divided into five data groups. The nasal side was between 58°and 54°, the temporal side was between 93° and 89°, the up was between 59° and 56°, and the down was between 69° and 63°. These data were in the range of the field of view for people with normal vision.

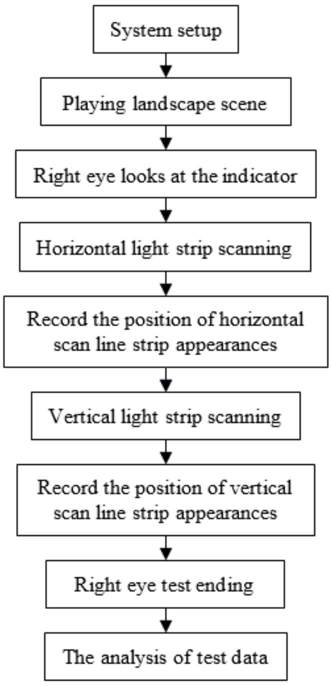

Fig. 5. Visual Field Test Flow Chart of One Eye.

The analysis result of comprehensive research shows the following.

(a) Because the sensitivity of each person's eyes changes with the degree of mental relaxation, the same subject also slightly changes the starting point and end point of the scanning light strip if the subject looks at the edge of the visual field with its peripheral vision. This is the most significant source of measurement error. Light strip brightness can be changed to decrease scan speed.

TABLE I. TEST DATA OF THE MAXIMUM VISUAL FIELD OF FIFTEEN SUBJECTS

Group	Nasal	Temporal	Up	Down	Number of subjects
1	58°	93°	59°	69°	2
2	54°	89°	56°	63°	1
3	55°	92°	58°	68°	4
4	57°	94°	57°	64°	6
5	56°	91°	58°	67°	2

(b) Because the raised part of everyone's nose is not sharp, it affects the test data of the visual field of the nasal.

(c) This system is only suitable for monocular visual field testing.

(d) The system is used in a closed space and is not easily affected by external interference.

(e) The brightness of the landscape scene and light strip can be adjusted, and the scanning speed of the light strip can also be adjusted.

(f) The subject can use the mouse button and play the program to perform the visual field test automatically.

IV. CONCLUSION

This research is carried out to provide an optical platform for tesing visual field test and establish an opto-electric visual field measurement for rapid operation and easy portability in a small size. Owing to the digital LCD and visual imaging technology, both dynamic and static visual fields can be tested. Fifteen subjects with normal vision were selected for testing in this experiment. The test data on the upper, lower, nasal, and temporal sides of the eyes were consistent with the normal visual field of the literature. This shows that this method is feasible and worthy of promotion in the optometry industry.

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