An improved apparatus of infrared videopupillography for monitoring pupil size

T.-W. Huang*[a], M.-L. Ko[a, b], Y. Ouyang[c], Y.-Y. Chen[d], B.-S. Sone[d], M. Ou-Yang[a], J.-C. Chiou[a]
[a]Department of Electrical and Computer Engineering, National Chiao Tung Univ., Hsin-Chu city 30001, TAIWAN; [b]National Taiwan Univ. Hospital, Hsin-Chu Branch, Hsin-Chu city 30059, TAIWAN; [c]Department of Electrical Engineering, Chang Gung University, Taoyuan County 33302, Taiwan; [d]Institute of Electrical Control Engineering, National Chiao Tung Univ., Hsin-Chu city 30001, TAIWAN.

ABSTRACT

The intraocular pressure (IOP) can diagnose or track glaucoma generally because it is one of the physiology parameters that are associated with glaucoma. But IOP is not easy and consistent when measured under different measure conditions. Besides, diabetes is associated with diabetic autonomic neuropathy (DAN). Pupil size response might provide an indirect means about neuronal pathways, so the abnormal pupil size may relate with DAN. Hence an infrared videopupillography is needed for tracking glaucoma and exploring the relation between pupil size and DAN. Our previous research proposed infrared videopupillography to monitor the pupil size of different light stimulus in dark room. And this portable infrared videopupillography contains a camera, a beam splitter, the visible-light LEDs for stimulating the eyes, and the infrared LEDs for lighting the eyes. It can be mounted on any eyeglass frame. But it can modulate only two dimensions, and we cannot zoom in/out the eyes. Moreover, the eye diameter curves were not smooth but jagged because of the light spots, lone eyelashes, and blink. Therefore, we redesign the optical path of our device to have three dimension modulation. Then we can zoom in the eye to increase the eye resolution and to avoid the LED light spots. The light spot could be solved by defining the distance between IR LED and CCD. This device has smaller volume and less cost then our previous videopupillography. We hope this new infrared videopupillography proposed in this paper can achieve early detection of autonomic neuropathy in the future.

Keywords: Glaucoma, videopupillography, intraocular pressure, pupil, pupil size, pupillometer

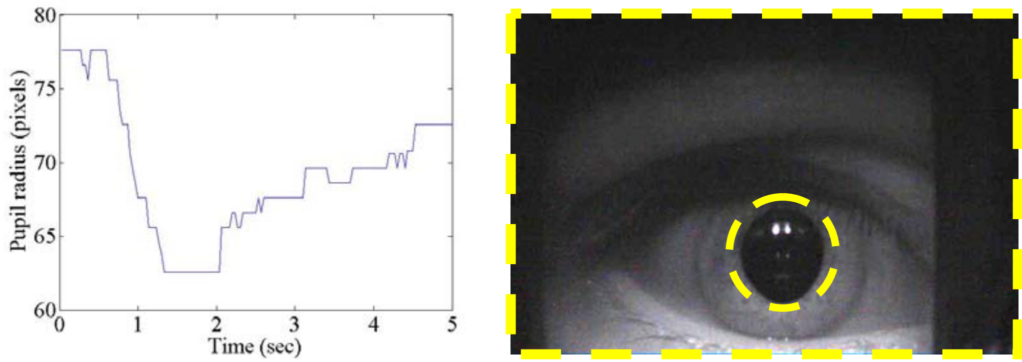
1. INTRODUCTION

The symptoms of glaucoma are usually neglected by people because these symptoms are not usually very obvious. Because the intraocular pressure (IOP) is one of the physiology parameters that are associated with glaucoma, we diagnosed or tracked glaucoma by IOP generally. But IOP measurement is not easy and consistent under different measure conditions. The pupil response was also discussed in many medical studies [1]-[5]. Moreover, pupil size and response to light have been used to investigate the neurological injury of brain. The pupil size is controlled by circular and radial muscles. The circular muscle and radial muscle are innervated by parasympathetic fibers and sympathetic fibers respectively. Hence, the pupil size is controlled by the former muscles in response to the light. This phenomenon is called the pupil light reflex [6]. Besides, diabetes is associated with autonomic neuropathy called diabetic autonomic neuropathy (DAN). Therefore, the response of pupil size may provide indirect methods about neuronal pathways, and it is reasonable to expect that the abnormal pupil size may relate to DAN. Hence, analysis of some parameters from pupil size is important [7]. From what is mentioned above, there are some correlations between the pupil response and some diseases under the different stimulating light. A device to monitor the pupil size is necessary to explore the correlations between some diseases and the pupil response. Therefore, an infrared videopupillography is a device to track the location of pupil and to measure and record the pupil size with different stimulating light sources.

However, pupil disease is unobvious to be found easily, and usually examined by pupillometer. It is not easy to have a pupil examination because pupillometer has big volume and heavy weight, thus is not convenient to monitor the pupil monitor for a period of time. Moreover, it costs a lot of money and does not exist in every hospital. In our previous paper, we proposed an apparatus of infrared videopupillography with visible light LEDs to monitoring the pupil size. It is lighter and smaller than the present product, and is applied to explore the correlations between glaucoma and the pupil

Infrared Sensors, Devices, and Applications IV, edited by Paul D. LeVan, Ashok K. Sood,
Priyalal Wijewarnasuriya, Arvind I. D'Souza, Proc. of SPIE Vol. 9220, 92200T
 · doi: 10.1117/12.2062059

response. But the eye diameter curves showed as fig.1 (a) were not smooth bur rather jagged, and they were caused by the infrared light spots shown as fig.1 (b), eyelashes, and blink. And the optical module of beam splitter limited the field of view (FOV) shown as fig.1 (b).



(a) (b)

Figure 1. (a) The eye diameter curves were not smooth but rather jagged. (b) The infrared light spots affect the analysis

Thus in this paper, we redesign the optical path of our infrared videopupillography to have three dimensions of modulation, then we can zoom in the eye to increase the eye resolution and to avoid the LED light spots. The light spot could be solved by defining the distance between IR LED and CCD. It still contains several wavelengths of stimulating light to stimulate pupil for exploring the correlations between some diseases and the pupil response. The infrared videopupillography system is introduced and some experiments are shown.

2. INFRARED VIDEOPUPILLOGRAPHY SYSTEM

In this paper, the new design of infrared videopupillography system is similar to the one in our previous paper. It still contains stimulating and lighting system, a camera, an image software, and an analysis program of pupil size, but the optical module of beam splitter is eliminated because it had large volume and limited the FOV of camera. Therefore, the flow chart of Infrared videopupillography system is similar to previous one shown as Fig. 2.

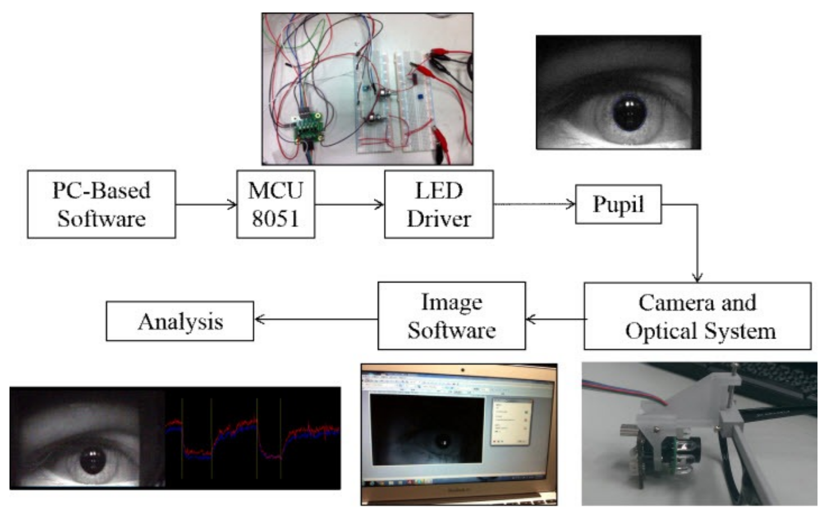
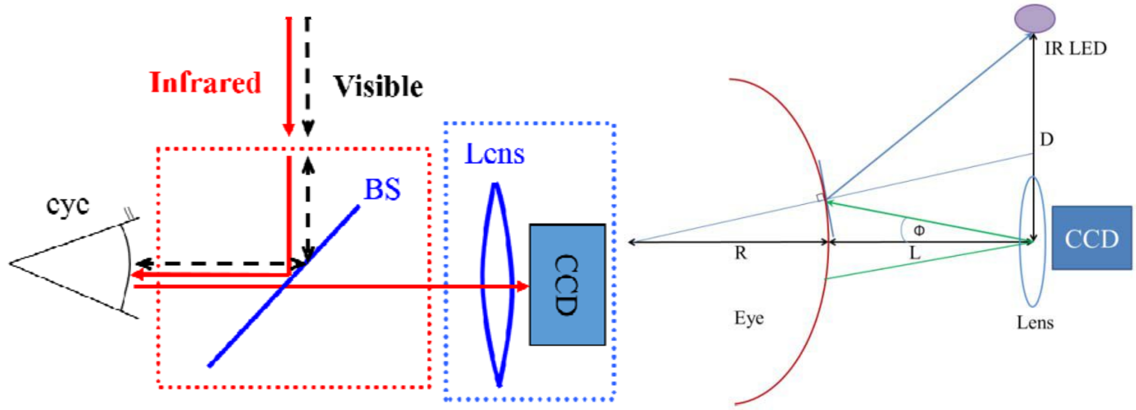


Figure 2. The flow chart of Infrared videopupillography system

The command is assigned to MCU by PC-Based software. Then the signal passes to LED driver to control LED. Besides, the light source of stimulating and lighting system adopting LEDs is same as in previous paper. The different wavelength of the stimulating LED are shown as the following: (1) white light, (2) red light (wavelength = 640nm), (3) green light (wavelength = 534nm), and (4) blue light (wavelength = 470 nm). The wavelength of the lighting LED is 900nm, and it will not be seen by human eyes. The LED light will stimulate the eye, then the image transfers by the optical module and is record by Camera. Finally, the image is analyzed. The resigned optical path is introduced in the following.

The previous optical path of this infrared videopupillography system is showing as Fig. 3(a). The beam splitter limits the FOV, and the volume of shell for holding the beam splitter, LED light source, and camera is big. Therefore, we redesigned the infrared videopupillography system without the optical module of beam splitter (BS). Moreover, the light spot will affect the analysis of pupil diameter, we want to eliminate the light source artifacts in our new design of infrared videopupillography system. Hence, we need to change the location of LED light source for the elimination of the light spots, the method is discussed in Fig. 3(b). We set the LED light source around the CCD of the camera. There is a light spot reflecting from pupil. It would affect the accuracy of the system. The method to solve this problem is determining the distance between lens and pupil shown in Fig.3 (b). The radius of eye is R. The distance between eye and lens is L. The field of view angle is Φ. The distance between IR LED and CCD is D. There is a position where pupil would not reflect the IR LED to. The distance L relates with the distance between IR LED and CCD and the field of view angle of IR LED. The result of distance between IR LED and CCD are shown in (1) and (2). Hence, from Fig. 4, we can easily eliminate the light spot when the set of LED light sources and camera moves closer to eye.



(a) (b)

Figure 3. (a) The previous optical path of this infrared videopupillography system. (b) The new optical design of reducing the IR LED light spot reflection. The radius of eye is R. The distance between eye and lens is L. The field of view angle is Φ. The distance between IR LED and CCD is D.

$$\mathrm{D} = \mathrm{X}[\tan\left(2sin^{-1}\frac{Xtan\emptyset}{R} + \emptyset\right) + \tan\emptyset] \tag{1}$$

$$\mathrm{X} = \frac{cos^2\emptyset[-2(L+R) + \sqrt{4(L+R)^2 + 4L(L+2R)(2 - \frac{1}{cos^2\emptyset})}]}{4cos^2\emptyset - 2} \tag{2}$$

We eliminated the beam splitter and replaced the big shell with the compressed. Then the new mechanism of infrared videopupillography system is showing as Fig. 5. The structure in Fig. 5 (a) and Fig. 5(b) back-side view and front-side view of the frames. And the brace on the rail can modulate the location in horizontal direction, that show as Fig. 6(a) and Fig. 6(b).

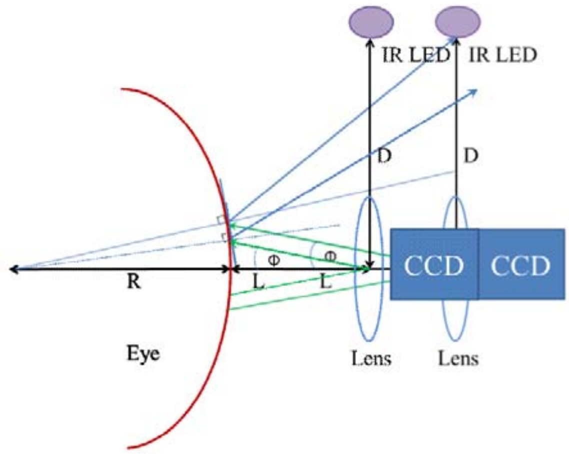
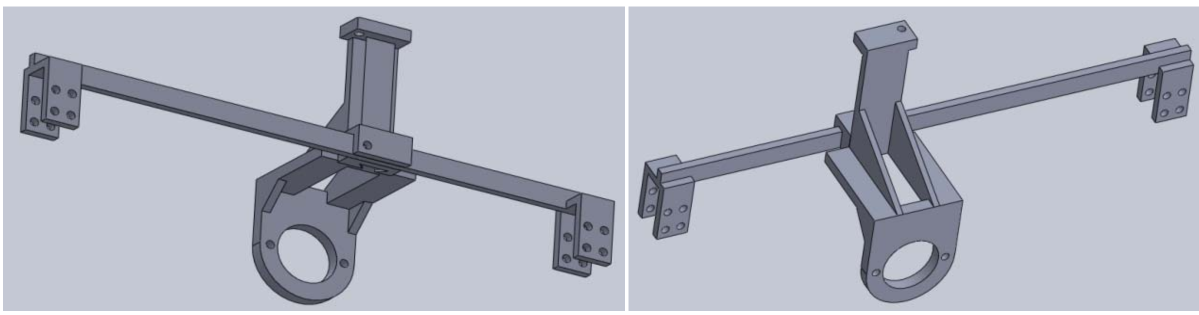


Figure 4. The optical design of reducing the IR LED light spot reflection. The radius of eye is R. The distance between eye and lens is L. The field of view angle is Φ. The distance between IR LED and CCD is D.



(a) (b)

Figure 5. The mechanism of infrared videopupillography system can be modulated on the eyeglass frame. The structure (a) can fix on the brace (b) that can modulate the location at both vertical and horizontal direction.

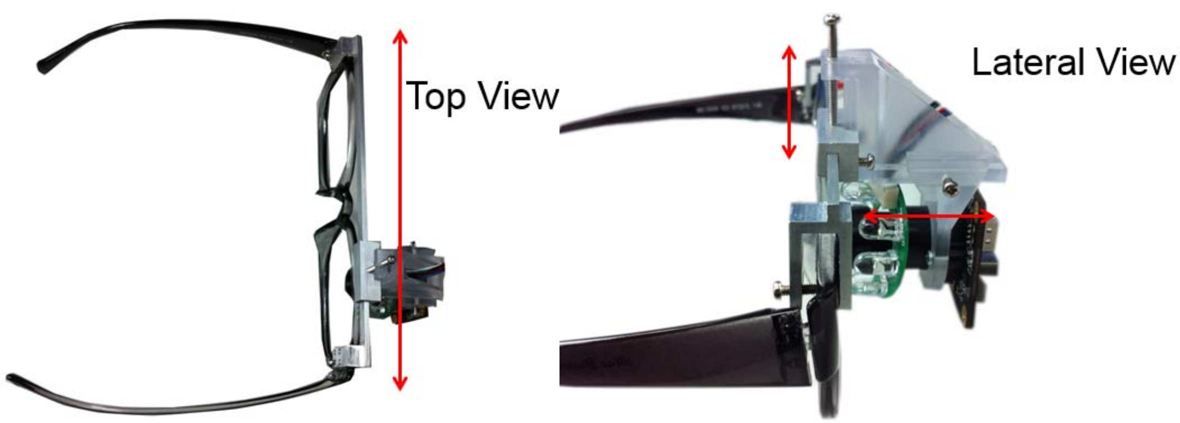


Figure 6. The optical path of this infrared videopupillography system: the visible light is marked by black dotted line and the infrared is marked by red line.

3. EXPERIMENTS

The picture of infrared videopupillography system in the experiments is shown as Fig. 7. The eye images obtained from the video are shown as Fig. 8. We can find that the light spots are eliminated under our new design. When the subject eye stimulated by the green light of 50 mcd. One cycle of LED stimulus has 0.01 seconds of stimulus and 10 second of rest. The eye diameter curves of maximum and minimum are shown in Fig. 9(a). We find that the curve in Fig. 9(a) is not smooth but jagged, and this results caused by blink. Blinks occur during recording pupil size and it affects the program to analyze pupil size. Thus, the image processing program was designed to recognize blinks location automatically from pupil size image and delete it first as Fig. 9(b) shows, then use interpolation to recover the curve as Fig. 9(c) shows.

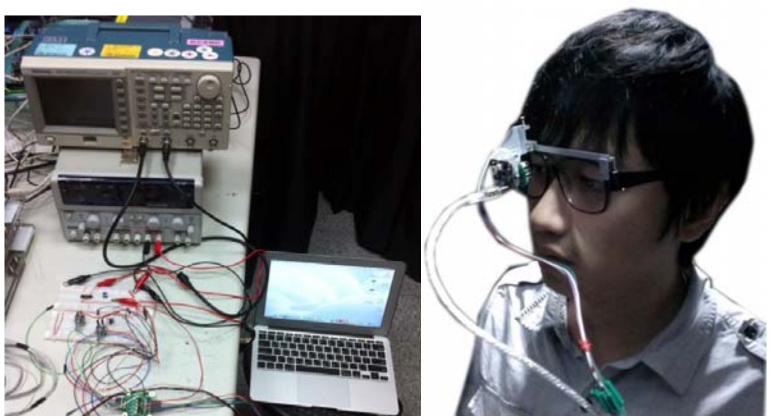


Figure 7. The pictures of infrared videopupillography system in experiments

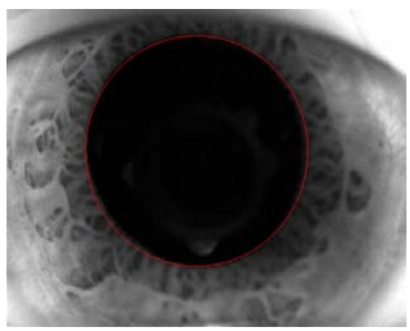


Figure 8. The eye images obtained from the video, and there are no light spots on the pupil.

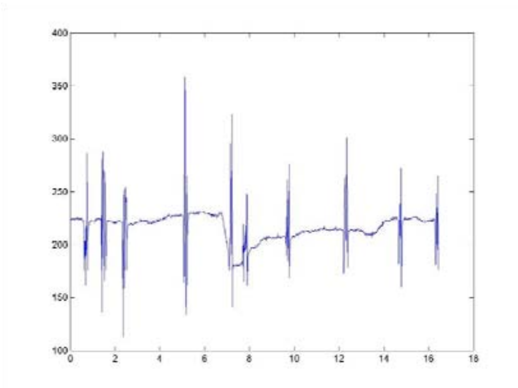
4. CONCLUSIONS

In this study, we proposed a new design of vediopupillometer system for reduced volume of vediopupillometer system and elimination of light spots. With the camera fixed on the frames in our new design, we can zoom in the eye to increase the eye resolution and to avoid the LED light spots. The light spot could be solved by defining the distance between IR LED and CCD. It is easy to analyze any parameters from the result of pupillometer and the result keeps most of information from subjects. It could stimulate with different colors of light, and record the activity of pupil size. The device could solve the problems about big volume and high prices of pupillometer. We hope this new infrared videopupillography proposed in this paper can achieve early detection of autonomic neuropathy in the future.

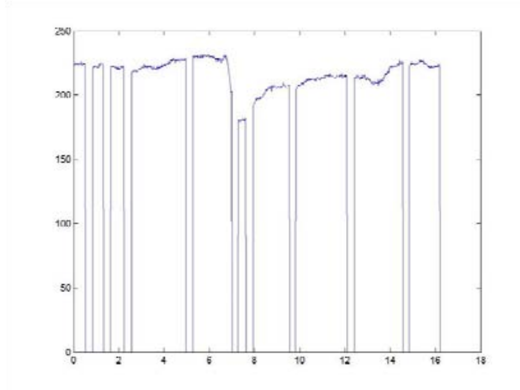
ACKNOWLEDGEMENT

This paper was particularly supported by the Aim for the Top University Program of the National Chiao Tung University, the Ministry of Education of Taiwan (Contract No. HCH102-39), National Taiwan University Hospital, the

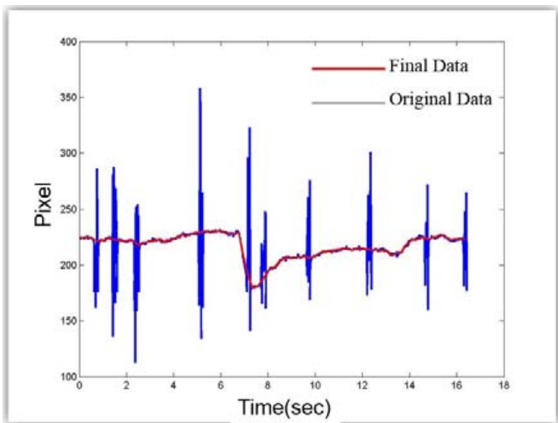
National Science Council of Taiwan (Contract No. NSC 102-2220-E-009-016), and Industrial Technology Research Institute of Taiwan. The authors also want to thank them for providing experimental assistance and related information.



(a)



(b)



(c)

Figure 9. The eye diameter curve: (a) the curve is not smooth and jagged, and this results caused by blink. (b) The image processing program was designed to recognize blinks location automatically from pupil size image and delete it. (c) Then we use interpolation to recover the curve marked as red line.

REFERENCES

[1] Wilhelm, H. and Wilhelm, B., "Clinical applications of pupillography," Journal of Neuro-ophthalmology Paper 23(1), 42-49(2003).

[2] Kawasaki, A., Crippa, S., Anderson, S., and Kardon, R.H., "The Pupil Response to Large Regional Stimuli in Patients with Focal Visual Field Loss," Journal of Neuro-ophthalmology Paper 29(4), 143–147(2005).

[3] Kawasaki, A. and Kardon, R.H., "Disorders of the pupil," Ophthalmology Clinics of North America Paper 14(1), 149-168(2001).

[4] Girkin, C.A., "Evaluation of the pupillary light response as an objective measure of visual function," Ophthalmology Clinics of North America Paper 16(2), 143-153(2003).

[5] Sobaszek, A., Nowak, W., Hachol, A., and Moron Z., "Measurement of the eye pupil response to light stimuli with regulated waveform, wavelength and photopic level," Journal of Physics: Conference Series Paper 238(1), 012032(2010).
[6] Ferrari, G. L., Marques, J. L., Gandhi, R. A., Heller, S, R, Schneider, F. K, Tesfaye, S., and Gamba, H. R, "Using dynamic pupillometery as a simple screening tool to detect autonomic neuropathy in patients with diabetes:a pilot study," BioMedical Engineering OnLine 9(26), (2010).
[7] Pittasch, D, Lobmann, R, Behrens-Baumann, W, and Lehnert, H, "Pupil Signs of Sympathetic Autonomic Neuropathy in Patients with Type 1 Diabetes," Diabetes Care 25, 1545-1550(2002).