Indirect Ophthalmoscopic Stereo Video System Using Three-Dimensional LCD

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ABSTRACT

Binocular indirect ophthalmoscope (BIO) provides a wider view of fundus with stereopsis contrary to the direct one. Proposed system is composed of portable BIO and 3D viewing unit. The illumination unit of BIO utilized high flux LED as a light source, LED condensing lens cap for beam focusing, color filters and small lithium ion battery. In optics unit of BIO, beam splitter was used to distribute an examinee's fundus image both to examiner's eye and to CMOS camera module attached to device. Captured retinal video stream data from stereo camera modules were sent to PC through USB 2.0 connectivity. For 3D viewing, two video streams having parallax between them were aligned vertically and horizontally and made into side-by-side video stream for cross-eyed stereoscopy. And the data were converted into autostereoscopic video stream using vertical interlacing for stereoscopic LCD which has glass 3D filter attached to the front side of it. Our newly devised system presented the real-time 3-D view of fundus to assistants with less dizziness than cross-eyed stereoscopy. And the BIO showed good performance compared to conventional portable BIO (Spectra Plus, Keeler Limited, Windsor, UK).

Keywords: Funduscope, Ophthalmoscopy, Indirect Ophthalmoscope, Stereoscopy, 3D LCD

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1. INTRODUCTION

Ophthamoscopy is a routine examination of fundus to reveal the pathological changes in retina, retinal blood vessels, optic disk head and choroid. It is useful in detecting and evaluating various retinal diseases (e.g. such as retinal holes and tears, retinal detachment, retinal vascular disorders, diabetic or hypertensive retinopathy). And there are two types of ophthalmoscope (ie. direct and binocular indirect ophthalmoscopes) to observe the fundus.

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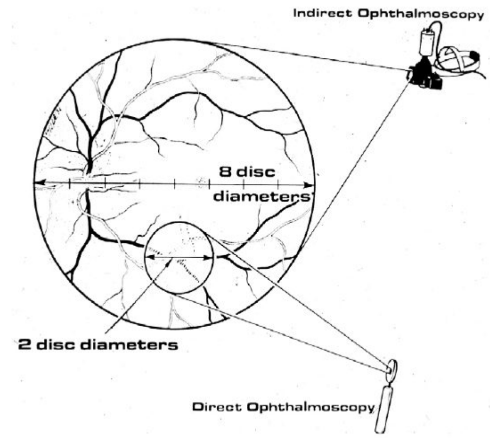
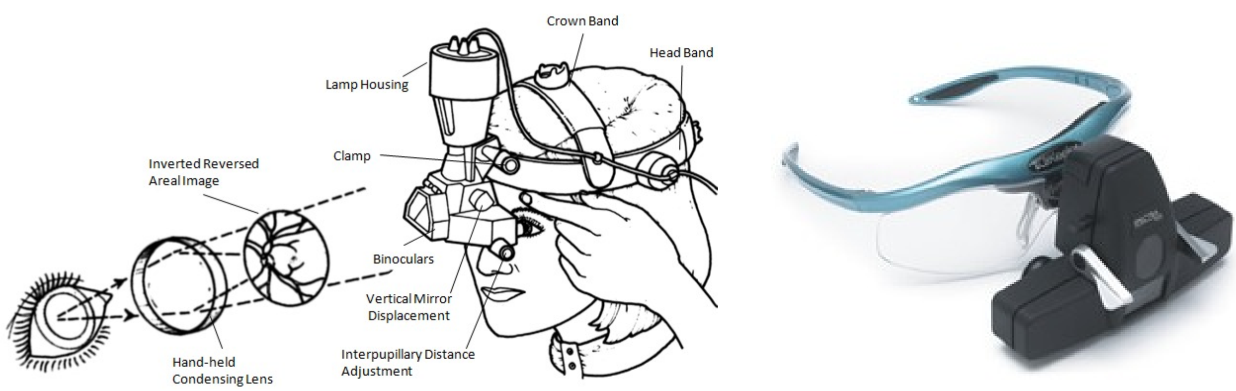


Fig. 1. Comparison of viewing angle between direct and indirect ophthalmoscopes

Direct ophthalmoscope is small-sized, light-weighted and provides good spatial resolution in magnified view. And it is convenient to assess focal lesions around optic disk. But it is inclined to be affected by the degree of transparency of vitreous, cornea and lens. Because of limitation of examination technique, there are difficulties to utilize it to youth. Besides it does not provide the stereopsis to examiner.

Binocular indirect ophthalmoscope (BIO) is not influenced by turbidity of the vitreous or lens and provides large field of view (Fig. 2). Thus it is convenient to evaluate the large-sized pathological changes such as diabetic retinopathy. Since it enables the examiner to view the fundus stereoscopically, it is suitable for visualizing the retinal detachment especially. However, BIO requires high degree of operator skills since it shows reversed and inversed image of retina and requires the proper magnifying lens which should be handled simultaneously during the examination. And generally it is somewhat heavy to wear on head for a long time. In case of the video-assisted indirect ophthalmoscope, it is much heavier than conventional one, thus it is not so commonly adopted even for the educational purpose. Recently, glasses-type BIO (Spectra Plus, Keeler Limited, Windsor, UK) is commercially available for light-weighted and easy wearing prototype. However it cannot provide the assistant view.



(a) (b)

Fig. 2. Conventional binocular indirect ophthalmoscope (BIO) (a) and portable glasses-type BIO released recently (b)

To overcome the drawbacks of conventional BIO, we developed the specially designed indirect ophthalmoscopic stereo video system which provides stereopsis not only to examiner but also to other persons (e.g. assistants) through three-dimensional LCD. And the performance of our BIO system was compared with that of commercialized portable indirect ophthalmoscope.

2. MATERIALS & METHODS

The proposed system is composed of optics, illumination, video camera and 3D viewer units as shown as Fig. 3. The ray of light from the illumination unit is condensed into the retina of examinee and the reflected image of fundus is sent to the examiner's eye directly through the optics unit or to the assistants by the video camera unit. And the assistants can view the fundus image stereoscopically using the 3D viewer unit.

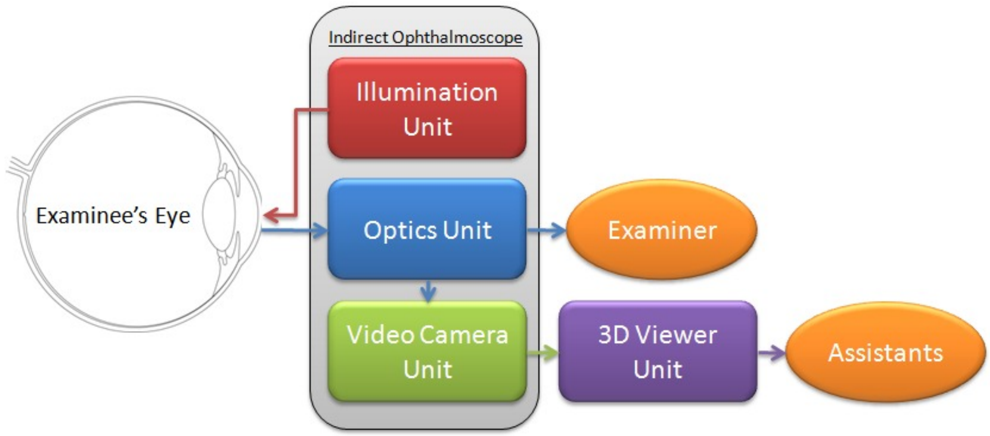
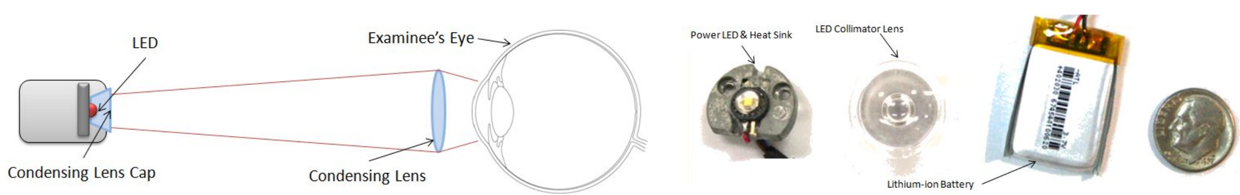


Fig. 3. Block diagram of our BIO system which consists of illumination, optics, video camera and 3D viewer units.

2.1 Illumination Unit

As an illumination source, the white light emission diode (LED) with 1 W power was used instead of halogen bulb that is used as the illumination source of conventional BIO. The LED provides bright and homogenous light with less heat. And its low power consumption and long durability more than 100,000 hours lengthened the period of the replacement of illumination source. The desired angle of illumination by LED light source was acquired with the condensing lens cap which was located on the LED and focused the beam into the examinee's eye fairly well in the degree of 8°. A compact 3.7V lithium ion battery was used as a power source. It can be clipped onto the waist belt when in use and charged through USB port of personal computer. When charged fully, the battery continuously lasted for about 5 hours without recharging



(a) (b)

Fig. 4. Illumination unit: illumination process (a) and real picture of used components (b)

2.2 Optics Unit

The optics unit is consisted of binocular eyepieces and hand-held condensing lens. Light emitted from the illumination unit is condensed into the examinee's eye. Reflected fundus image is magnified, inverted and reversed through hand-held condensing lens. And this virtual image is transmitted into the binocular eyepieces (Fig. 5).

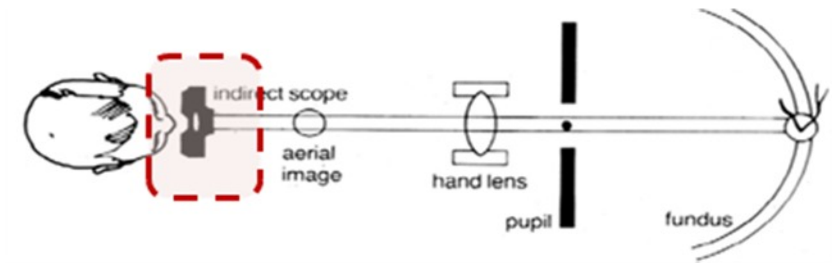
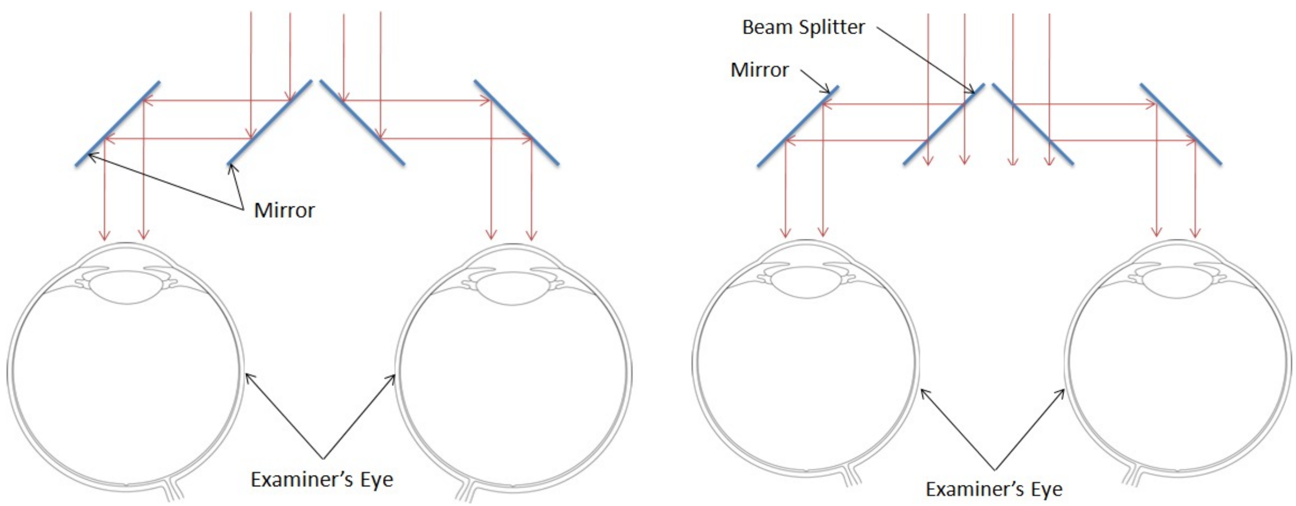


Fig.5. Optics unit composed of binocular eyepieces and hand-held condensing lens

In conventional BIO, the visual axis is fully reflected on two 45°-tilted mirrors (or prisms) and the aerial image of fundus is sent to examiner's eyes (Fig. 6 (a)). In our new system, the image at first meets the polarizing beam splitter, which splits randomly polarized beams into two orthogonal, linearly polarized components. P-polarized light is reflected to the 45°-tilted mirror and then transmitted into examiner's eye, while T-polarized light is directly transmitted into the tiny video camera sensor modules (Fig. 6 (b)). The ratio of reflection and transmission used in this design was 1:1.



(a) (b)

Fig. 6. Optics unit: schematic representations of the conventional BIO (a) and ours (b).

The newly developed optics unit is shown as (Fig. 7). The interpupillary distance of the binocular eyepiece can be adjusted between 55 and 75mm according by the examiner. As a hand-held condensing lens, the conventional 20 diopter aspheric lens was used (Fig. 7).

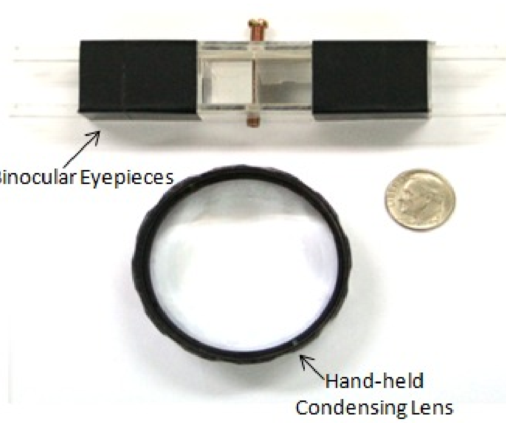
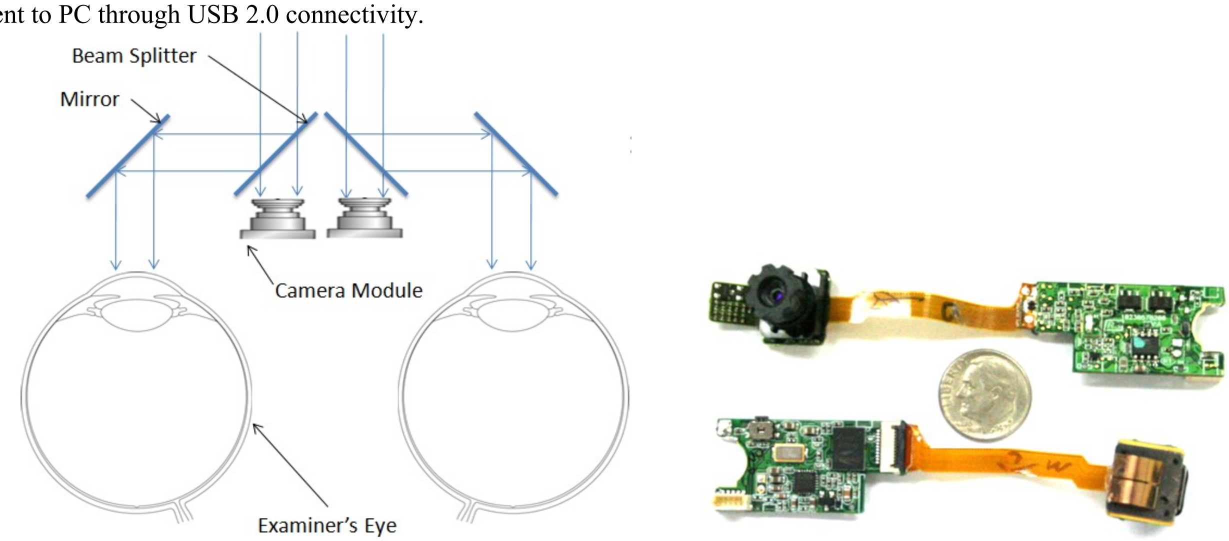


Fig.7. Optics unit: real pictures of binocular eyepiece (upper) and 20 diopter condensing lens (lower)

2.3 Video Camera Unit

Two CMOS camera modules were attached to the beam splitters as shown as Fig. 8 and used to capture the video stream of fundus image at a rate of 25 frames per second. Captured retinal video stream data from stereo camera modules were sent to PC through USB 2.0 connectivity.



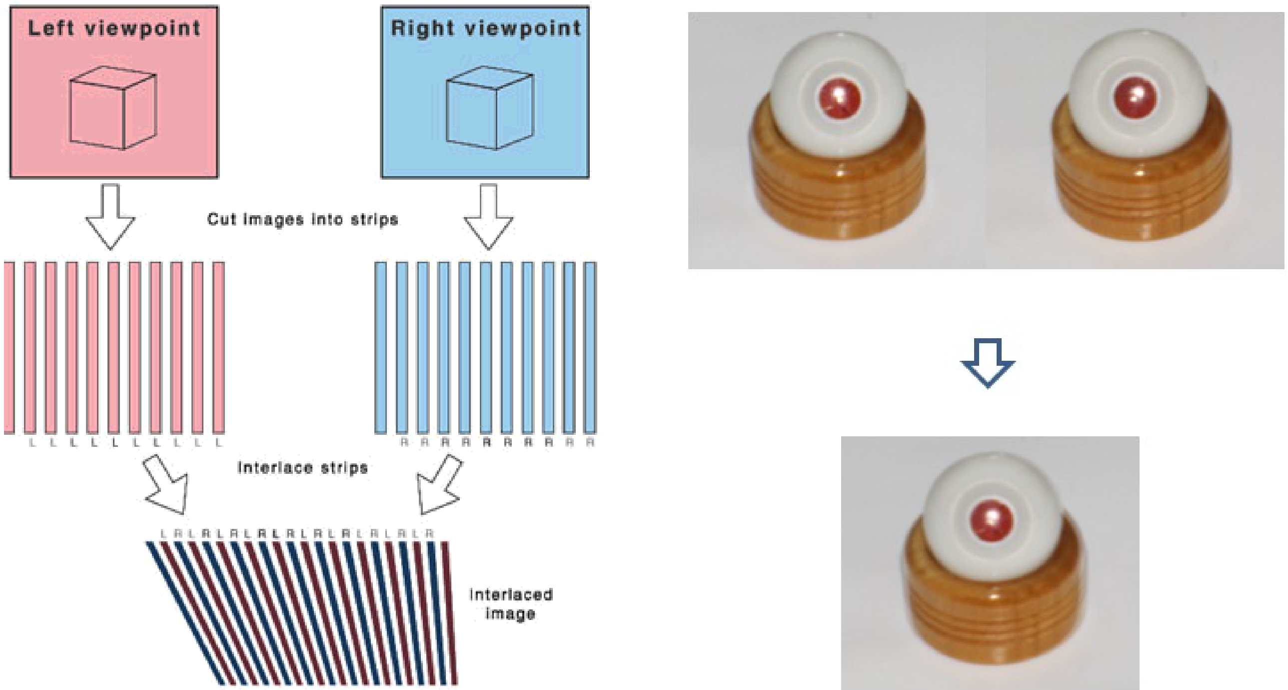
(a) (b)

Fig. 8. Video camera unit: schematic representations of our BIO (a) and real picture of used camera modules (b).

2.4 Three dimensional Viewer Unit

For sharing the stereopsis of BIO, the 3D viewer unit was newly devised. It is consisted of viewing software (SW) running on personal computer, 3D LCD (ZM-M220W, Zalman, Seoul, Korea) and circularly polarized glasses.

In the viewing SW, Two video stream data having parallax between them were aligned vertically and horizontally and made into the side-by-side (i.e. stereo-pair) video stream for cross-eyed stereoscopy. And the data were converted into autostereoscopic video stream using vertical interlacing method (Fig. 9(a)) for the 3D LCD (ZM-M220W, Zalman, Seoul, Korea) which has glass 3D filter attached to the front side of it. Through the circularly polarized glasses, the assistants can view and feel the stereoscopic or 3D effect of fundus image with examiner simultaneously. Additionally the program provides several image processing features such as image flipping, contrast enhancement, still-shot capturing.



(a) (b)

Fig. 9. Procedure making interlaced image from side-by-side image (stereo-pair image) (a) and example of autosteroscopic image for 3D LCD (b)

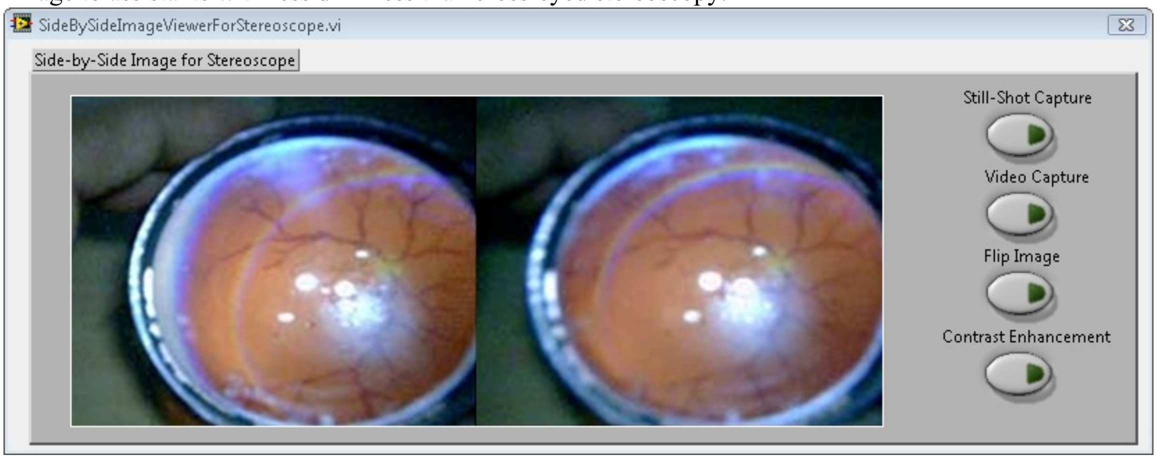
3. RESULTS

The newly devised BIO integrated with the illumination, optics, video camera units is shown in Fig. 10(a). The BIO can be clipped on wrap-around glasses and be swung up to allow the examiner to observe examinee's eye directly.

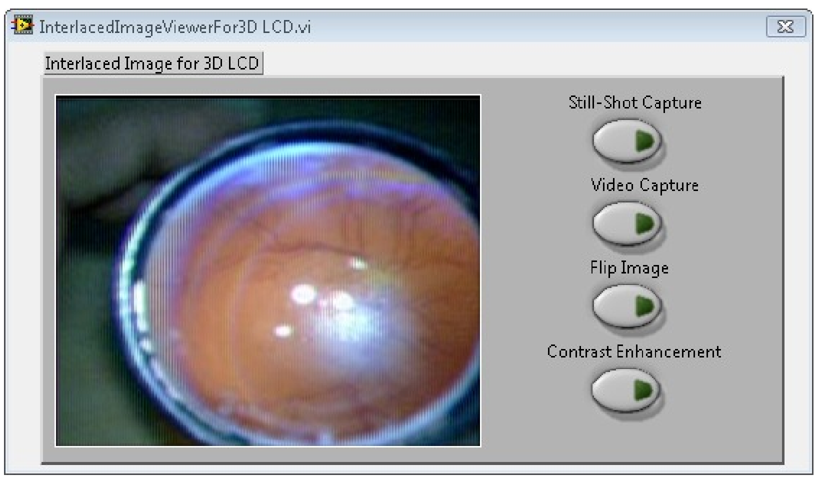
(a) (b)

Fig. 10. Real picture of our newly desined BIO (a) and test for the artificial eye-ball model (b)

The performance of the newly designed system was compared with the conventional portable BIO (Spectra Plus, Keeler Limited, Windsor, UK) as shown Fig. 2(b). It provided long lasting and white homogenous illumination and continuous power consumption for hours. And it was more light-weight and inexpensive than conventional one. Moreover it provided real-time 3D view of fundus to assistants with the video camera unit contrary to the conventional one. For 3D viewing method, preference between the autostereoscopic fundus image (Fig. 11 (a)) with 3D LCD and the side-by-side fundus image (Fig.11 (b)) for cross-eyed technique with normal LCD was examined. Our system showed stereoscopic fundus image to assistants with less dizziness than cross-eyed stereoscopy.



(a)



(b)

Fig. 11. Results of 3D viewing SW for aritificial eye-ball model: side-by-side image for the cross-eyed technique (a) and interlaced image for the 3D LCD (b).

4. DISCUSSION AND CONCLUSION

We developed the portable BIO system, which successful provided the real-time 3-D view of fundus to assistants as well as examiner using stereo cameras and 3D LCD. Because the patient's 3D ophthalmoscopic data can be transmitted to remote server computer through internet and accessed by remote doctors at any time, system could be easily expanded to telemedicine and home healthcare.

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