Fundus imaging using DCRA toward large eyebox

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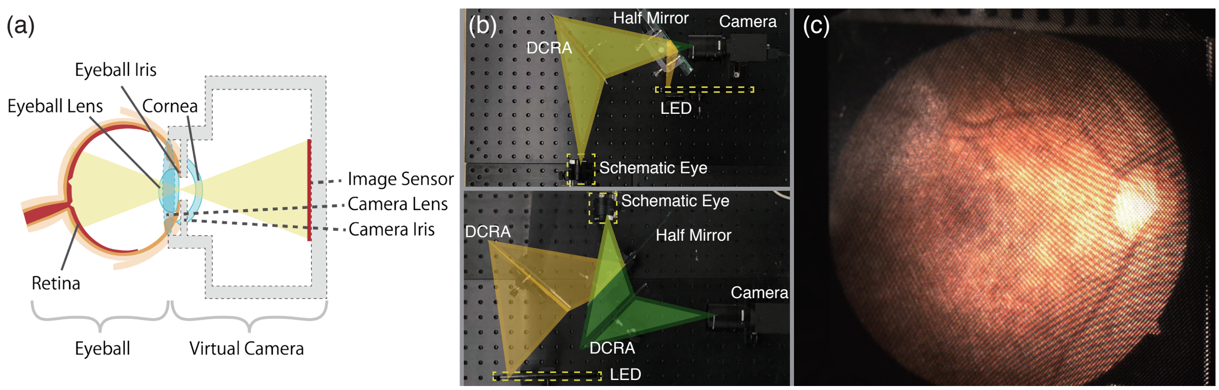

Figure 1: (a) Concept of virtual camera that overlaid to the eyeball using DCRA. (b) Our optical system consisted of camera and two DCRA and light source. (c) A captured image. We used the schematic eye instead of the real eye.

ABSTRACT

We propose a novel fundus imaging system using a dihedral corner reflector array (DCRA) that is an optical component to work as a lens but does not have a focal length or an optical axis. A DCRA has a feature that transfers a light source into a plane symmetric point. Conventionally, using this feature, a DCRA has been used to many display applications, such as virtual retinal display and three-dimensional display, in the field of computer graphics. On the other hand, as a sensing application, we use a DCRA for setting a virtual camera in/on an eyeball to capture a fundus. The proposed system has three features; (1) robust to eye movement, (2) wavelength-independent, (3) a simple optical system. In the experiments, the proposed system achieves 8 mm of large eyebox. The proposed system has a possibility to be applied to preventive medicine for households that can be used in daily life.

CCS CONCEPTS

• **Hardware → Emerging technologies**; *Sensor applications and deployments.*

KEYWORDS

fundus photography, dihedral corner reflector array, light field

SA '19 Posters, November 17-20, 2019, Brisbane, QLD, Australia

ACM Reference Format:
Yui Atarashi, Kazuki Otao, Takahito Aoto, and Yoichi Ochiai. 2019. Fundus imaging using DCRA toward large eyebox. In *Proceedings of SA '19 Posters.* ACM, New York, NY, USA, 2 pages. https://doi.org/10.1145/3355056.3364579

1 INTRODUCTION

Fundus photography is a significant important technique that can examine not only eye diseases but also lifestyle-related diseases because the retina is the only part of the human body where the blood vessels are optically exposed. However, conventional fundus imaging system based on a Maxwell view has a problem that is sensitive to eye movement due to exit pupil is too small. Additionally, to ensure optical performance with a full-color image, wavelength design for microscopy or high-precision manufacturing for laser scanner is required. Therefore, for preventive medicine equipment that can be used in households in daily life, a simple and inexpensive fundus camera with robust to eye movement is desired.

In the near-eye display field, enlarged eyebox method for virtual retinal display (VRD), also known as retinal projection has remarkable attention [Kim et al. 2019]. Ochiai *et al.* [2018] proposed a simple optical system for a VRD that provides a robust to eye movement using a DCRA which is usually applied to the three-dimensional displays [Kim et al. 2014]. Inspired by previous VRD study, we propose a novel fundus imaging method using a DCRA with the following features:

- robust to eye movement.
- wavelength independence.

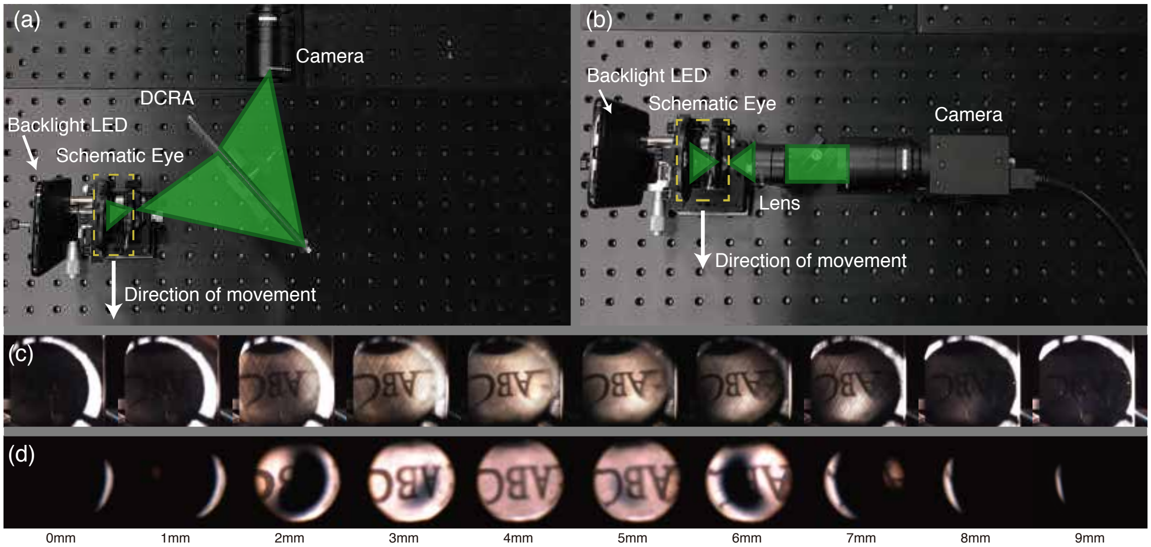

Figure 2: Comparison of the optical system and eyebox measurement. (a) The proposed method using a DCRA. (b) Conventional system based on a Maxwellian view. (c) Captured images by the proposed method. The eyebox is 8 mm. (d) Captured images by conventional method. The eyebox is 3 mm.

- a simple optical system.

2 FUNDUS IMAGING USING DCRA

A DCRA is an optical component that can image input light source to the symmetric position [Maekawa et al. 2006]. Unlike general lenses, a DCRA does not have inherent optical axis or focal length, and is wavelength-independence since it is composed of micromirrors. In the proposed method, we generate a virtual camera overlaid to the eyeball as shown in Fig. 1 (a).

Figure 1 (b) shows the proposed optical system consists of a camera and two DCRAs and light source. A DCRA transfers a physical camera into a plane symmetric position. The DCRA is ASKA3D[1] with a pitch size of 0.5 mm as a DCRA. The camera is GS3-U3-23S6C-C (Grasshopper, FLIR). The resolution is 1920×1200 pixels and the pixel size of image sensor is 5.86 µm. The focal length of the lens is 12 mm. The camera captures printed retina as shown in Fig. 1 (c).

3 EXPERIMENTAL RESULT

We show a comparison of the optical system using the proposed system in Fig. 2 (a) and the optical system based on a Maxwellian view using a conventional lens in Fig. 2 (b). In this experiment, we use a schematic eye consisted of iris, lens, and screen instead of a real eye. Figure 2 (c) and (d) show the result of eyebox when we move the schematic eye to horizontal by 1 mm. In conventional method based on Maxwellian view, the eyebox was 3 mm. On the other hand, the size of eyebox reached 8 mm was achieved in the proposed system.

4 DISCUSSION AND CONCLUSION

There is a trade-off between eyebox and depth-of-field (DOF) by the pitch size of a DCRA. By increasing the pitch size of a DCRA, the eyebox becomes larger and DOF decreases. Although the pitch size of a DCRA could not change dynamically, we can change relative pitch size by changing the optical path length between the DCRA and the camera. When the pitch size of a DCRA is extremely small (i.e. approximately pinhole size), a DCRA behaves as a perfect plane-symmetric transfer optics. However, in that case, the size of the eyebox is equivalent to a Maxwellian view, and image blurring by diffraction effect would occur.

In this paper, we demonstrated and evaluated the principle with the proof-of-concept prototype on the optical bench. We showed that a large eyebox can be achieved with a simple lensless optical system using a DCRA.

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