Open-view Binocular Double-pass System for the Study of Dynamic Accommodation

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Abstract. We present a new open-view dynamic double-pass (DP) system for the study of accommodative response in binocular natural viewing conditions. The DP point spread function (PSF) of the eye is analyzed to compute the Visual Strehl Ratio (VSR) fluctuation as a function of time at 50 Hz frame rate. Preliminary results showed that the proposed method can quantify the temporal dynamic of the optical and visual quality of both eyes simultaneously.

1 Introduction

The interaction of light with the human eye has been widely employed to describe its optical properties [1]. The optical quality of the eye is mainly limited by both scattering and aberrations contributions [2]. In that sense, aberrometers (Hartmann-Shack sensor, Laser Ray Tracing, etc.), and double-pass (DP) systems are commercially available technologies that provide complementary characterization of the optics of the human eye. While aberrometers are used to reconstruct the wavefront aberration through the pupil of the eye, DP technology uses the retinal image from a point source to compute the double-pass *Point Spread Function* (PSF), or the single-pass Modulation Transfer Function (MTF) or the Visual Strehl Ratio (VSR) of the eye [3].
In the last years, accommodation has been one of the most studied functions of the visual system due to the direct relationship to presbyopia progression, myopia development or the restoration of near vision in pseudophakic eyes.

In that sense, DP technology emerged as an excellent objective tool to assess the accommodative response through the information about the optical quality of the eye provided by DP imaging. For the assessment of the dynamics of accommodation it is essential to make binocular measurements [4].
New open-view configurations, have allowed to measure the dynamic response of the optics of the eye in both binocular and natural viewing conditions using DP imaging and aberrometers [5].

The aim of this study was first to introduce a new open-view binocular DP system for the study of accommodation in natural viewing conditions. We present the methodology to obtain optical quality information from DP images. Finally, preliminary testing results from measurements on living human eyes are presented.

2 Methods

2.1 Experimental system

The system incorporates a super luminescent LED (SLED) centred at 840 nm as illumination source. The beam is collimated and split into two identical entrance pupils by means of a 50:50 beam splitter and an adjustable twin mirror system (dual-pupil positioning unit in Fig. 1) to control the spatial separation of the two entrance beams. The entrance pupils are optically conjugated with a refraction correction unit composed of two programmable opto-electronic lenses that compensate for the spherical (defocus) error of each eye, and the natural pupils of the subject itself.

Before reaching the correction unit, the entrance beams are deflected to two optical arms that allow simultaneous control of both eye´s pupils and binocular retinal illumination (See Fig. 1). A couple of hot mirrors (HM) separate the infrared illumination from the visual stimuli. One of the HMs was mounted into a micrometric slider to adjust the interpupillary distance of each subject. The DP system was designed in open-view configuration to allow natural visual conditions.

After retinal reflection (i.e. double-passing), aerial DP images are combined within the same optical pathway preserving the original separation at the entrance pupil of the system and are sampled in a single fundus camera. The optical separation of the entrance pupils was stablished to avoid overlapping of the DP images at the (common) sensor plane.

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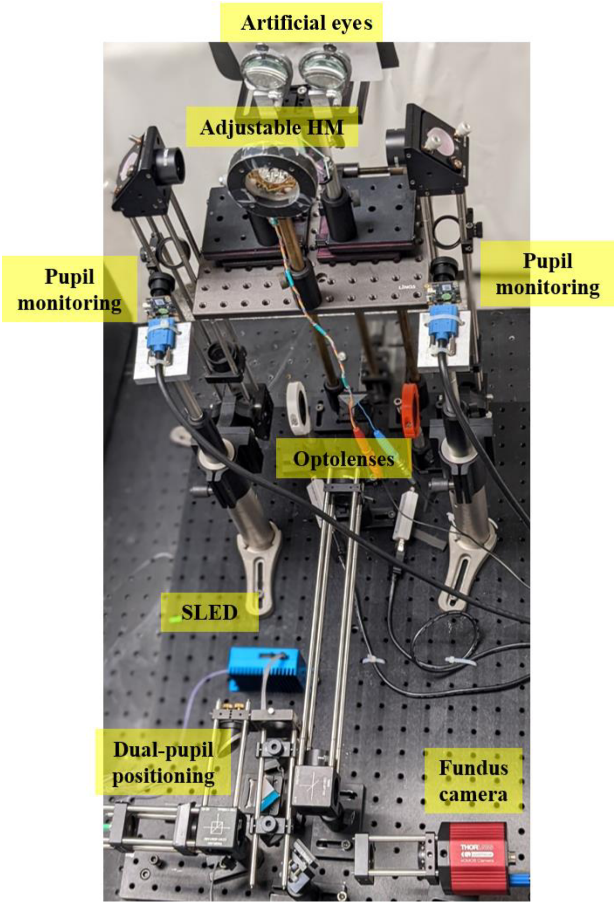

Fig. 1. Top view of the binocular DP system.

2.2 Optical quality analysis

The temporal fluctuations of the optical quality of the eye during accommodation were assessed by computing the VSR from the intensity DP images of each eye, defined as the ratio of the maximum irradiance of the eye´s PSF to that of a diffraction limited PSF for the same aperture.

3 Results

Fig. 2 shows the visual Strehl ratios of both eyes computed form the aerial double pass PSF, recorded at frame rate of 50 Hz. We can observe fluctuations of visual quality even for a constant vergence of the fixation target. In this case the VSR was not normalized by that of a perfect system, so that the vertical axis represents relative values. The right eye (Fig.2b) shows roughly double quality than the left eye, as well as higher fluctuations.

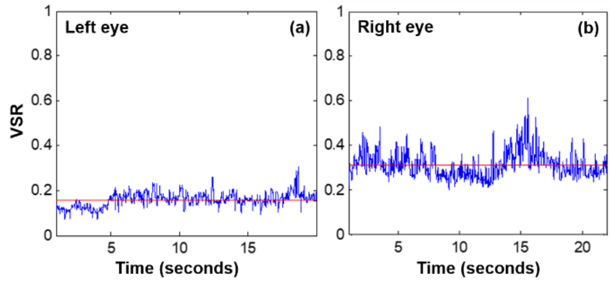

Fig. 2. VSR as a function of time under binocular conditions for one subject. Red line: Averaged VSR value.

4 Conclusions

This work presented an open-view binocular double-pass system to study the temporal dynamics of accommodation in natural viewing conditions. Optical quality fluctuations of the eye were assessed by computing the VSR from intensity DP images and tested in a real eye.

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