Investigating the potential for plenoptic imaging of the retina

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Introduction

Plenoptic imaging is a relatively new imaging technique, in which both position and direction of a ray of light are recorded. This is achieved by placing an array of microlenses between the objective lens of the camera and the sensor, with the two possible configurations shown in Fig. 1 [1, 2]. By capturing this extra information, more comprehensive post processing analysis of the scene can take place from a single image acquisition, including digital refocusing, change of perspective, increased depth of field, depth maps and a topographic surface image. Many of these attributes could provide significant advantages for retinal imaging. Firstly, as all the information is collected in a single image acquisition, this will reduce motion artefacts of the eye which can occur in methods which require many pictures or have to raster across the retina. The increased depth of field is achieved with a large numerical aperture, which will reduce acquisition time or increase the intensity of light recorded compared to a standard image with the same acquisition time and depth of field of the plenoptic image. Depth maps and topographic surface images would show great benefit in retinal imaging, as many diseases are characterised by changes to the retinal surface profile, often difficult to visualise with conventional photography.

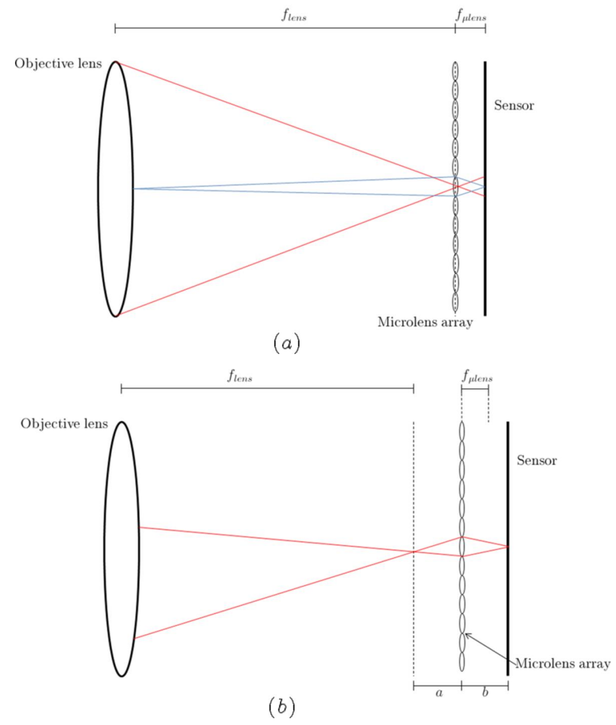

Fig. 1. Configurations of two different plenoptic cameras: (a) The traditional plenoptic camera. (b) The focused plenoptic camera.

Numerical experiments and results

Plenoptic imaging has already proven its capabilities to determine depth and give 3D topographic information in free space models, however no study has shown how it would perform through scattering media such as the retina. In order to study this, simulations were performed using MCML, a multi-layered Monte Carlo modelling software [3]. The first experiment is looking at the undeviated (straight through) photons as they travel through the neural retina to the RPE whilst varying the retinal thickness. This experiment is important as plenoptic cameras can only deduce the depth from the last point of scattering, so if few or no photons reach the RPE unscattered, then a quantitative distance cannot be calculated. Fig. 2. shows the results of this first experiment.

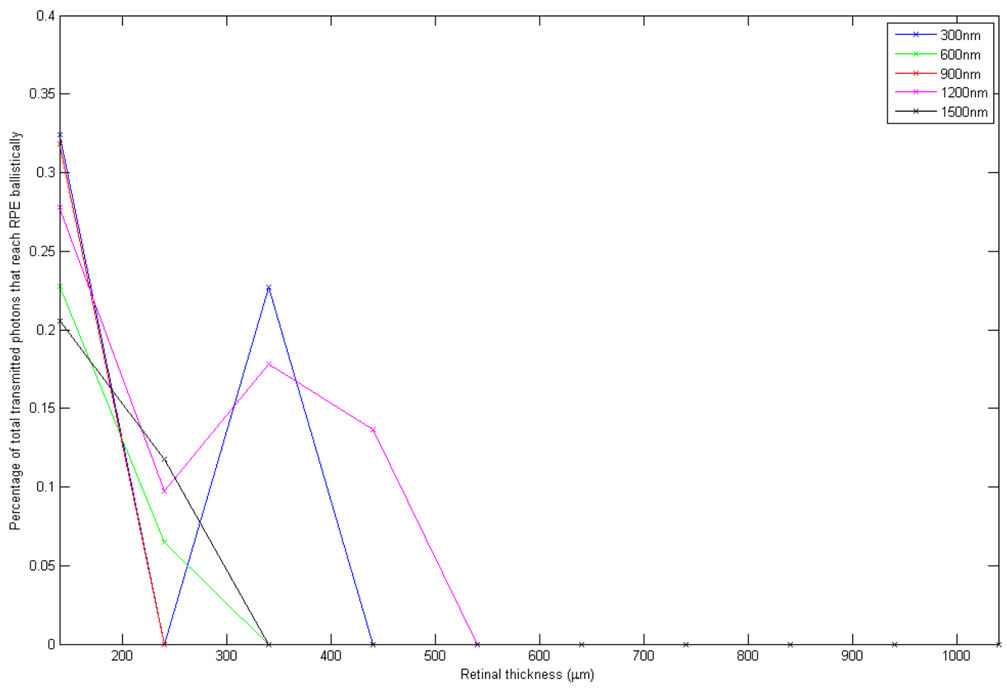

Fig. 2. The amount of undeviated photons transmitted through to the RPE at varying retinal thicknesses. This experiment was performed with 5,000,000 photons.

The second of these experiments was to investigate whether the angular distribution of the reflected photons changes as a function of retinal thickness. As plenoptic imaging records not only spatial information but also angular information, if the angular distribution has any dependence on retinal thickness, it could be deduced that plenoptic imaging may be able to distinguish between regions of different thicknesses. The results of this can be seen in Fig. 3.

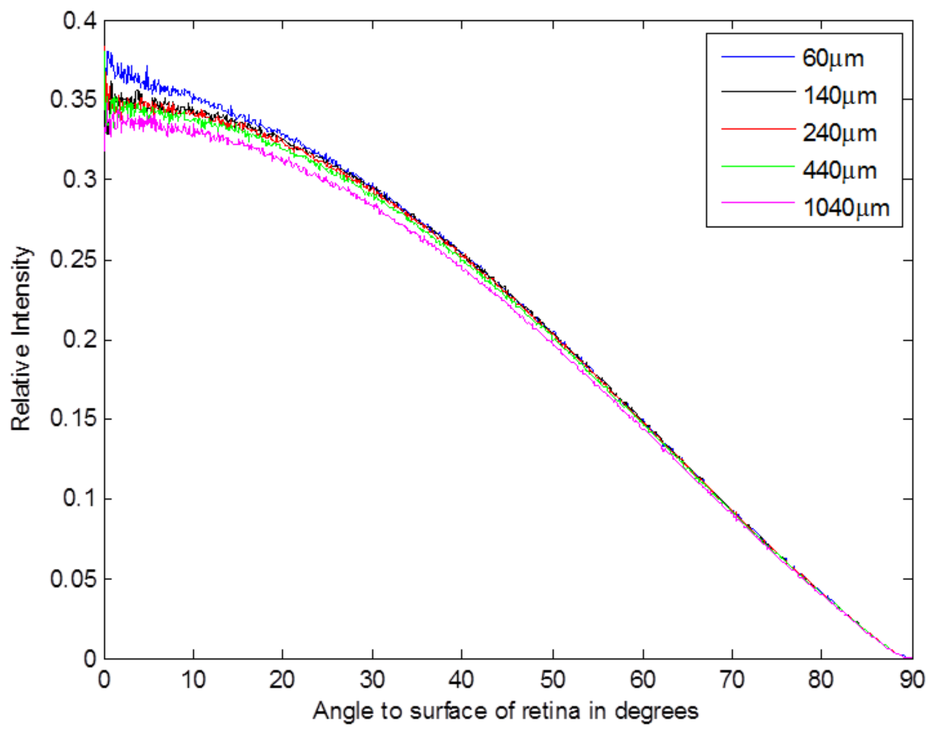

Fig. 3. The angular distributions of light reflected from the surface of the retina at different thicknesses. This experiment was performed at 800nm and with 50,000,000 photons.

Conclusion

The first experiment shows that either not enough or no photons travel unscattered to the RPE, indicating that a quantitative thickness could not be achieved via refocusing. The second experiment shows no significant changes to the angular distribution during retinal thickening, therefore plenoptic imaging cannot be used to diagnose DME by assessing retinal thickening. However, as the angular distribution is independent of the layers below, topographic images of the surface could be produced without any interference from light reflected from layers below. This could be beneficial in diagnosing glaucoma by assessing the cup-to-disc ratio, not easily available using standard retinal photography.

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