Towards A Transparent, Flexible, Scalable, and Disposable Image Sensor

Motivation

Conventional optoelectronic techniques have forced image sensors to a platforms shape. Recent approach solves this situation. For instance, silicon photodiodes are interconnected by electronic transfer elements for realizing a hemispherical detector geometry that mimics the shape of the human eye – theoretically enabling a wide field of view and low aberrations (Ko, et al., Nature 2008 [1]). Organic photodiodes, as another example, allow the application of inkjet digital lithography to implement sensors on fully flexible substrates (Ng, et al., Applied Physics Letters 2008 [2]).

Thin-film luminescent concentrators (LCCs) are polymer films doped with a fluorescent dye that absorbs light of a specific wavelength and re-emits it at a longer wavelength (cf. Figure 1). Waveguides based on an LC toward the emitted light towards the edges of the LC by total internal reflection at an attenuation that is proportional to the travel distance. They are normally used for increasing the efficiency of solar cells with respect to supporting larger incident angles. Photodiodes glued to the LC surface create an interface with higher optical density than air or the polymer of the LC. This causes light to be decoupled from the LC at the positions of the photodiodes. The attenuation of the measured light at these positions allows recovering the location of an incident light point via simple triangulation. Thus, LCCs have also been used for camera free laser-pointer tracking on large surfaces by scaling surface area (Ko, et al., Optics Express 2010 [3]).

LCCs share several interesting properties: They are flexible, transparent, and low cost (and therefore scalable and disposable) polymer films. The state of the art that applies LCCs for light sensing is currently only able to reconstruct simple point images. Our approach makes it possible to reconstruct entire images that are focused on the LC surface.

Image Reconstruction

The correlation of the transport losses between discrete entrance points (i.e., pixels) on the LC surface with many photodiodes (d) placed at the boundary of the LC surface can be represented with a = Tp, where T is the light transport matrix that can be calibrated.

In principle, an image focused on the LC can be reconstructed with the inverse light transport matrix (a = Tf), or with filtered backprojection. However, since each photodiode measures the integral of all pixel contributions, the light transport matrix would be dense with a high condition number, and image reconstruction becomes very unstable (in particular in the presence of sensor noise). A tomographic reconstruction would be seriously undersampled.

For solving this problem, we cut the LC edges into triangular aperture slits and place the photodiodes appropriately on the surfaces of these slits (cf. Figures 2 and 3). Reflective paint at the backside of the slits causes a higher decoupling efficiency.

With this, we are recording the transport of a two-dimensional light field within the LC film using multiple line scan cameras surrounding the imaging area. In this case, the light transport matrix becomes sparse. Its condition number is reduced, and more positional and directional samples are available for a tomographic reconstruction. We apply SART for reconstruction (cf. Figure 4).

In this setup, we are recording a tomographic image focused on the LC surface.

Future Work

We will investigate curved and flexible sensor shapes and the application of multiple stacked LC layers with different wavelength responses that enable the reconstruction of color images. We will as well seek for more robust and faster image reconstruction techniques, and will explore new applications, such as novel touch interfaces.

References


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More information at: www.jku.at/cg

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