LumiConSense: A Transparent, Flexible, Scalable, and Disposable Image Sensor Using Thin-Film Luminescent Concentrators

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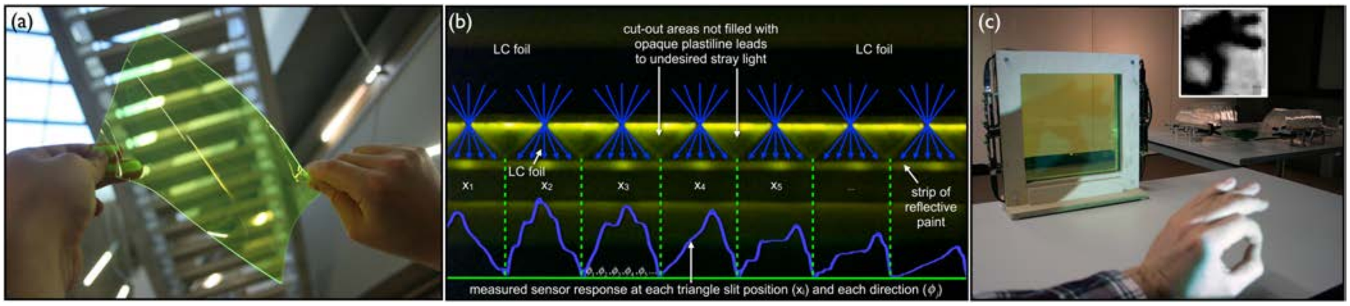

Figure 1: *The edges of a thin-film luminescent concentrator (a) are cut into triangular aperture slits (b) and photodiodes are placed on the surfaces of these slits. They measure the light-transport of a two-dimensional light field $l(x, \phi)$ that is propagated inside the LC film. It can be used to tomographically reconstruct the image being focussed on the LC surface in real time (c).*

CR Categories: I.4.1 [IMAGE PROCESSING AND COMPUTER VISION]: Digitization and Image Capture;

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Our sensor [Koppelhuber and Bimber 2013] consists of a thin, transparent polycarbonate film, referred to as luminescent concentrator (LC), that is doped with fluorescent dyes. Light of a particular wavelength sub-band that penetrates the film is emitted in longer wavelengths, while wavelengths outside the sub-band are fully transmitted. The example shown in figure 1(a) absorbs blue and emits green light. The emitted light is mostly trapped inside the film by total internal reflection (TIR), and is transported with reduced multi-scattering towards the LC edges while losing energy over transport distance. The bright film edges indicate decoupling of the light integral transported to each edge point from all directions inside the LC.
The challenge of reconstructing an image that is focussed on the LC surface without in situ photodetectors was addressed previously. It lies in measuring and demultiplexing the complex light integral that leaves the edges. As illustrated in figure 1(b), we achieve this by cutting the LC border regions into a structure of adjacent triangular apertures. The apertures act as an array of one-dimensional pinholes that multiplex the light integral into a two-dimensional light field $l(x, \phi)$, which encodes the fractions of the light transported from a particular direction ϕ to a particular position x on the LC edges.
The projected light field is measured at the film edges with line scan cameras. Tomographic reconstruction allows for a real-time estimation of images being focussed on the film surface.
Figure 1(c) illustrates a prototype that reconstructs images of shadows cast onto the LC surface at a speed of up to 12fps and a resolution of up to 64x64 pixels.
This is the first method that enables a fully transparent (no integrated circuits or other structures such as grids of optical fibers or photodiodes), flexible (makes curved sensor shapes possible), scalable (sensor size can be small to large at similar cost, pixel size is not restricted to size of the photodiodes), and disposable (the sensing area is low-cost and can be replaced if damaged) image sensor. By stacking multiple LC films, it enables a variety of information, such as color, dynamic range, spatial resolution, and defocus, to be sampled simultaneously. By enabling focus shifts without additional optics, our latest work [Koppelhuber et al. 2014] extends the sensor towards lens-less multi-focal imaging and depth estimation. In contrast to widely applied touch sensors which are mainly limited to planar shapes and interaction through direct touch, our approach has the potential to lead to new human-computer interfaces that are unconstrained in shape and sensing-distance.

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