

THE LIGHT FIELD MICROSCOPE

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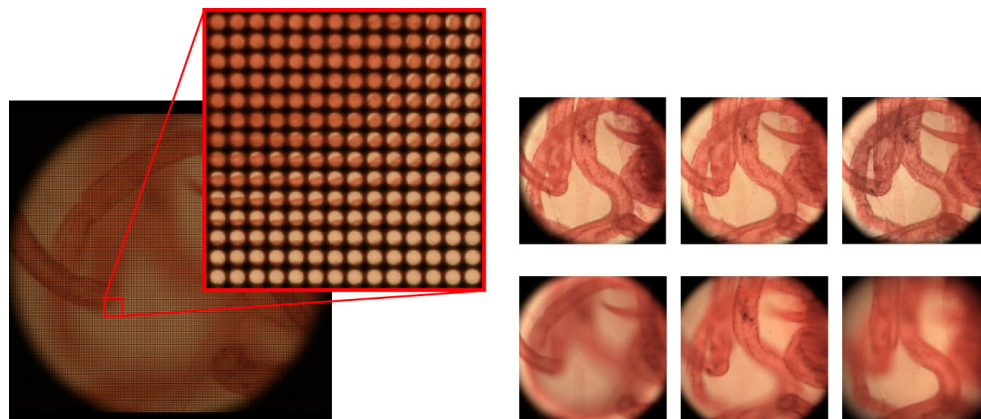


Figure 1. At left is a light field of several insect legs, captured in a single snapshot by a microscope into which a microlens array has been inserted. The objective was 25x/0.45NA. Magnifying a portion of this light field (inset), we see the circular subimages formed behind each microlens. Each is a view of the microscope's aperture. At right is a sequence of perspective views (top) and a focal stack (bottom), computed from this light field.

The scalar light field is defined as radiance as a function of position and direction in space. A simple way to think about light fields is as a 2D array of views of a scene, each taken from a slightly different observer position. By extracting slices from this 4D array, one can produce perspective views from observer positions not included in the original data [1]. By warping and summing these slices, one can produce a single image with a shallow depth of field and a plane of focus that can be digitally positioned anywhere in the scene, including obliquely [2].

To exploit these ideas, our group has built a number of devices for capturing light fields, including a 100-camera array [3], a handheld camera whose photographs can be refocused after they are captured [4], and the microscope whose imagery is shown above. Although diffraction places a limit on the product of spatial and angular resolution in microscopic light fields, we can nevertheless produce useful perspective views and focal stacks from them. Since microscopes are inherently orthographic devices, perspective views represent a new way to look at microscopic specimens. The ability to create focal stacks from a single photograph allows moving or light-sensitive specimens to be recorded. Applying 3D deconvolution to these focal stacks, we can produce a set of cross sections, which can be visualized using volume rendering.

We recently demonstrated a prototype light field microscope (LFM), analyzed its optical performance, and showed perspective views, focal stacks, and reconstructed volumes for a variety of biological specimens [5]. We are currently building a real-time software viewer, which permits the microscopist to simultaneously translate the microscope stage and digitally tilt the specimen around the X or Y axes. Together these affordances constitute a novel and potentially useful way to navigate through thick microscopic specimens.

- [1] M. Levoy and P. Hanrahan, Light field rendering, *Proc. SIGGRAPH* (1996)
- [2] V. Vaish et al., Synthetic aperture focusing..., *Proc. CVPR* (2005).
- [3] B. Wilburn et al., High Performance Imaging Using Large Camera Arrays, *Trans. Graphics* **24**(3) (2005)
- [4] R. Ng et al., Light Field Photography with a Hand-Held Plenoptic Camera, *Stanford CSTR 2005-02*
- [5] M. Levoy et al., Light field microscopy, *Trans. Graphics* **25**(3) (2006)