



4







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Stanford multi-camera array

Lytro Illum (micro-lens array)

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Source



- Everything is in focus.
- Very light inefficient.

- Only one plane is in focus.
- Very light efficient.

A lens measures all rays radiated from the object (up to aperture size).

We can capture the same set of rays by using a pinhole camera from multiple viewpoints

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How can we merge these images into a lens-based, defocused image?

Require 3D to represent attributes across occlusions











4-dimensional function $L(u, v, s, t)$

Rays are parameterized based on their intersections with two planes.

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Rays are parameterized based on their intersections with two planes.

$L(u = u_o, v = v_o, s, t)$

Termed: a light field slice

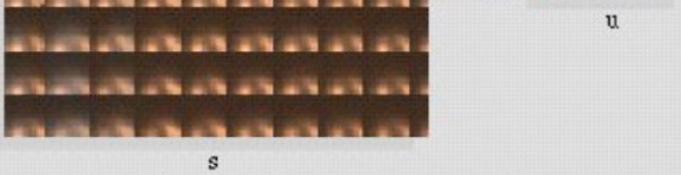
50

Lightfield slice $L(u, v, s = s_o, t = t_o)$

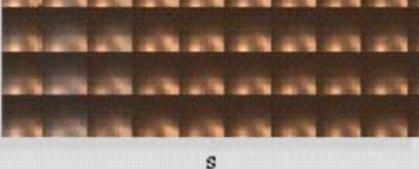
55



(b)



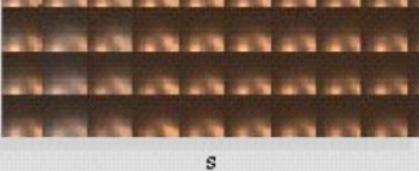
(b)



Demo:

<http://lightfield.stanford.edu/lfs.html>

(b)



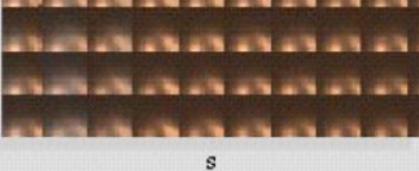
Demo:

<http://lightfield.stanford.edu/lfs.html>



We will see 3 different ways to do it.

(b)



Demo:

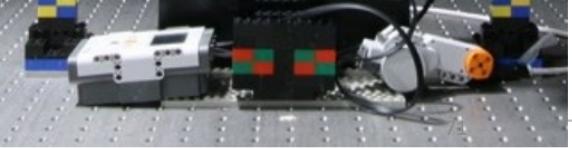
<http://lightfield.stanford.edu/lfs.html>



Image: National Geographic

Mosquito eye, image: Raija Peura, University of Oulu
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Lightfield imaging: Stores the angular information (i.e., different points of view) for each point in the scene.

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Source: <http://lightfield.stanford.edu/>





<https://augmentedperception.github.io/deepviewvideo/>

Lightfield $L(u, v, s, t)$

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Source: Raytrix

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when the picture was taken, lay on a line joining one globule with the point M of the object. The process which now occurs will be the opposite of what happened when the picture was taken. In other words, the eye will receive from the globule a view of the image m of the point M . Other globules will send images of the point M , etc., at the same time, so that the eye will see the different portions of the image coming from all the different globules. In this way a complete image of the object originally pre-

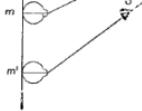


Diagram to illustrate the principle of Lippmann's integral photography.

Proposed Aeronautic Map

At a recent meeting of the Académie des Sciences, M. Lallemand, chief of the French Government Survey Department, presented the project which the Aeronautic Commission intends to carry out establishing an aeronautic map. The proposed map is of 1:200,000 size, and is drawn up after a provisory model made by the Aero Club. Each plate of the aeronautic map will be a sheet taking in one degree in latitude and longitude and there will be twenty-

Notice the date: more than a century ago.

Reappeared under different forms and names throughout the century.

- The left paper is from 1930, the right one from 1970.

EVERY BODY in the light and shade fills the surrounding air with infinite images of itself; and these, by infinite pyramids diffused in the air, represent this body throughout space and on every side." Leonardo da Vinci [1] near

Fig. 1. Diagram from Leonardo's notebooks illustrating the fact that the light rays leaving an object's surface may be considered to form a collection of cones (which Leonardo calls "pyramids"), each cone constituting an image that would be seen by a pinhole camera at a given location.

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Fig. 5. Array of miniature pinhole cameras placed at the image plane can be used to analyze the structure of the light striking each macropixel.

ision

Sources: [CMU 15-463](#)

To the photographer, the plenoptic camera operates exactly like an ordinary hand-held camera. We have used our prototype to take hundreds of light field photographs, and we present examples of portraits, high-speed action and macro close-ups.

Keywords: Digital photography, light field, microlens array, synthetic photography, refocusing.

2 Related Work

The optical design of our camera is very similar to that of [Adelson and Wang's plenoptic camera \[1992\]](#). Compared to Adelson and Wang, our prototype contains two fewer lenses, which significantly shortens the optical path, resulting in a portable camera. These differences are explained in more detail Section 3.1 once sufficient technical background has been introduced. The other main differ-



Kodak 16-megapixel sensor

125 μ square-sided microlenses

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[Ng et al., Stanford Technical Report 2005]

From a roomful of cameras to a micro-lens array specially adhered to a standard sensor, the Lytro's Light Field Sensor captures 11 million light rays.



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Sources: [CMU 15-463](#)



www.crunchbase.com/organization/lytro



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- Can do video.
- Very expensive.



Toshiba

Pixar

[Raskar et al. 2007]

Adobe

Cafadis

- And of course, nobody thought of commercializing them.

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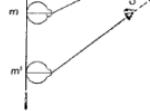


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Right eye



What are these circles?

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Lightfield $L(u, v, s, t)$















Sampling only the central portion of each microlens





Source



How do I refocus?

Sum all pixels in
each lenslet view.

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Sources: [CMU 15-463](#)

How do I refocus?

- Need to move sensor plane to a different location.

Sum all pixels in
each lenslet view.

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What are these circles?

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Source: <http://www.plenoptic.info/>

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Sources: [CMU 15-463](#)

Source: <http://www.plenoptic.info/>

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Sources: [CMU 15-463](#)

Source: <http://www.plenoptic.info/>

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Source: <http://www.plenoptic.info/>

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Sources: [CMU 15-463](#)



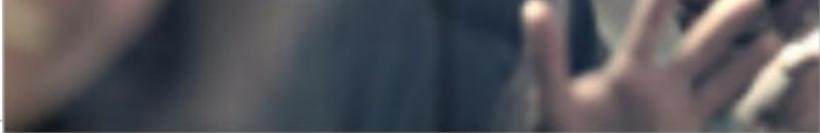
[Ng et al. 2005] Light Field Photography with a Hand-held Plenoptic Camera.



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Each has pros and cons.

For videos, paper, etc.: <https://augmentedperception.github.io/welcome-to-lightfields/>
<https://augmentedperception.github.io/deepviewvideo/>



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NeRF can be considered as a computational method that attempts to infer a light field from a set of 2D images

spatio-angular resolution (and baseline), bandwidth, storage...

