Light Field Cameras 11

CS184: Computer Graphics and Imaging

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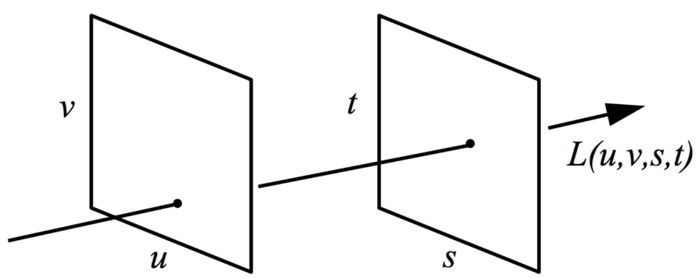
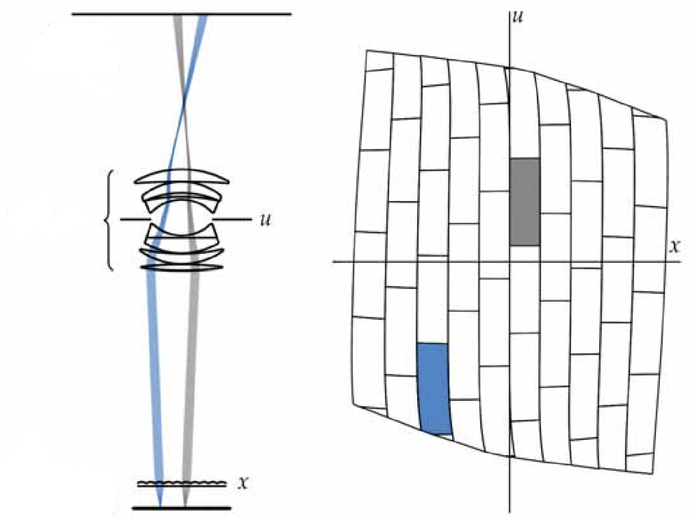
1 Light Field Parameterization

A light field is a function describing the radiance along each ray. One of the most common ways to represent this is the two-plane parameterization (also called the light slab representation), where each ray is parameterized by its intersection points with two fixed planes in space.



1. In the diagram of a plenoptic camera below, which two planes define the light field parameterization? Which components of the camera determine the sampling resolution for each of these planes?



Solution: The two planes that parameterize the light field sampled in a plenoptic camera are the camera aperture plane and the microlens plane. The sampling resolution of the aperture plane is determined by the number of pixels under each microlens, and the sampling resolution of the microlens plane is determined by the number of microlenses.

2. A slice of the sampled light field at a single location on the u plane in the plenoptic camera diagram is typically called a sub-aperture image. Describe in your own words what this slice of the light field represents and how it should appear.

Solution: This represents an image taken with a pinhole camera where the pinhole location is the specific point on the u plane. It should look like an image of the scene with infinite depth of field. Different sub-aperture images can be considered as images of the same scene from different viewpoints.

2 Computational Refocusing

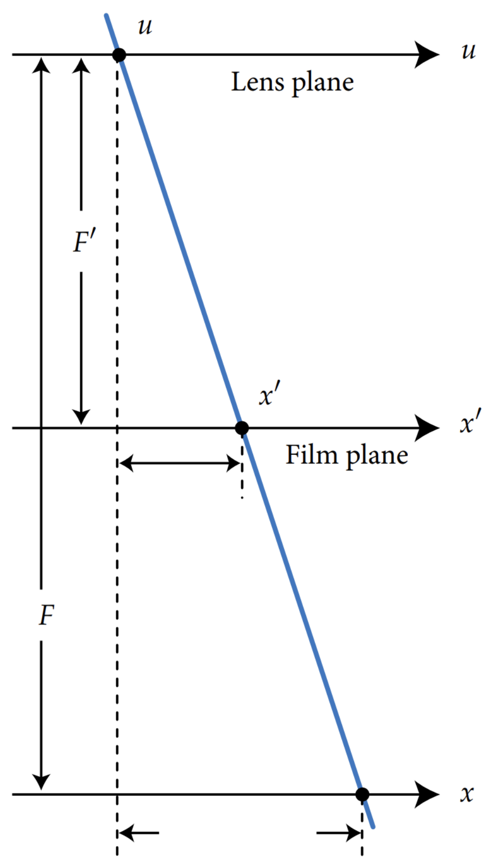
A conventional image records the irradiance on the sensor plane. This can be expressed as an integral of the radiance entering the camera through the lens as:

$$E_F(x, y) = \frac{1}{F^2} \int \int L_F(x, y, u, v) du dv \tag{1}$$

where F is the separation between the exit pupil of the lens and the sensor, E_F is irradiance on the sensor plane, L_F is the light field inside the camera body, and the optical vignetting cosine falloff factor has been absorbed into the definition of the light field for simplicity.

Refocusing the recorded image to a different depth corresponds to changing the separation between the lens and sensor planes. We can derive an equation for the image refocused to a new sensor depth F' by expressing the camera body light field $L_{F'}(x', y', u, v)$ in terms of the original light field $L_F(x, y, u, v)$. Note that only the x and y coordinates of the light field are being reparameterized because we are just moving the sensor plane and not the aperture plane.

1. Derive an expression for the re-parameterized camera body light field $L_{F'}(x', y', u, v)$. The figure below visualizes the relevant similar triangle relationship necessary for this derivation.



Solution:

$$
\begin{aligned}
L_{F'}(x', y', u, v) &= L_F(u + \frac{x' - u}{\alpha}, v + \frac{y' - v}{\alpha}, u, v) && (2) \\
&= L_F(u(1 - \frac{1}{\alpha}) + \frac{x'}{\alpha}, v(1 - \frac{1}{\alpha}) + \frac{y'}{\alpha}, u, v) && (3)
\end{aligned}
$$

where we define $\alpha = \frac{F'}{F}$.

2. Combine this derivation of the reparameterized camera light field with the imaging equation that expresses the recorded image as the irradiance on the sensor plane to derive the computational refocusing equation that expresses how the recorded light field can be reparameterized and integrated to compute images refocused to different depths.

Solution:

$$E_{F'}(x', y') = \frac{1}{\alpha^2 F^2} \int \int L_F(u(1 - \frac{1}{\alpha}) + \frac{x'}{\alpha}, v(1 - \frac{1}{\alpha}) + \frac{y'}{\alpha}, u, v) du dv \tag{4}$$