CAMERAS AND LIGHT FIELDS 10

CS184: COMPUTER GRAPHICS AND IMAGING

April 9, 2019

1 Cameras and Lenses

1.1 Terminology

When dealing with cameras and lenses, it is easy to get bogged down by the various terms and mix up how they all relate to one another. Some have direct relationships, while others have inverse relationships, and so on. Let's start by defining the terminology that we commonly use when talking about cameras and lenses.

1. Briefly define each of the following terms in your own words. Where applicable, also draw an accompanying diagram to help explain the concept.
   (a) Focal length
   (b) Field of view
   (c) Exposure
   (d) Shutter speed
   (e) Aperture
   (f) F-stop
   (g) Circle of confusion
   (h) Depth of field

1.2 Configurations and Effects

1. Assuming focal length is the distance between the sensor and lens, how are focal length and field of view related? For a fixed sensor size, how does increasing focal length affect field of view?

2. An image captured with a 50mm focal length is considered to have a "normal" field of view. What about an image taken with a 15mm focal length? How about 150mm focal length? Do these types of images have special names?

3. Which of the following camera configurations has the smallest field of view?
   (a) 36mm wide sensor and 50mm focal length lens
   (b) 12mm wide sensor and 18mm focal length lens
   (c) 24mm wide sensor and 8mm focal length lens

4. How are sensor size and field of view related? What happens to the field of view if I don't move my sensor, but increase its size? What about decreasing its size?

5. If my F-number is increasing, then what can I deduce about the size of my aperture and/or my focal length?

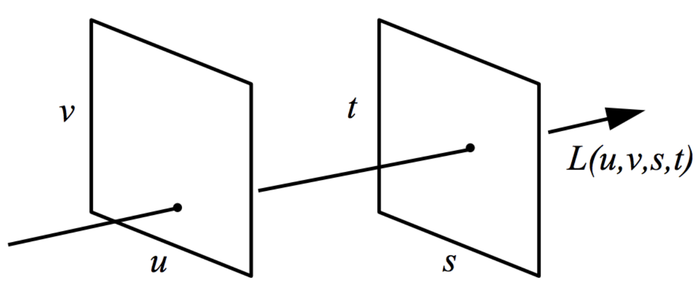
6. To help reduce motion blur when I capture photos, I can increase the shutter speed of my camera (which reduces the amount of time the sensor is exposed to light). What are the tradeoffs of doing so? What can I do to mitigate the tradeoffs?

7. How are depth of field and aperture size related? What happens to the depth of field if I reduce the size of my aperture? What else happens if I reduce the size of my aperture?

8. Briefly explain why photographers must choose between depth of field and motion blur for moving objects.

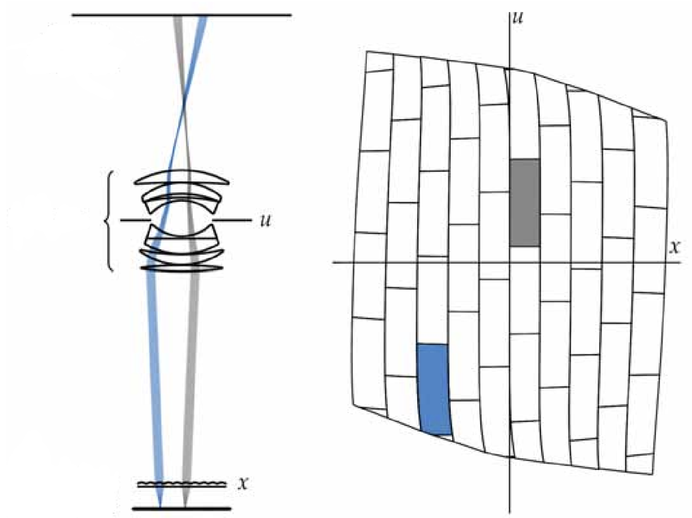
2 Light Field Parameterization

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?



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.

3 Computational Refocusing

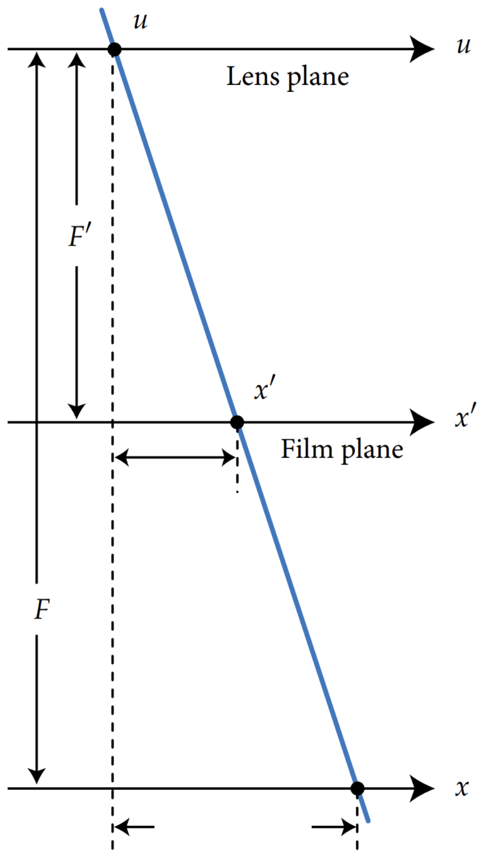
A conventional image records the irradiance on the sensor plane. This can be expressed as an integral of the radiance entering the camera through the lens as:

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

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.



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.