Lecture 32:

Light Field Cameras I

Computer Graphics and Imaging
UC Berkeley CS184/284A, Spring 2017
Topics

2D Photographs vs 4D Light Fields
Capturing Light Fields With Plenoptic Cameras
Computational Refocusing
Computational Correction of Lens Aberrations
Other Light Field Capture Systems
Three Focus-Related Problems in 2D Photography

1. Need to focus before taking the shot
Three Focus-Related Problems in 2D Photography

2. Trade-off between depth of field and motion blur

- $f/4$ at 0.01 sec
- $f/11$ at 0.1 sec
- $f/32$ at 0.8 sec
Three Focus-Related Problems in 2D Photography

3. Lens designs are complex due to optical aberrations
Light Field Photography Demo
Light Field Photographs
Lens Designed For Light Field Computation

Lytro ILLUM with 30-250mm (equiv) lens F/2
2D Photographs vs 4D Light Fields
What’s Happening Inside the Camera?

Cross-section of Nikon D3, 14-24mm F/2.8 lens
2D Photographs vs 4D Light Fields

Photograph = irradiance at every pixel on plane (2D)
Light field = radiance flowing along every ray (4D)
The 4D Light Field Flowing Into A Camera

Cross-section of Nikon D3, 14-24mm F/2.8 lens
The 4D Light Field Flowing Into A Camera
The 4D Light Field Flowing Into A Camera
What Does a 2D Photograph Record?
Imagine Recording the Entire 4D Light Field
Capturing Light Fields
A Plenoptic Camera Samples The Light Field
Where Microlenses Go Inside Camera

Cross-section of Nikon D3, 14-24mm F/2.8 lens
Where Microlenses Go Inside Camera
Where Microlenses Go Inside Camera
Glass
(0.5 mm thick)

Air
(0.04 mm thick)

Microlenses
(0.02 mm spacing)

CMOS pixels
(0.0014 mm spacing)
Raw Data From Light Field Sensor
Raw Data From Light Field Sensor
Raw Data From Light Field Sensor

One disk image
Raw Data From Light Field Sensor

One disk image
Raw Data From Light Field Sensor

One disk image
Raw Data From Light Field Sensor
Mapping Sensor Pixels to \((x,y,u,v)\) Rays

Microlens location in image field of view gives \((x,y)\) coord

Pixel location in microlens image gives \((u,v)\) coord
Mapping Sensor Pixels to \((x,y,u,v)\) Rays

Microlens location in image field of view gives \((x,y)\) coord

Pixel location in microlens image gives \((u,v)\) coord
Analogy: Shooting RAW vs JPG (2D Photos)

RAW Bayer 14-bit data preserves intensity information, and provides flexibility over exposure and color.
Shooting 4D Light Field vs 2D Photographs

Light field data preserves directional intensity information, and provides flexibility over focus and aberrations.
Test Your Understanding
Sub-Aperture Images

Image from selecting same pixel under every microlens

Sub-aperture image, min u
Sub-Aperture Images

Image from selecting same pixel under every microlens

Sub-aperture image, max u
Sub-Aperture Images
Sub-Aperture Images