Announcements

• Read LaValle, Chapter 4,5.

• **MP2** - due on Oct 3, 11am.

• Midterm 1
Optical Distortion

Do you notice problems? blur? color? shape?

Put the Oculus Rift lens 40 mm away from the paper. Look through the lens and see which grid "appears" to be least distorted. Mark your result!
Optical Distortion

- less in the center
- more on periphery (for wide FOV)

pincushion ➔ barrel

Spherical lens (convex) ➔ Aspheric lens
Optical Distortion Correction

Optical Engineering challenges: /Software

- Approximate lens distortion parameters
- Approximate the barrel-pincushion annihilation parameters
- How do you test the result?
  (Do you trust your perception of parallel lines?)
Spherical Aberrations

https://www.youtube.com/watch?v=EL9J3Km6wxI&app=desktop
Spherical Aberrations

Spherical surfaces are the cheapest to manufacture!

Solution: aspheres

No Aberration  Spherical Aberration

https://www.youtube.com/watch?v=EL9J3Km6wxI &app=desktop
Astigmatism

[Diagram of light rays passing through a lens, showing vertical and horizontal planes, and focusing on the issue of astigmatism with images of different aberrations: No Aberration, Tangential Astigmatism, Sagittal Astigmatism, and a photo of a street scene with lights.]
Coma

Image

\[ \theta \]

No Aberration

Coma
Lens Focal Length, FOV trade-off

Trade-offs:
- Size
- Weight
- Focal length
- Field of view
- Distortion
- Cost of materials
- Ease of manufacturing
- Aberrations

Fisheye lens
Extreme wide-angle lenses of 6–8mm are known as fisheyes. They record a circular image of at least 180°, with some lenses even looking behind the camera with a 220° angle of view. The resulting image is very distorted, with vertical and horizontal lines bowed.

Wide-angle lens
Wide-angle lenses of 18–35mm have more general applications than fisheye lenses. Angles of view are generous and depth of field at all apertures is extensive. Poor-quality wide-angle lenses may sometimes show some distortion toward the edges of the image.

Standard lens
A standard 50mm lens is fitted on most 35mm SLRs. Useful for most types of subject, it often has a wide maximum aperture, making it good in low light. It does not show the same distortion as a wide or long lens, and its angle of view is similar to that of the human eye.

Long-focus lens
Angles of view of long-focus lenses of 80–400mm start to diminish rapidly. With so little of the scene filling the frame, the subject is shown very large, making a long lens ideal for distant subjects or detailed close-ups. Depth of field decreases as the lens gets longer.

Extreme long-focus lens
Focal lengths above 400mm are specialized and are not usually found on standard zooms. The use of a tripod to support the lens is essential because of its relatively heavy weight. A long lens has a shallow depth of field and a small maximum aperture.
One More Issue
Electromagnetic vs Visible Spectrum

- Red
- Orange
- Yellow
- Green
- Blue
- Indigo
- Violet

Electromagnetic Spectrum

Visible Region: 400 nm to 700 nm

- High Energy: Gamma Rays, X-rays, UV
- Low Energy: Infrared, Micro-Waves, Radio Waves

Wavelength:
- 0.001 nm to 1 nm
- 1 mm to 1 meter

f = \frac{c}{\lambda}

faster

slower
Spectral Power of a Light Source is like a histogram of wavelengths.
Spectral Power of a Light Source is like a histogram of **wavelengths**.
Spectral Reflectance of Material

- Snow
- Soil
- Grass
- Dry Grass
- Healthy Vegetation
- Stressed Vegetation
- Turbid Water
- Clear Water
Perceiving Color of an Object

- In white light, the object appears red.
- In red light, the object appears red.
- In green light, the object appears black.
Spectral Power Models

90s

better
Chromatic Aberration

https://www.youtube.com/watch?v=bcRYQKY4jc
Chromatic Aberration Correction

- Find and use material with a high Abbe number (refractive index does not depend on wavelength)

https://www.youtube.com/watch?time_continue=6&v=-bcRYQKY4jc
Reducing Weight and Cost: Fresnel Lens
Imaging System Inside of a Human Eye

output pixels: RGB

input pixels: photoreceptors
How Does Our Brain Pieces Images Together?

https://www.youtube.com/watch?v=MHMvEMy7B9k

https://www.youtube.com/watch?v=2NcUkvIX6no
https://www.youtube.com/watch?v=eR2j-fh18mk
https://www.youtube.com/watch?v=3_dm7jSX4Cw
Peripheral Vision

[Diagram of peripheral vision, showing light rays from an object hitting different areas of the retina]
Photoreceptors

There are two types:

**Rods**
- 120,000,000
- Low light
- Black/white
- Peripheral vision

**Cones**
- 6,000,000
- Bright light
- Color, RGB
- Straight, high-res
Rods And Cones Sensitivity

Examples: 1. We do not see colors at night, or on periphery
2. Red rose at dusk
3. Green leaf at dusk
4. Red t-shirt on periphery
Rods and Cones Placement

Which eye is this?

Why is there asymmetry?

Density at fovea: \(~200,000\) rec/\(1\) mm\(^2\)
Examples

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Evolution Choice for Humans

mammals

vertebrates