Midterm Review

CS 184 - Discussion 12, [Date]

[TA]

Logistics

👾 Midterm 2 is next Thursday, 4/21

- Logistics + Old exams on Piazza
- Covers everything

🎒 Final Project Milestone due 4/26

Agenda

1. Cameras & Lenses
2. Animation & Simulation
3. Color Science
4. Image Sensors
5. Light Fields

NOTE: This is not exhaustive the entire course content till now is in scope!

Cameras and Lenses Checklist

- Camera Settings - F-stops, shutter speed, exposure, ISO
  - What do these settings do?
  - How does increasing or decreasing them affect the image?
- Lenses:
  - Focal length
  - Field of view (FOV)
  - Circle-of-confusion
  - Ray Diagrams
  - Thin lens equation

Thin Lens (Su20 Exam 2)

11. (Total : 10 points) Thin lens model

Assuming a camera with an ideal thin lens with 50 mm focal length, with an f/2 aperture, and which is focused at infinity (far away). Now consider a tiny bee at a distance of 1 meter.

(11a) (6 points) Draw a ray diagram representing this problem that includes the following items and labels them: tiny bee, lens, focal point, sensor, rays from the bee passing through the lens onto the sensor, circle of confusion, distance from lens to bee z_0, distance from lens to image of bee z_1, and focal length f. Your drawing does not need to be drawn to scale.

(11b) (4 points) Derive the size of the circle of confusion (in mm) that the bee makes on the sensor surface. (Leave fractional expressions if you need to.)

Thin Lens (Su20)

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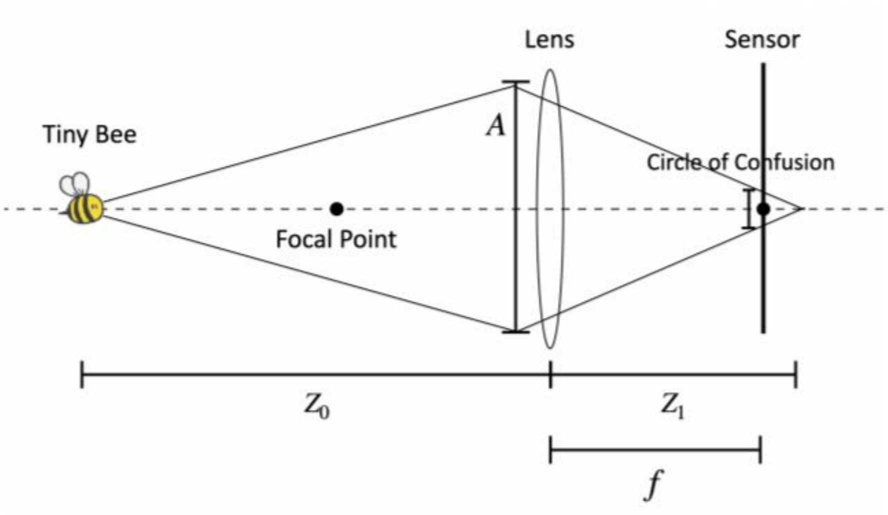
Solution:



Thin Lens (Su20 Exam 2)

(11b) (4 points) Derive the size of the circle of confusion (in mm) that the bee makes on the sensor surface. (Leave fractional expressions if you need to.)

Solution: $\frac{1}{f} = \frac{1}{z_0} + \frac{1}{z_1}$

$z_1 = \frac{1}{\frac{1}{f} - \frac{1}{z_0}} = \frac{1000}{19}$

Because f number is f/2, aperture diameter is $50/2 = 25$mm

Using similar triangle, the circle of confusion has size $25/20 = 1.25$mm

Animation & Simulation Checklist

- Keyframe Animation
- Forward vs. Inverse Kinematics
- Mass spring systems
- Particle Simulation
    - Explicit/Implicit Euler, Verlet integration

Euler Integration (Sp20)

(6a) (10 points) Euler Steps

Suppose we have a particle of mass $m = 1.0$ with the following initial conditions at time $t = 0$:

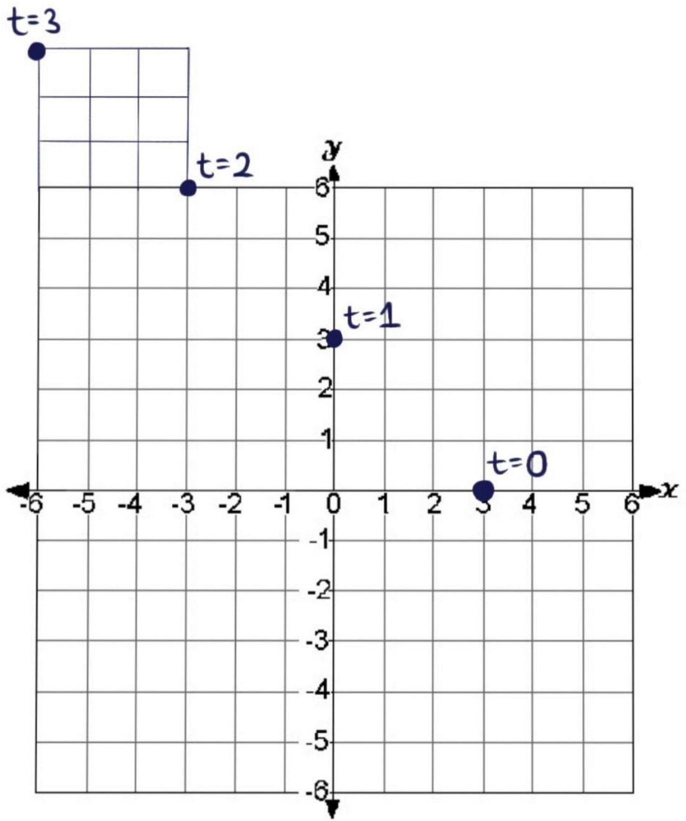
$$(x, y) = (3, 0) \qquad (\dot{x}, \dot{y}) = (-3, 3)$$

This particle is subject to a force due to an undamped spring attached to the origin at one end and the particle at the other. The spring's position at the origin is fixed, whereas the particle is allowed to move around. The spring constant of this spring is $k = 1$, and its rest length is 3.

We wish to find the trajectory of this particle using explicit (non-modified) Euler integration with a timestep of $\Delta t = 1$. **Draw the first three steps of this particle (not including its position at $t = 0$) and write out its final computed position.**

Euler Integration (Sp20)

Solution:



Color Science Checklist

- Physical basis of color
  - Spectral power distribution
- Tristimulus theory of color
  - Color primaries/matching
- Biological basis of color
  - Human cone cells
  - Spectral response functions
  - Metamers
- Color reproduction
- Color representation
  - sRGB, CIE XYZ, CIELAB, HSV

Spectral Power Distributions (Sp18)

(a) (4 points) Consider two spectral power distributions, $s_1(\lambda)$ and $s_2(\lambda)$ that are metamers. For the following statements, fill in the blanks with true (T) or false (F).

____ They appear the same color to a human observer.

____ A linear combination of these two SPDs, $(a\, s_1(\lambda) + b\, s_2(\lambda))$, would also be a metamer, where a and b are scalar constants.

____ They must carry the same total photon power, integrated over all visible wavelengths.

____ They will be indistinguishable to a color-blind human observer who has only two types of cone cells instead of three.

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__**F**__ They must carry the same total photon power, integrated over all visible wavelengths.

__**T**__ They will be indistinguishable to a color-blind human observer who has only two types of cone cells instead of three.

Image Sensors Checklist

- Photoelectric effect
- Color Sensor Mosaics
  - De-mosaicking
- Dynamic Range
  - Multiple shot HDR
  - Pixel mosaicking for HDR
- Imaging Noise
  - SNR
  - Poisson Shot process

Signal-Noise Ratio (Sp18)

(b) (4 points) Exposure and Noise
In the following, assume that all the image sensors considered have 100% quantum efficiency and zero read noise (i.e. the only noise present in the signal is due to Poisson shot noise). Each of the following cameras is used to take a picture of a patch of the same, uniformly illuminated white wall, with the same shutter duration across all cameras. The pixels do not saturate in any camera. If the individual pixels in the first camera have an SNR as shown below, calculate the SNR for the individual pixels in the other two cameras. Show your work.

Camera 1: 10x10mm sensor with 50mm f/2.0 lens and 4 million pixels.

SNR = 100

(i) Camera 2: 20x20mm sensor with 50mm f/4.0 lens and 16 million pixels.

SNR = ___________

(ii) Camera 3: 5x5mm sensor with 25mm f/1.0 lens and 2 million pixels.

SNR = ___________

Signal-Noise Ratio (Sp18)

Solution:

By Poisson statistics, the SNR is the square root of the photon count.

The first factor for change in photon count is that it changes in inverse proportion to the square of the f-number. Photographers know that the exposure on the sensor is doubled with each stop change in the f-number. f/1 is two stops brighter than f/2.0, which is two stops brighter than f/4.0. The radiometric way to calculate this is to note that the radiance arriving from the wall to all points on the lens aperture is the same, so the irradiance on the sensor is proportional to the solid angle of light arriving at the sensor from all parts of the lens aperture. If the f-number is 2x higher (e.g. f/4.0 instead of f/2.0), the solid angle is 4 times smaller from the definition of the f-number.

The area of the sensor pixel is the second factor. The number of photons captured is proportional to the pixel sensor area.

Putting this together, for (i), there is an increase in photon count decrease by 4x due to the f-number and no change due to pixel area (same pixel size). So the photon count is 1/4 and the SNR is 1/2. The SNR is 50.

For (ii), there is an increase by 4x due to f-number, and 2x decrease due to pixels that are half the area. So the photon count is 2x higher, and the SNR is $\sqrt{2}$ higher. SNR $= 100\sqrt{2}$.

Light Fields Checklist

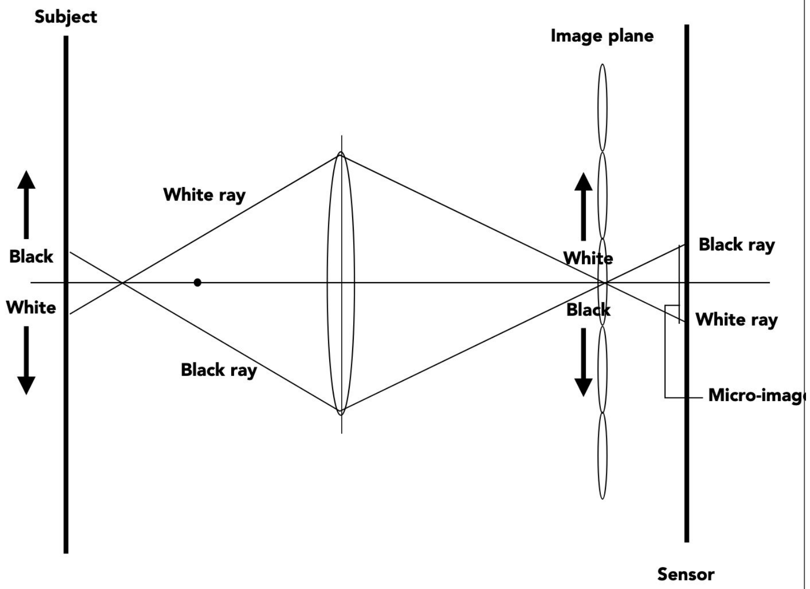
- 4D light capture
- Computational refocusing

Light Field Camera (Sp 17)

(c) (10 points) Consider a photograph that shows an edge with white on the bottom and black on the top. Now consider shooting this scene with a light field camera (plenoptic type), and also consider changing the focus so that the lens is focused slightly *closer* than this white / black edge. In the light field sensor's pixel data, the disk micro-images located near the edge will also show a black-white edge inside the disk micro-image. Within these micro-images, will it be white above or below the edge? Justify your answer with a ray diagram and brief explanation.

Light Field Camera (Sp 17)

Solution:



If a photo would be white on bottom, the sensor image must have white on the top due to optical inversion, as shown. Since the lens is focused in front of the subject, the ray-diagram shows that there will be another optical inversion for the micro-image so that in the micro-image the white portion will appear opposite from the photograph orientation. Therefore, in the micro-images the white portion will be on the top.