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Grade received 54.16%

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To pass 70% or higher

Retake the assignment in **7h 59m**

1. Active illumination methods use a programmable light source (e.g., a laser pointer) whose properties (e.g., intensity, position, projected pattern) can be varied in a controlled way to derive information such as the 3D shape or reflectance properties of the objects in the scene. Which of the following is an active illumination method?

1 / 1 point

- ○ Structured Light
- ○ Time-of-Flight
- ○ Photometric Stereo
- ● All of the above
- ○ None of the above

Correct
Structured light, time-of-flight and photometric stereo are all active illumination methods because they all require controlling the scene lighting. Photometric stereo requires varying the position of the light source. Structured light uses one separate projector to identify the changes in the scene lighting, and time-of-flight measures the time for light to get reflected from objects in the scene and arrive back at the sensor.

2. What is the main difference between the classical photometric stereo system and photometric sampling?

0 / 1 point

- ○ Photometric sampling does not need to know the reflectance parameters of the scene objects
- ○ Photometric sampling does not need to know the position of the light sources

- ◯ Photometric sampling uses stochastic methods to reduce the number of distinct light sources used
- ◉ Photometric stereo is also able to detect the surface normals of the scene objects

⊗ **Incorrect**

3. Which of the following is NOT a valid reason for why the use of LEDs/High-Speed cameras allows for real-time relighting using photometric sampling? **0 / 1 point**

- ◯ The fact that LEDs can be rapidly turned on and off
- ◉ The fact that LEDs brightness and color can be precisely controlled
- ◯ The fact that LEDs can faithfully simulate the lighting conditions of the locations that we would like to drop the actors into
- ◯ The fact that High-Speed cameras can capture many distinctly-lit images in a very short time span

⊗ **Incorrect**

4. Consider a Point-based Range Finding System consisting of a projector and a 1000x1000 pixel camera. The projector illuminates one pixel at a time. The camera captures 8-bit images. What is the total amount of raw image data that the camera would need to capture to create one depth map? **0 / 1 point**

- ◉ 1 KB
- ◯ 1 MB
- ◯ 1 GB
- ◯ 1 TB
- ◯ 1 PB

⊗ **Incorrect**

5. Consider the following Point-based Range Finding System. The origin of the coordinate system is located at the optical center of the camera (center of its lens) with the z axis aligned with the optical axis. Given the equation of the light ray emitted by the projector as $\frac{x+9}{3} = \frac{y-6}{2} = \frac{2z}{3}$ and the camera's focal length $f = 2$, what is the depth z of the scene point corresponding to the illuminated point at the image coordinates (2, 4)?

0 / 3 points

- ○ 5
- ◉ 6
- ○ 8
- ○ 9

⊗ **Incorrect**

6. Consider the following Light-stripe-based Range Finding System. The origin of the coordinate system is located at the optical center of the camera (center of its lens) with the z axis aligned with the optical axis. Given the equation of the light plane emitted by the projector as $4x + 7y + z - 12 = 0$ and the camera's focal length $f = 3$, what is the depth z of the scene point corresponding to the illuminated point at the image coordinates (4, -1)?

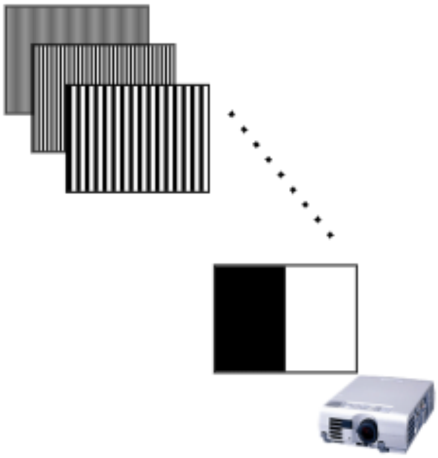
0 / 3 points

- ○ 6
- ◉ 4
- ○ 3
- ○ 2

⊗ **Incorrect**

7. A Light-stripe-based Range Finding system (as shown below) uses binary coded patterns (column of pixels is either illuminated or not). The camera has a 1920x1080 resolution. How many column patterns would be needed to assign a unique code to every column of pixels in the image?

0 / 2 points



- ◯ 7
- ◉ 8
- ◯ 9
- ◯ 10
- ◯ 11

Incorrect

8. A Phase-shifting range finding system, in general, requires a minimum of three images. However, consider a controlled scenario as in manufacturing where there is no ambient light. In this case, what is the minimum number of images needed?

2 / 2 points

- ◯ 1
- ◉ 2
- ◯ 3
- ◯ Cannot be determined

Correct

In general, a Phase-shifting method requires a minimum of three images because there are three unkowns for every camera pixel - the scene depth, the brightness of the scene point, and the strength of ambient lighting incident on the scene point. If there is no ambient light, there is only two unkowns, thus needing only two images (e.g., two sinusoid patterns with shifts of $\phi = 0$ and $\phi = \pi$).

9. You were tasked with designing a Structured Light System. Since the depth recovery will not occur in a tightly controlled environment (such as industrial production), the camera and the projector cannot be carefully radiometrically calibrated. The colors and reflectance properties of the scene objects cannot be guaranteed. Since the depth recovery should occur in real-time, you would like to minimize the number of images taken to construct a single depth map.

2 / 2 points

Which of the following Structured Light methods is best suited for the task?

○ Line-based Structured Light

◉ Binary-coded Structured Light

○ Color-coded Structured Light

○ Phase Shifting Methods

Correct
Since we cannot ensure a careful radiometric calibration of the camera and the projector, we can't use Phase Shifting. Furthermore, since we can't control color and reflectance properties, Color-coded Structured Light is not suitable. And since Line-based Structured Light would be too slow, the best choice would be Binary-coded Structured Light.

10. iPhone's LiDAR (Light Dectection and Ranging - a time-of-flight-based sensor) emits a light pulse toward a scene point P. The pulse takes 1 microsecond to travel to P and back. How far is P from the camera?

2 / 2 points

(Assume speed of light $c = 3 \times 10^8 m/s$)

○ 5 meters

○ 50 meters

◉ 150 meters

○ 500 meters

Correct
The depth d is given as $d = \frac{cr}{2}$, where c is the speed of light, and τ is the travel time. The factor of 2 accounts for back-and-forth travel. Using $\tau = 1\ \mu s = 10^{-6} s$ and the speed of light $c = 3 \times 10^8 m/s$ we get $d = 150$ meters.

11. A time-of-flight based 3D camera emits light with frequency $f = 10MHz$. The light travels to the scene and gets reflected back. The camera then measures the phase-shift ϕ of the returned light with respect to the emitted light to measure scene depth. Suppose the measured phase-shift for a scene point is $\psi = \pi$. What is the scene depth?

3 / 3 points

(Assume speed of light $c = 3 \times 10^8 m/s$)

- ○ 2.5 meters
- ○ 5 meters
- ◉ 7.5 meters
- ○ 10 meters

Correct

The depth d is given as $d = \frac{c\psi}{4\pi f}$, where c is the speed of light. Using $\psi = \pi, f = 10MHz$ = $10^7 Hz$, and the speed of light $c = 3 \times 10^8 m/s$:

$$d = \frac{c\psi}{4\pi f}$$

$$d = \frac{3 \times 10^8 \pi}{4 \times 10^7 \pi}$$

$$d = \frac{30}{4}$$

$$d = 7.5$$

12. A time-of-flight based 3D camera emits light which can be modeled as $\cos(x)$. with frequency $f = 10MHz$. The camera measures the phase-shift τ of the reflected light with respect to the emitted light. What is the maximum range of depths that the camera can measure unambiguously?

3 / 3 points

- ○ 5 meters
- ◉ 15 meters
- ○ 25 meters
- ○ 50 meters
- ○ 100 meters

Correct

The range of phase shifts for light signal $cos(x)$ is 0 to 2π. Therefore, the $d_{min} = 0$ and $d_{max} = \frac{2\pi c}{4\pi f} = \frac{c}{2f}$, where c is the speed of light $c = 299,792,485m/s$. For $f = 10MHz = 10^7Hz, d_{max} \cong\ 15$ meters. Therefore, this camera can only distinguish a range of 15m.