Assignment 1

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1 Designing the Pinhole Camera

1.1 Pinhole Camera Parameters

- Camera: iPhone 15 Pro, taken with the ProCam app.
- Dark Box: We use a regular shoe box as our dark box (Length: 13 inches (33 cm), Width: 7 inches (18 cm), Depth: 5 inches (13 cm).
- Pinhole Size: We have three sizes of the pinhole: 1mm, 3mm, and 5mm in diameter

Figure 1: Different sizes of pinholes. From left to right: 1mm, 3mm, 5mm in diameter

1.2 Setup

In this section, we demonstrate the setup process for our pinhole camera. We selected one side to serve as the image plane, which we covered with white paper. The remaining areas of the camera were covered with black duct tape to prevent light leaks. On the side opposite the image plane, we drilled a hole to accommodate the pinholes. These pinholes were created in pieces of black cardboard, which can be seen in Figure 1. This design allows for easy interchange of pinholes with different diameters by simply taping the cardboard over the drilled hole. Additionally, to minimize camera shake during the lengthy exposure times required, we constructed a stand within the dark box to securely hold our iPhone. See Figure 2 for more detailed views of our pinhole camera.

Figure 2: Visualization of the setup of the pinhole camera

2 Results

We captured both the pictures on the second floor of the Ash Hall inside the Corps of Cadets.

2.1 Scene 1

Here is the first scene, displaying images captured using different pinhole sizes.

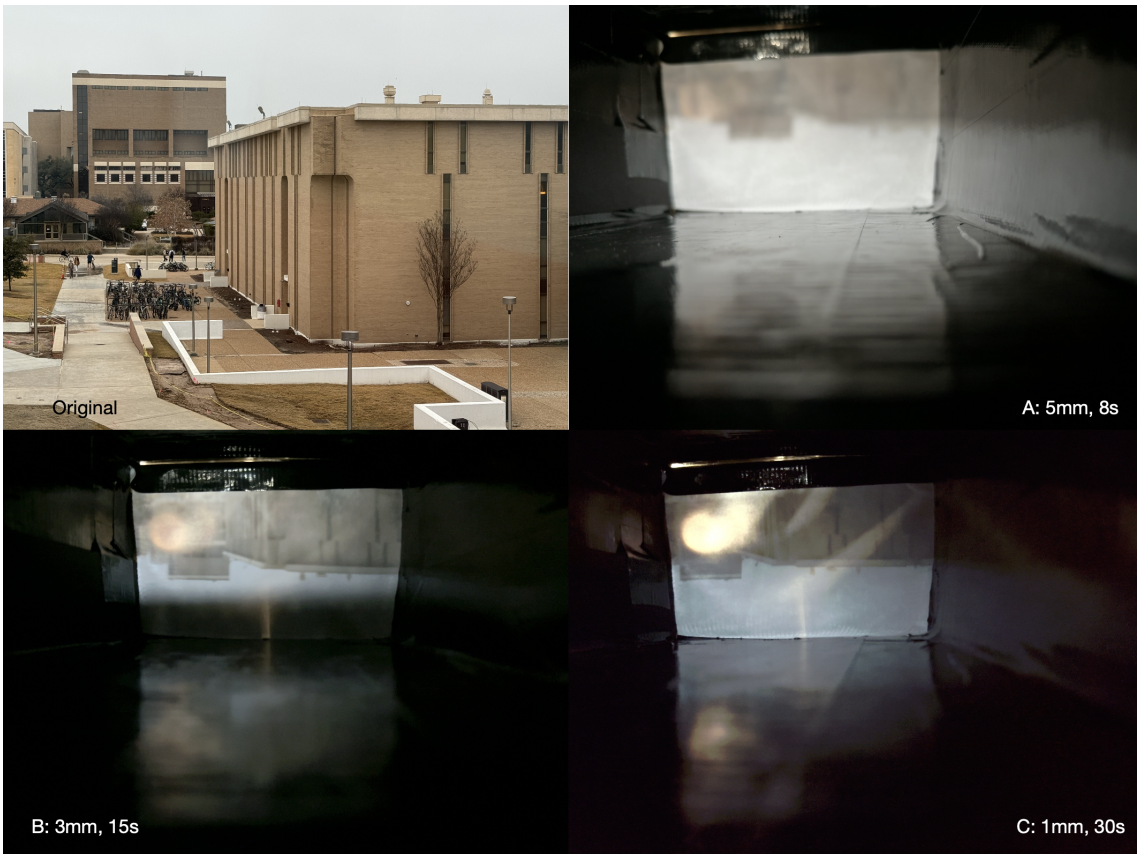

Figure 3: Scene 1: Top-Left: The original image; A: Image taken with 5mm pinhole, 8s exposure; B: Image taken with 3mm pinhole, 15s exposure; C: Image taken with 5mm pinhole, 30s exposure

2.2 Scene 2

Here is the second scene, displaying images captured using different pinhole sizes.

Figure 4: Scene 2: Top-Left: The original image; A: Image taken with 5mm pinhole, 8s exposure; B: Image taken with 3mm pinhole, 15s exposure; C: Image taken with 5mm pinhole, 30s exposure

3 Analysis

The image presented above features an inverted view with a sharply defined building structure, showcasing a depth of color with beige and brown tones being the most prominent.

We observed a consistent trend: as the aperture, or pinhole, decreased in size, the sharpness of the image increased. A smaller aperture allows less light to pass through, limiting the light rays from wide angles to a specific region of the object. This limitation enhances image clarity and reduces the spread of the image. However, we noted a decline in image clarity beyond a certain aperture size, which, in our case, was 3mm. This decline was attributed to the effects of diffraction.

Significantly, we found that a pinhole size of 3mm, combined with an exposure time of 15 seconds, produced the highest-quality image for both scenes. This balance enabled sufficient light to achieve image clarity while preventing overexposure, resulting in a visually appealing outcome.

With longer exposure times, an interesting phenomenon became apparent — the appearance of bright spots in the images. A detailed examination of our setup revealed that these spots aligned with small, uncovered gaps in the shoebox, unavoidable due to its inherent structure where the box closes and overlaps.

3.1 Scene 1 Analysis

A notable difference between Scene 1 and 2 was the superior image quality of the 1mm camera hole size with a 30-second exposure in Scene 1 compared to the same parameters in Scene 2. We suspect this disparity may arise from differences in lighting conditions, with direct sunlight on Scene 2 and the buildings being farther away.

3.2 Scene 2 Analysis

Conversely, a 1mm camera hole size paired with a 30-second exposure time in Scene 2 resulted in a dark image, highlighting the delicate interplay between exposure duration and pinhole size. The brightness of spots in Scene 2 surpassed those in Scene 1, supporting our hypothesis that Scene 1's better image quality was due to indirect sunlight and closer buildings.

We can notice that the brightness of spots on the image generated in scene 2 is much higher when compared to the spots on the image generated in scene 1. This would allow us to conclude our hypothesis that the image quality of scene 1 was better because the sunlight was indirectly pointed onto the hole and the buildings were much closer, so the sharpness of the image is much better.

3.3 Final Conclusion

Shrinking the aperture results in clearer images while longer exposure is needed to maintain the brightness. However, there is a threshold beyond which a further reduced aperture will increase diffraction, resulting in a loss of image clarity.

Overall, we believe for our scenes and the camera setup, 3mm camera size and 15 seconds of exposure time produced the best images.

4 Extra Credit

4.1 Light Painting

Light Painting is a photographic technique utilized to capture the light movements. It's almost like the painter painting the world with light instead of a paintbrush.

4.1.1 Set Up

- Camera: iPhone 15 Pro, taken with the ProCam app.
- Dark Apartment Room: We captured the scene in our apartment with all lights turned off.

4.1.2 Results

Figure 5: Light Painting Scene 1. Image taken on iPhone 15 Pro camera with 8s exposure. The light was generated with the iPhone 15 Pro torch light.

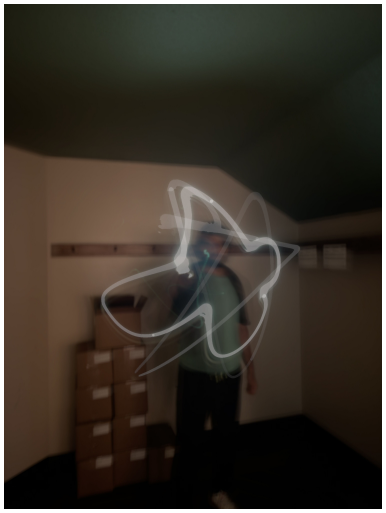

Figure 6: Light Painting Scene 2. Image taken on iPhone 15 Pro camera with 8s exposure. The light was generated with the iPhone 15 Pro torch light.

4.1.3 Analysis

In Figure 5, the movement of light is captured as it forms a zigzag and spirals into a ball. Different shades of white light are observable, which we believe result from the camera's settings, where the exposure is adjusted to balance both cooler and warmer tones. A similar effect is evident in Figure 6, where the image was captured in a basement. The long exposure setting allows the moving light to create an effect akin to a painting along its path.

4.2 Stereo Pinhole

4.2.1 Pinhole Camera Parameters

4.2.2 Setup

We adapted our existing setup from our black-and-white scene-capturing pinhole camera. The sole difference between the two camera setups lies in the pinhole design. To capture a stereoscopic light picture, we used two holes: one covered with a red filter, and the other with a blue filter. We positioned the red and blue filters vertically, with the red filter on top. Each hole was drilled to a diameter of 3 mm. See Figure 7

Figure 7: Stereo Camera Setup

4.2.3 Results

We captured both pictures outside the Zachry Engineering Education Complex.

4.2.4 Scene 1

Figure 8: Stereo Pinhole Scene 1. Image taken on iPhone 15 Pro camera with 15s exposure. The left one is the original image while the right is the one taken from the stereo pinhole camera.

4.2.5 Scene 2

Figure 9: Stereo Pinhole Scene 2. Image taken on iPhone 15 Pro camera with 15s exposure. The left one is the original image while the right is the one taken from the stereo pinhole camera.

4.2.6 Analysis

The image formed in Figure 8 & 9 showcases an illusion of depth that was created with two filters (red and blue). We utilized a 3mm camera hole and 15 seconds of exposure time to capture both scenes.

4.2.7 Final Conclusion

Increasing the exposure time decreased the image quality as the image was being overexposed to the light. We noticed this pattern earlier as well where the camera pinhole size was the same but there was no filter.

Similarly, decreasing the exposure time did not increase the image quality as the image was blurry which we believe would be due to sufficient exposure. This was tested with multiple scenes but none of them resulted in a better image quality than a 3mm camera size and 15 seconds exposure time.

Overall, we believe for our scene and the camera setup, 3mm camera size and 15 seconds of exposure time produced the best images.