Learnings from the process of making different camerae obscurae

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Abstract: This lab report conveys the exploration of fundamentals of imaging principles through the construction and experimentation of different camera obscura setups. Divided into 3 separate attempts, the first is a small cardboard box pinhole camera, the second being a refined Pringles container pinhole camera, and the last being a large pinhole camera. The effects of varying aperture sizes on image sharpness and lighting could be observed with these varying designs. The principle of Metadocumentary was used to capture the pictures within the camera.

Keywords: keyword-1, keyword-2, keyword-3, keyword-4, keyword-5

1 Materials and Method

Figure 1: *all 3 cameras*

This section details the materials used for each of the three pinhole cameras. For all cameras, the basic materials required were scissors and electrical tape. Unique materials for each are listed below.

1.1 Small Camera Obscura

Figure 2: *small camera*

This camera was made with a 6"L x 6"W x 6"H cardboard box. The inside was lined with thick black paper with the sides covered by electrical tape to prevent light from seeping through. The side parallel to the side with the hole was covered with white paper. Two holes were made on the other parallel side; one hole was made to fit the lens of a phone camera, and the other hole was covered with aluminum foil with a small hole that was made by poking a needle through it.

1.2 Refined Adjustable Camera Obscura

Figure 3: *adjustable camera*

This camera was made with a Pringles container, small rectangular box, and parchment paper. The pringles container was cut to split at around two-thirds of its entire length. The longer one was then cut down the side vertically and taped with a smaller diameter, enough to fit inside the other tube. This extendable design allows for the "zoom-in, zoom-out effect of a camera as the size of the images depends on the distance between the object and the pinhole. The video linked in this report will further demonstrate how this was made.

1.3 Big Camera Obscura

Figure 4: *big camera*

This camera was created in a similar method to the first camera, but just with a bigger box.

2 Results and Discussion

2.1 Tables

Similarly, tables can be shown and labeled like figures. Referencing a table using its label: Table 2.

Table 1: *Experimentation Camera Dimensions*

Type	Measured Aperture d	Focal Length
Small	0.9mm	15cm
Adjustable	1.1mm	16-24cm
Big	2mm	22cm

2.2 Metadocumentary

Below are some results of the picture of the pictures taken.

Figure 5: *iPhone photo through small camera*

During my first attempt at making this small box camera, I found that light was still coming through the corners and the cardboard. I then closed off the corners and covered the inside with electrical tape and thick black paper. The results of this are shown below.

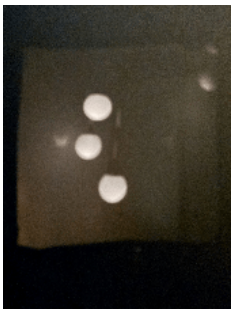

Figure 6: *iPhone photo through small camera after fixes*

As for the carefully made adjustable camera with a screen, the image was sharper and the focal length could be adjusted.

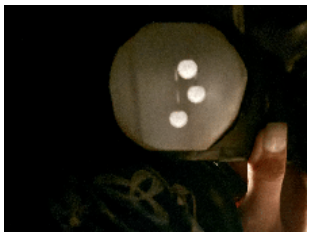

Figure 7: *iPhone photo of screen of adjustable camera*

For this last photo, I used the big camera and added a lens.

Figure 8: *experimenting with taping lens to aperture*

Figure 9: *iPhone photo through big camera*

2.3 Analysis of results based on experiments

Through experimental analysis of comparing the small camera and big camera, some things could be observed. In terms of pinhole sizes, generally a smaller pinhole yielded a sharper image. However, if the pinhole size was too small, it also resulted in degradation of image quality. During experimentation, the optimal pinhole size for the large camera was determined based on a tradeoff between the clarity achieved with a smaller aperture and the potential fuzziness as a result of diffraction. The other observation made was that although both the big box and the adjustable box had obviously longer focal lengths, the aperture diameter did not vary proportionally. In general, a longer focal length and a smaller aperture diameter could contribute to more

detailed images, although it may be dimmer. Therefore, larger cameras have greater detail and sharpness.

2.4 Mathematical Analysis

The formula for the optimal aperture diameter is given by:

$$d = c\sqrt{f \cdot \lambda} \tag{1}$$

where:

- d: Optimal aperture diameter
- $c \approx 2$
- f: Focal length (distance from aperture to image plane)
- $\lambda = 550\,\text{nm}$

Based on these calculations, the optimal hole aperture would be as follows:

Table 2: *Optimal Camera Dimensions Calculated*

Type	Optimal Aperture d	Focal Length
Small	0.57mm	15cm
Adjustable	0.59-0.73mm	16-24cm
Big	0.7mm	22cm

3 References

[1] S. Mann, "ECE516 Lab01, 2024: What is a camera? Fundamentals of Intelligent Image Processing." wearcam.org. http://wearcam.org/ece516/lab1.htm (accessed Jan. 19, 2024).