Effects of variations in exposure times and pinhole sizes to the quality of image projections by a camera obscura

Lyle Kenneth M. Geraldez*

National Institute of Physics, University of the Philippines - Diliman, Philippines
*Corresponding author: lgeraldez@nip.upd.edu.ph

Abstract

Camera obscura are darkened rooms with a pinhole structure where light enters and is usally projected to a screen showing an inverted image. The study aims to analyze the images semi-quantitatively by finding out the effects of exposure time and pinhole size to the images' projection parameters. Qualitatively, the study showed that there exists a direct correlation between resolution and exposure time for all pinhole sizes and there exists a direct correlation between intensity and pinhole size and an inverse correlation between resolution and pinhole size. Using Mathematica, the study showed that increasing exposure times resulted to a lower contrast feature on the histogram with a significant shifting from lower key to a higher key while increasing pinhole size resulted to increasing in contrast while maintaining the key of the image. Moreover, an increase in mean intensity and an increase in mean RGB values was observed by increasing the pinhole size while the skewness was decreased (shifted to the right of the histogram).

Keywords: camera obscura, image analysis

1 Introduction

A camera obscura is any dark room with a small hole (usually of pinhole size) the allows light to enter and project it into a screen. This forces light to travel in straight lines, and hence, appear inverted towards a projecting screen. Historically, this has alot of applications - from the the primitive development of the first cameras, to viewing eclipses, and as an art tool used to aid in drawing. In this study, we aim to explore the quality of the image projections on a camera obscura by varying the pinhole sizes and exposure times.

We hypothesize that the variation of said parameters will result to a change in intensity (how light or dark the iamge is) that may be detected through image analysis. We also hypothesize variations in color projection by analyzing the images' histograms. Color histograms are characteristic distributions of colors from darker ones to lighter ones. This allows us to quantify the key of the image by calculating its skewness and qualitatively figure out the contrasts of the images.

2 Methodology

The camera obscura setup relied on an LCD display to project the image as a light source. The object used was a coffee bottle with various contrasting colors placed on a dark table with a light background. It contains some words that can be used to qualitatively assess resolution. To avoid noise on the projection, the experiment was done in a dark room at night. The setup is shown below.

Figure 1: A shoebox setup was used to construct the camera obscura to project an image of a coffee bottle

A shoebox with a hole was used as the body of the camera obscura. Aluminum foil was place on the cut-out hole on the shoebox. For the study, three different foil pinhole size was used: A *small pinhole*

which has an approximate diameter 0.2 cm, a *medium pinhole* which has an approximate diameter 0.5 cm, and a *large pinhole* which has an approximate diameter of 1.0 cm. These terms will be used throughout the paper. The study also explored varying exposure times used to capture the projection in the dark room. The distance between the light source and the pinhole is fixed at 13 cm. The distance between the pinhole and the screen is fixed at 7.5 cm. The interior of the shoebox was completely painted black. The screen used was a piece of bondpaper. All sides of the shoebox were covered with improvised opaque materials except the side where the image was taken. This side was partially covered by phone; some light source may enter directly but has negligible qualitative effects to the image.

The study aims to explore the effects of exposure time and pinhole size to the image histogram, intensity of light, and qualitative descriptions of the images.

3 Results and Discussion

Mathematica was used to analyze the image individually. Although the absolute measured quantities have physical significance, only the relative quantities are needed to quantitatively explore the differences and effects of exposure times and pinhole sizes. The gathered data can be summarized in the table below.

	Exposure Time	Mean Intensity	R-value	G-value	B-value	Skewness
Small Pinhole	3 s	0.115409	0.097240	0.093405	0.102239	0.955337
Small Pinhole	10 s	0.123876	0.109061	0.100688	0.118184	0.729148
Small Pinhole	30 s	0.109758	0.096417	0.089648	0.095585	0.254450
Medium Pinhole	3 s	0.259794	0.242385	0.245907	0.281643	0.716595
Medium Pinhole	10 s	0.251060	0.234482	0.235284	0.276347	0.675305
Medium Pinhole	30 s	0.260257	0.248292	0.243666	0.289248	0.539220
Large Pinhole	3 s	0.236087	0.223359	0.220150	0.243885	0.920531
Large Pinhole	10 s	0.347199	0.348156	0.334176	0.362656	0.346706
Large Pinhole	30 s	0.342607	0.344580	0.329154	0.354705	0.350860

It can be observed that, for the 30-second exposure setup, the mean intensity rises due to a larger aperture; more light can enter as pinhole size is increased. It can also be observed that the RGB values increases, in general, across different pinhole sizes. There is a downward trend to the skewness (of the image histogram) as the exposure time is increased and also as the pinhole is increased. Conversely, there is no trend between the mean intensity of the images and the exposure time (as was contrarily hypothesized). Mean values are quantitatively compared in the later section.

3.1 Exposure Time Analysis

3.1.1 Small Pinhole

Figure 2: Images of the small pinhole projection was shown with varying exposure times from 3 seconds (left), 10 seconds (middle), and 30 seconds(right)

In the small pinhole setup, there is an apparent qualitative trend as exposure is increased from 3 seconds to 30 seconds. The images show became more resolved as the text in the coffee bottle image became more legible.

For the small pinhole, increasing the exposure time skews the color histogram of the projected image towards the right. In the 3 seconds exposure time, the image was mostly lowkey, tapering off and then

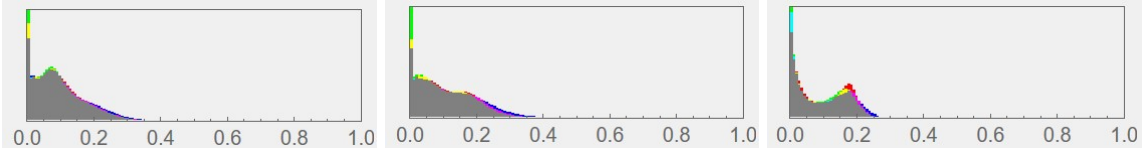


Figure 3: Histograms of the small pinhole projection was shown with varying exposure times from 3 seconds (left), 10 seconds (middle), and 30 seconds(right)

abruptly cut off. In the 10 seconds exposure time, the image became more balanced but still leaning towards a lowkey region. In the 30 seconds exposure time, the pixel content still was reduced but a U-shape feature can be seen. This implies a higher contract image where one can observe the whiter texts more clearly mounted on a darker background.

3.1.2 Medium Pinhole

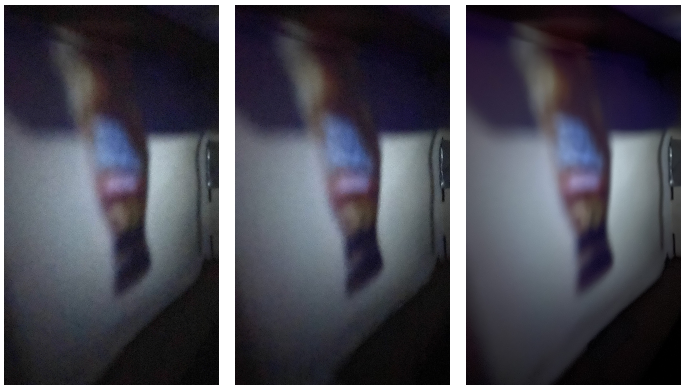


Figure 4: Images of the middle pinhole projection was shown with varying exposure times from 3 seconds (left), 10 seconds (middle), and 30 seconds(right)

Similarly to the small pinhole, the projected images of the medium pinhole also became more resolved as the exposure time is increased.

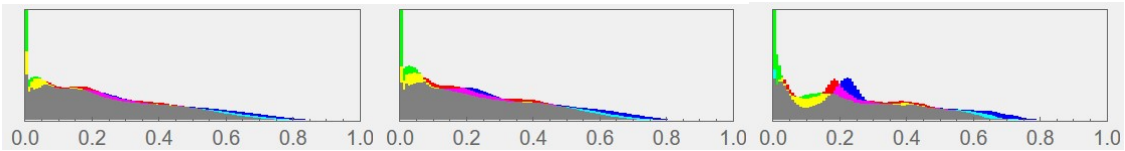


Figure 5: Histograms of the middle pinhole projection was shown with varying exposure times from 3 seconds (left), 10 seconds (middle), and 30 seconds(right)

Similar features can be seen here and from the small pinhole histograms. Increasing exposure made a crest travel from left to right, making a U-shape feature of higher contrast when the exposure is increased to 30 seconds. The difference here is that more light colored pixels are activated giving the histograms their characteristic tails.

3.1.3 Large Pinhole

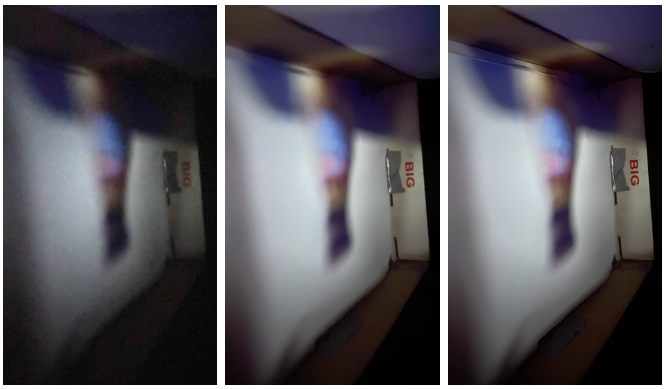
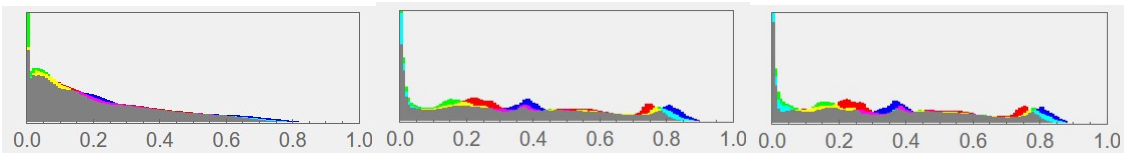


Figure 6: Images of the large pinhole projection was shown with varying exposure times from 3 seconds (left), 10 seconds (middle), and 30 seconds(right)

The large pinhole showed similar behavior as its resolution increases as the exposure time is increased.



(a) (b) (c)

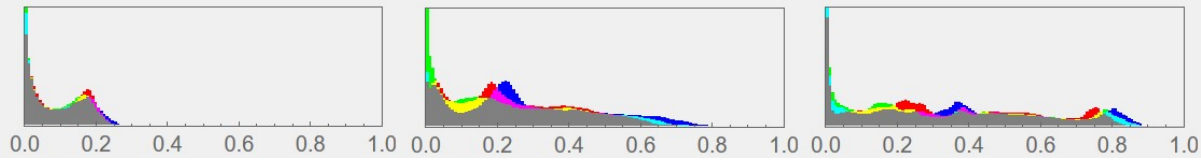
Figure 7: Histograms of the large pinhole projection was shown with varying exposure times from 3 seconds (left), 10 seconds (middle), and 30 seconds(right)

Multiple crests can be seen as the exposure time is increased in the large pinhole setup. This implies that the individual colors are more well-defined, increasing the contrast between colors, and hence, being more faithful to the original image source.

3.2 Pinhole Size Analysis

Figure 8: Images taken with 30-second exposure time was shown using a small pinhole (left), a medium pinhole (middle), and a large pinhole (right)

Increasing the pinhole size increases the intensity (as was discussed quantitatively) but reduces the overall resolution of the object. This may be observed by the legibility of the words on the surface of the coffee bottle.



(a) (b) (c)

Figure 9: Histograms of images taken with 30-second exposure time was shown using a small pinhole (left), a medium pinhole (middle), and a large pinhole (right)

Observe that the histograms of the 30-second exposure time setups became more and more high key as the pinhole size increased. Smaller pinhole corresponds to a greater contrast albeit having lower amount of pixels that are being activated. This explained why, even though the bigger pinhole size resulted to a brighter image projection, the words on the surface of the coffee bottle are less legible than the dimmer projection by the smaller pinhole.

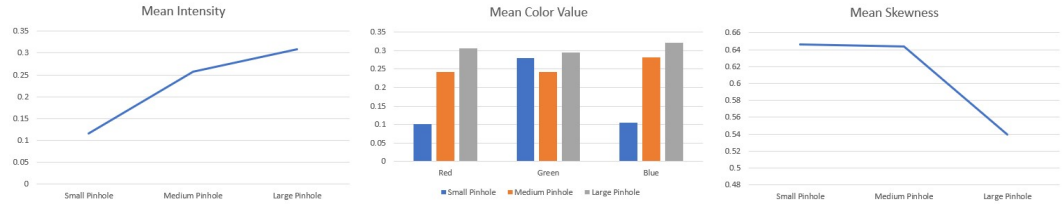


Figure 10: The graph shows a plot of the mean intensity, mean color value, and mean skewness averaged on all exposure times using the small, medium, and large pinhole

The mean intensity of the images showed an upward trend as the pinhole size is increased. This is due to more amount of light entering a larger aperture. There is a general upward trend of the mean color value of the image as the pinhole size is being increased. Of course, smaller pinhole are generally dimmer, and, hence must have a generally lower RGB components value. As was seen qualitatively in the histograms, the mean skewness for each pinhole size decreased (skewed to the right) as the pinhole size is increased due to the aforementioned reasons.

4 Conclusions

The study aimed to find out, semi-quantitatively, the effects of exposure times and pinhole size to the quality of the image projected into the camera obscura via an LCD screen light source. Using Mathematica to analyze individual images projected, several parameters are explored. Qualitatively, the images are analyzed with varying exposure time and pinhole sizes. There exists a direct correlation between resolution and exposure time for all pinhole sizes and there exists a direct correlation between intensity and pinhole size and an inverse correlation between resolution and pinhole size. The study showed that increasing exposure times resulted to a lower contrast feature on the histogram with a significant shifting from lower key to a higher key while increasing pinhole size resulted to increasing in contrast while maintaining the key of the image. An increase in mean intensity and an increase in mean RGB values was observed by increasing the pinhole size while the skewness was decreased (shifted to the right).

5 Selfie

Figure 11: Images show the projection of the author's face