15-463 Computational Photography (Fall 2023)

Assignment 1

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1. Developing RAW images

1.1. Implement a basic image processing pipeline (80 points)

[Raw image conversion]

(base) HAEJOON@haejoons-mbp myDCRAW % ./dcraw -4 -d -v -w -T campus.nef

Loading Nikon D3400 image from campus.nef ...

Scaling with darkness 150, saturation 4095, and

multipliers 2.394531 1.000000 1.597656 1.000000

Building histograms...

Writing data to campus.tiff ...

[Python initials]

Image shape: (4016, 6016)

Image datatype: uint16 (16bits)

New image datatype : float64

[Linearization]

Linearization

```
[130]
1  black = 150
2  white = 4095
3
4  img = (img - black) / (white - black)
5  img = np.clip(img, 0, 1)
```

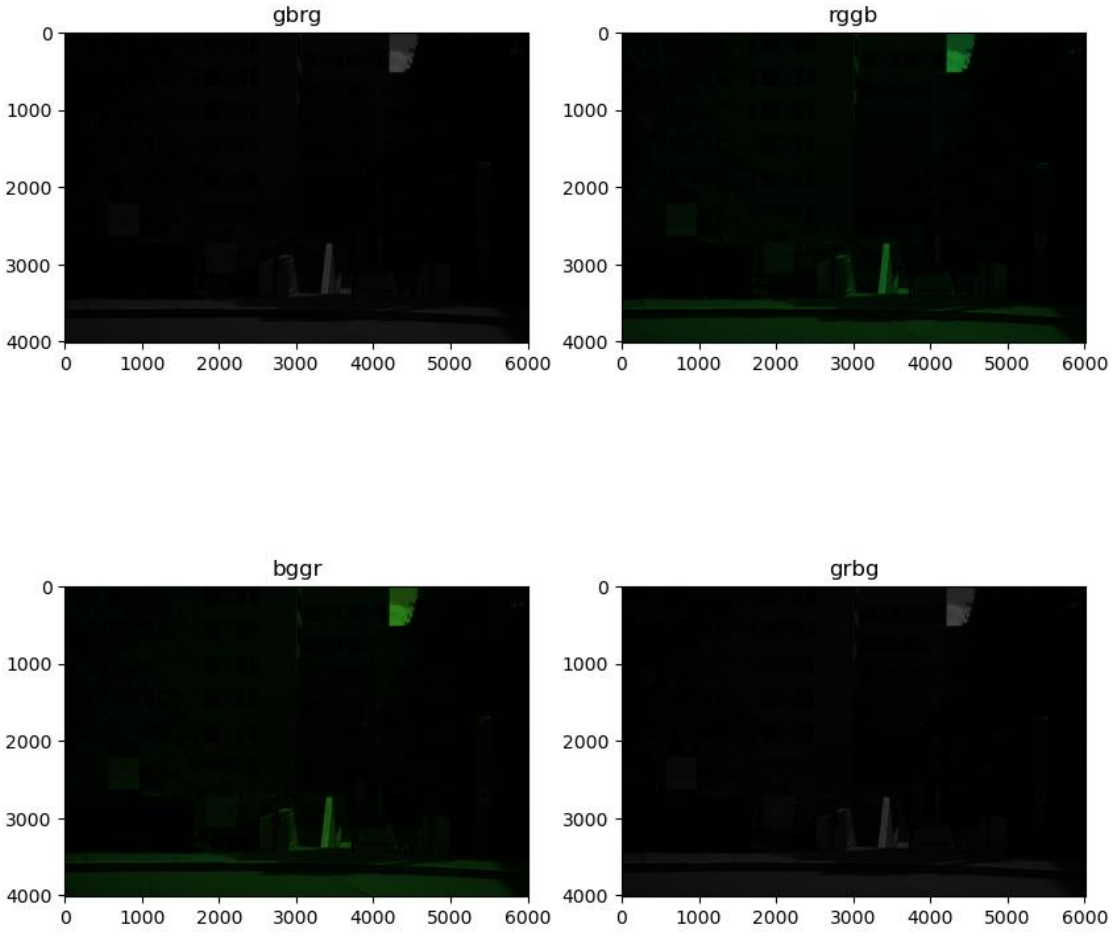
✓ 0.2s

[Identifying the correct Bayer pattern]

I expected that the diagonal components with similar values would be the green values. From the output, we could expect that the Bayer pattern is RGGB or BGGR.

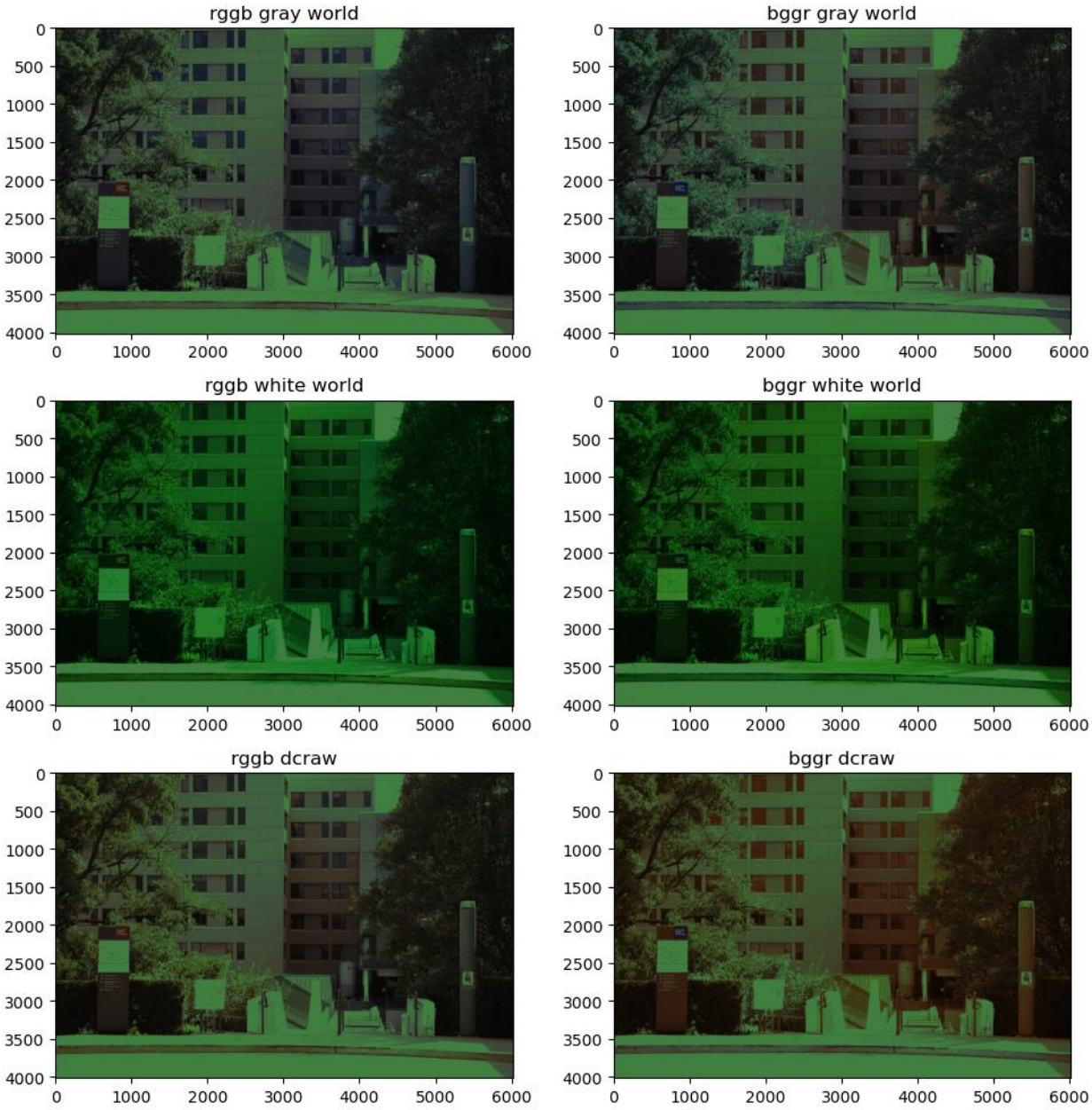
```
[131]
1  x = 0
2  print(img[x:x+2,x:x+2])
3  # Diagonal components with s
✓  0.0s

[[0.01267427 0.03954373]
 [0.05804816 0.01343473]]
```

First of all, I arranged the pixel values by all 4 patterns.



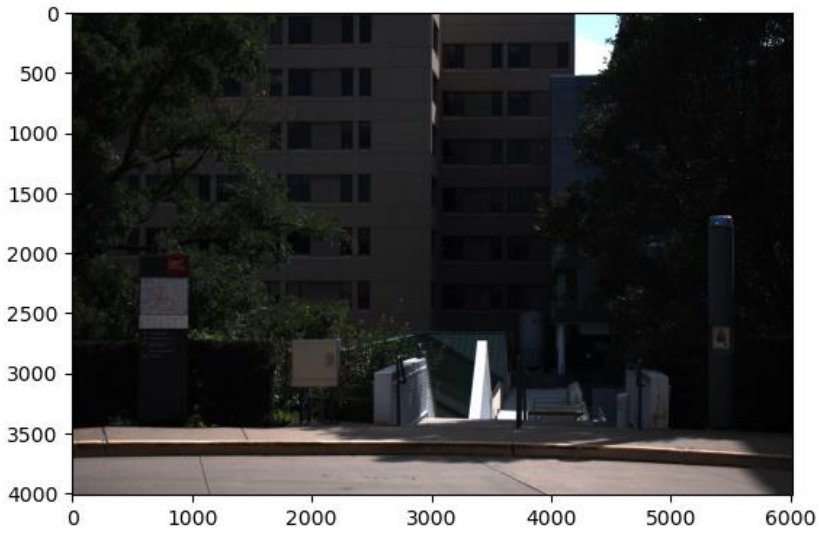
Then after applying white balancing algorithm, I noticed that only rggb pattern showed the correct red color on the CMU logo in the scene (will be shown in the next part). Thus, I decided to perform following procedure with the rggb image.

[White balancing]



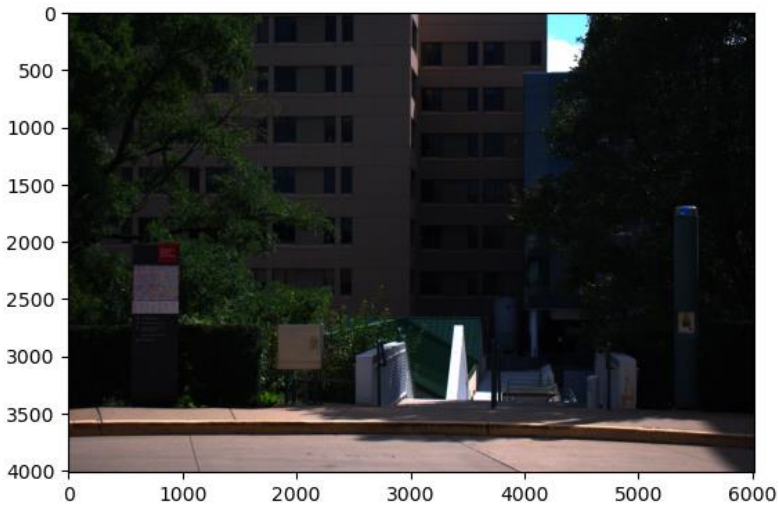
Performed each white balancing algorithm to rggb and bggr images. Rggb gray world image looked the best to me, and I decided to use it mainly for the following procedure.

[Demosaicing]

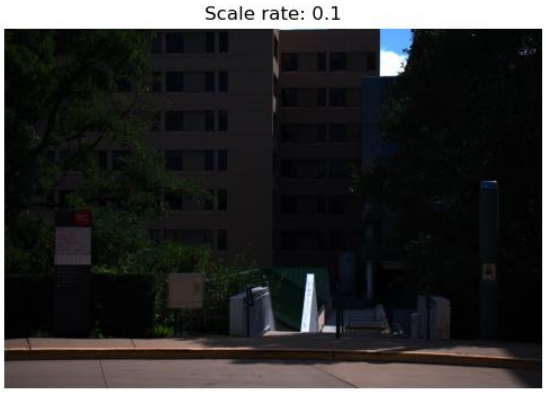


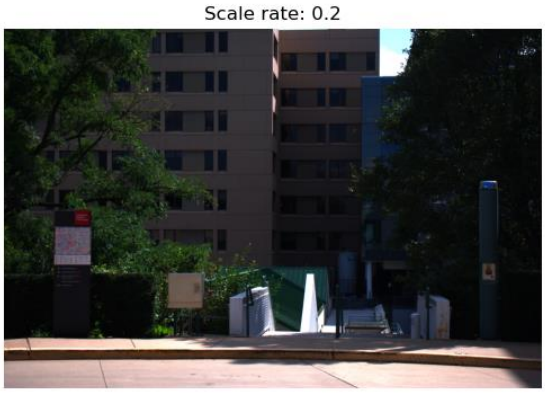
Above is the demosaiced rggb gray world image.

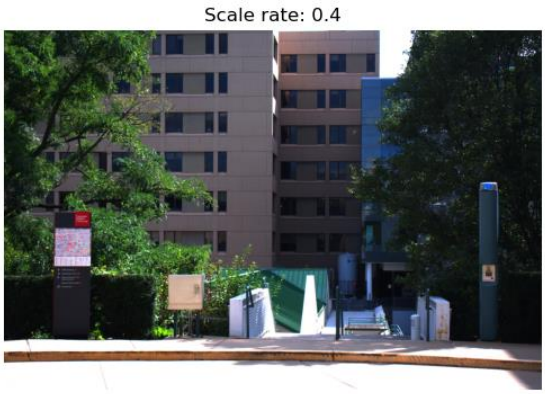
[Color space correction]



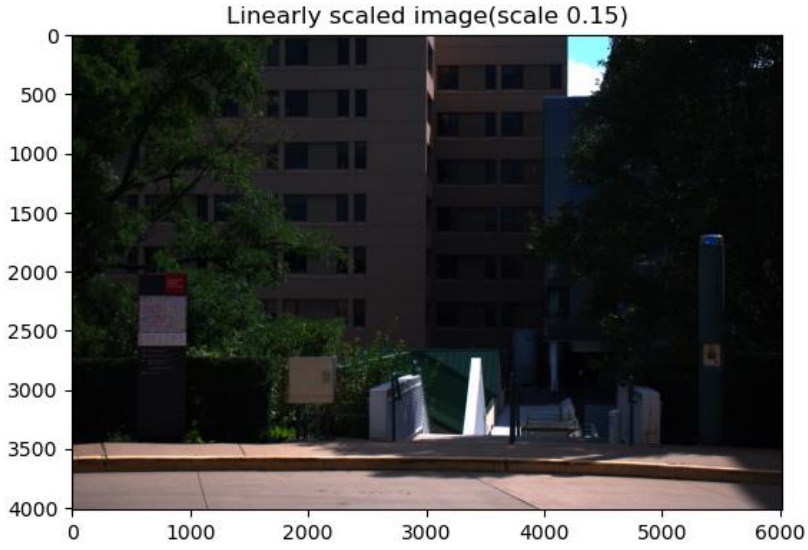
[Brightness adjustment and gamma encoding]

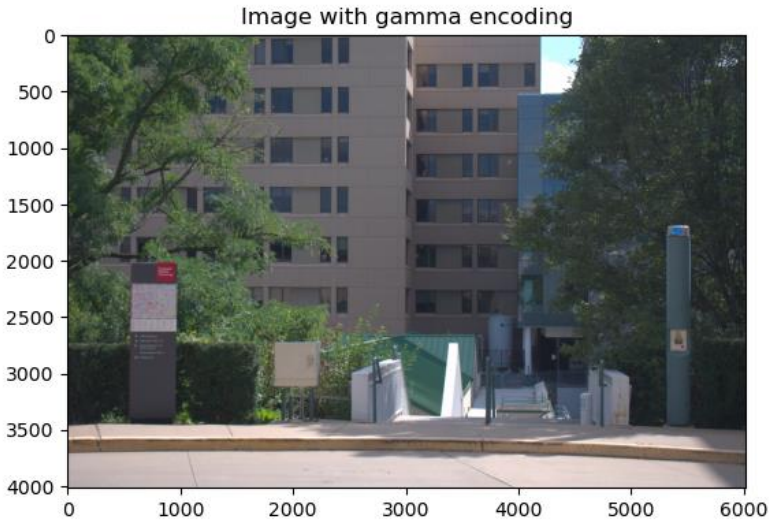






For the linear scaling, from 0.3 rate, sky started to be saturated. Thus decided to use 0.15 in the following.





[Compression]

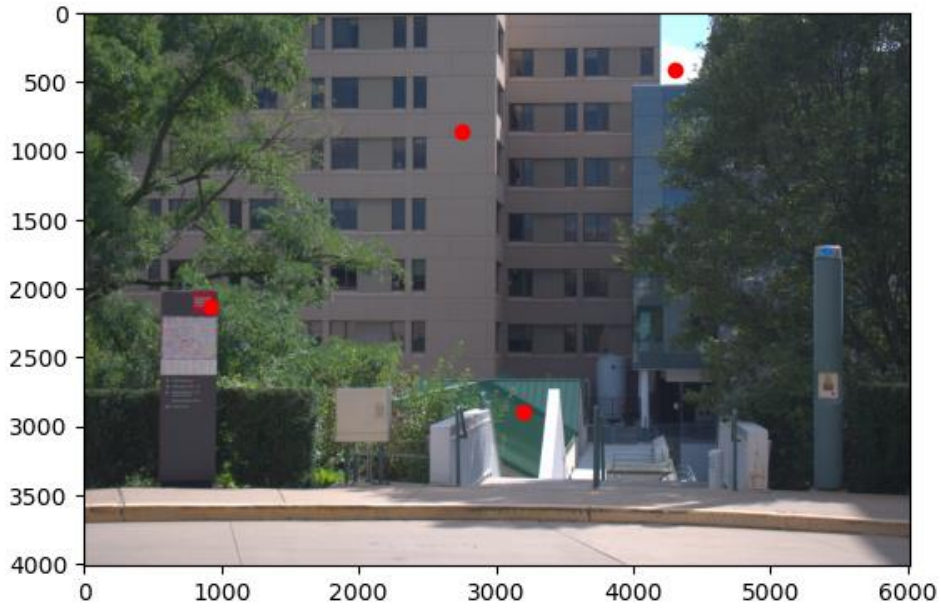
When I look into the .PNG format (no compression) and .JPEG format with the quality parameter set to 95, it is hard to tell the differences.

PNG size: 34,435,296 bytes

JPEG (QP of 95) size: 6,910,578 bytes

Compression ratio: 6,910,578 / 34,435,296 = 0.2006

1.2 Perform manual white balancing



Selected 4 points through gininput function, cropped 50x50 patch around the points, got average values for each channel of the patch and used them for scaling in white balancing. The results are as below.

Center: (4299, 408)

Center: (2747, 863)

Center: (921, 2136)

Center: (3196, 2894)

The fist patch from white cloud worked best for me. Probably the reason is that the white cloud is the most appropriate to be the criteria for ‘white’ color.

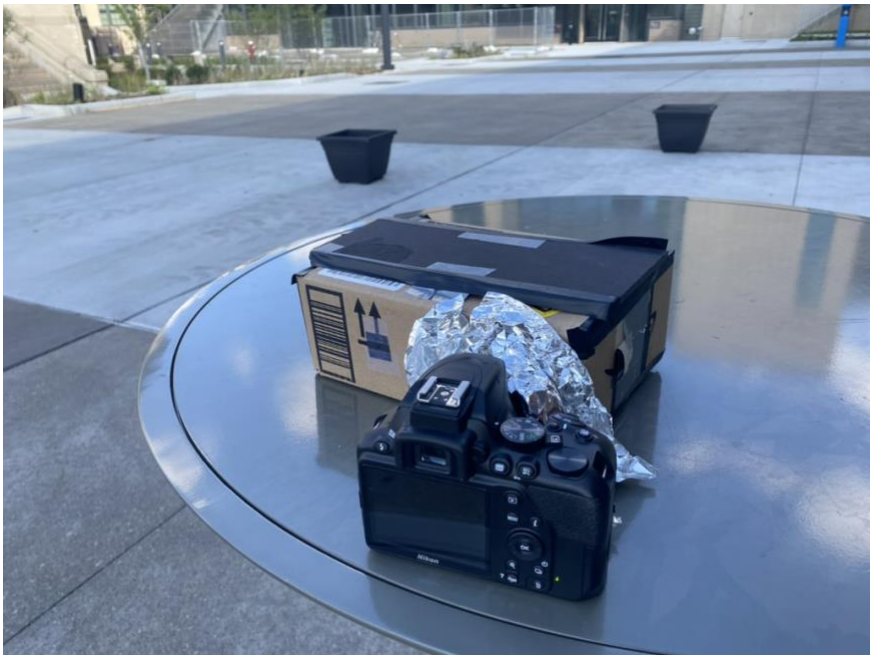
1.3 Learn to use dcraw

(base) HAEJOON@Haejoons-MacBook-Pro myDCRAW % ./dcraw -v -w -o 1 data/campus.net

The image developed from my implementation and dcraw look pretty much the same. The one provided in /data folder show a little more saturation in the sky and hard to discern cloud. Personally I liked the developed image from my code as it shows a little brighter than the dcraw one and preserves most of the details in the scene without saturation.

2. Camera obscura

2.1 Build the pinhole camera



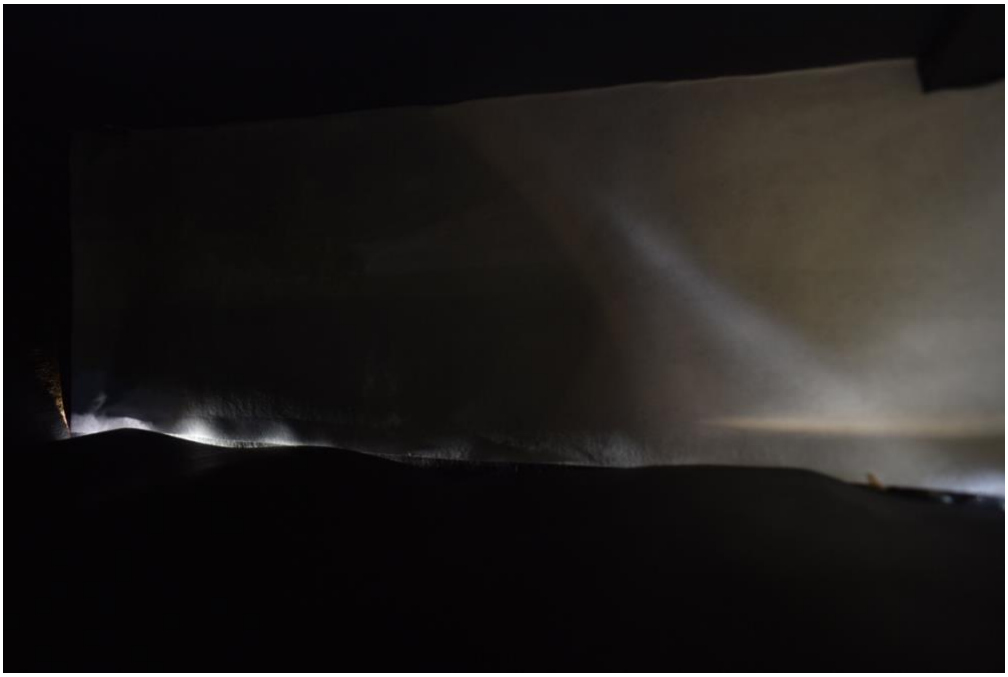
Focal length of lens: 18mm to make the field of view the widest as possible.

Aluminum foil to block light, flexible that I can tilt the camera.

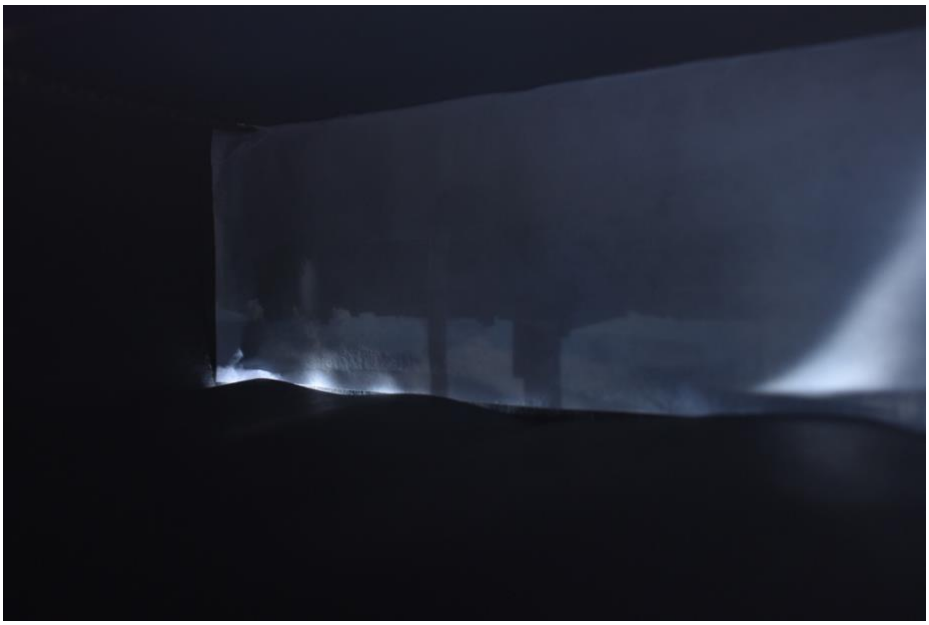
Pinhole on the slightly left side to make sure that camera doesn’t occlude light.

2.2 Use your pinhole camera

Scene 1



Scene 2



Scene 3

Pinhole diameter: 5, 2, 1mm.
Used full aperture size (F/3.5) and full exposure time with 30 sec.
0.189mm was the ideal value calculated, but so small to capture image even with the maximum exposure time. Thus, I used bigger ones.
As bigger pinhole I used, I could get brighter but blurrier image.

2.3 Bonus: Camera obscura in your room

I blocked the window using folded blankets (one of them was unfolded and little detached in the above photo). After set the timer, I ran to the window and made a small hole with the size of about 5cm diameter by opening the curtain (thus I couldn’t take a photo of the pinhole)