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INDIVIDUAL LAB REPORT 9

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TABLE OF CONTENTS

1 INDIVIDUAL CONTRIBUTION

1.1 PIPELINE FOR NOISE MEASUREMENT AND CALIBRATION

An illustration of the pipeline for sensor noise mesurement has been shown in the figure below:

Figure 1: THE SENSOR CALIBRATION PIPELINE

1.2 READ AND SHOT NOISE MEASUREMENT

SHOT NOISE: The Photon Shot Noise is introduced due to non uniform flux of this photon stream falling on the camera sensor elements. The square of the noise measure increases linearly with camera exposure values.

READ NOISE: Read Noise is introduced while converting the flux of incomimg stream of photons to a voltage signal. This is constant for images taken at different exposure values.

MEASUREMENT OF READ AND SHOT NOISE: Two consecutive images of a uniform light source are taken at the same exposure and are subtracted to cancel out the effects of thermal noise and PRNU. The standard deviation of the noise (standard deviation of all the pixel values) from the resulting image is then calculated and divided by $\sqrt{2}$ as independent noise sources adds up in quadrature,

$$\sigma(N_1)^2 + \sigma(N_2)^2 = \sigma(N_{total})^2$$

$$\sigma(N_1) \approx \sigma(N_2)$$

$$\sigma(N_1) = \sigma(N_{total})/\sqrt{2}$$

This would give us a datapoint $\{E_i, \sigma(N_i)\}$ and the steps can be repeated for a set of exposure values. An illustrative visualization for the measurement of the shot noise and read noise can be seen in Fig. 2

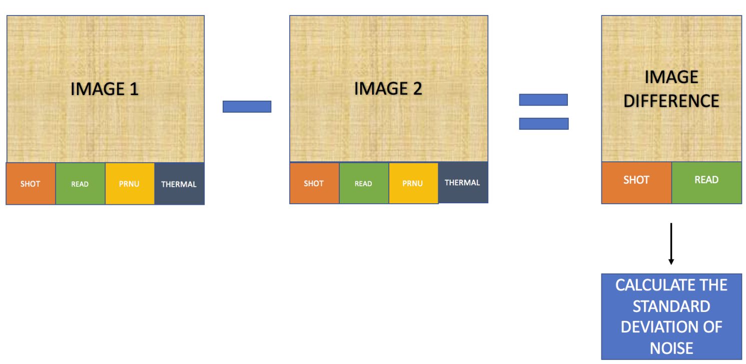


Figure 2: CALCULATING THE READ AND SHOT NOISE

EXPECTED PLOT

The expected plot can be seen from Fig. 3. The square of the standard deviation of the noise is a linear function of the exposure value.

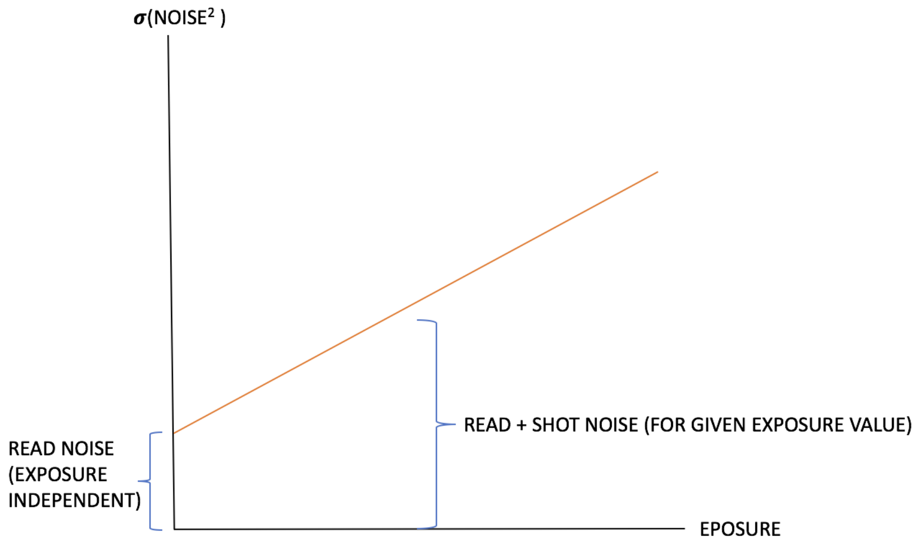


Figure 3: READ AND SHOT NOISE EXPECTED PLOT

1.3 RESULTS

The actual plot can be seen from Fig. 4.

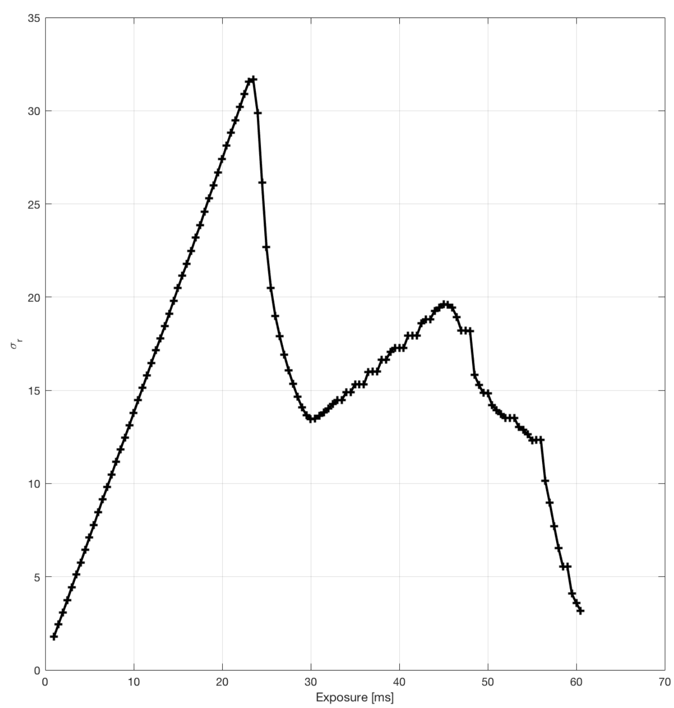


Figure 4: READ AND SHOT NOISE ACTUAL PLOT

1.4 EXPLAINATION

The plot is divided into 5 different zones as shown in Fig. 5.

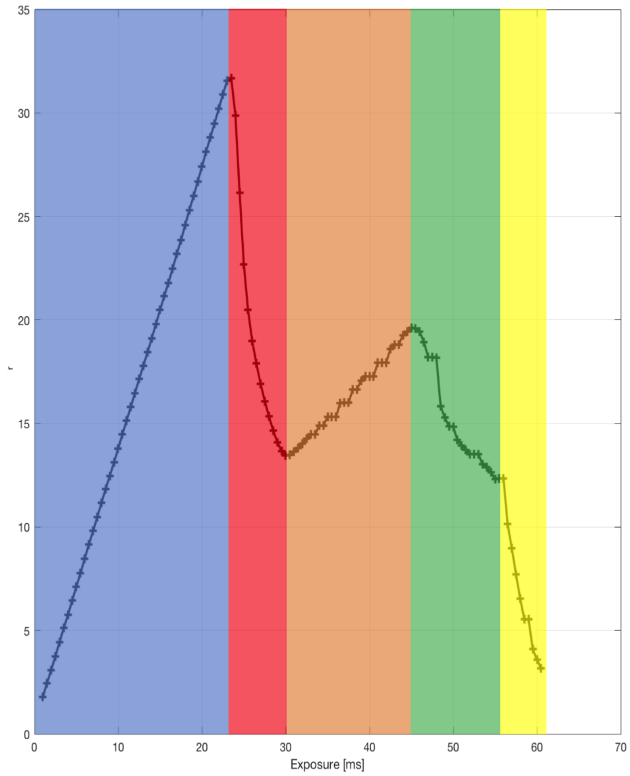


Figure 5: READ AND SHOT NOISE ACTUAL PLOT

1. BLUE ZONE: In this zone, the square of the noise increases linearly with exposure as expected. All pixels in the image are unsaturated and contribute to the growth of read and shot noise.
2. RED ZONE: At this point, the pixels start to saturate. There are 2 forces in play:
   - The rate at which pixels saturate which decreases the fraction of pixels contributing to the noise.
   - The unsaturated pixels which increase the noise with exposure.

   Note: The rate of pixels saturating is more than that of the noise contributed by the existing unsaturated pixels. At the end of the red zone, the pixel saturation fraction reaches 50%.
3. ORANGE ZONE: In this zone, 50% of the pixels have saturated but this percentage of saturated pixels remains constant. The remaining unsaturated pixels increase the noise linearly with exposure as expected
4. GREEN ZONE: In this zone, the pixels previously unsaturated(in the orange zone) start to saturate, hence decreasing the fraction of pixels contributing to the total noise, however, the rate of pixel saturation is comparable (but lesser than) to the rate at which the unsaturated pixels increase the total noise. Therefore the decrease is not very steep as compared to the yellow zone
5. YELLOW ZONE: In this zone, the remaining unsaturated pixels start rapidly saturating leading to a rapid decrease in the fraction of pixels contributing to the noise in the image.

2 CHALLENGES

One of the major challenges I encountered was that only 50% of the pixels saturated after the red zone. I did the following experiment to investigate into it:

1. I took a flat image at an exposure of 35000 (orange zone).
2. I then extracted a 100 x 100 patch from the center of the image and analyzed it by converting it to a binary image by thresholding at 95% of the maximum pixel saturation value (95% of 255).
3. Currently, I suspect the cause of this uniform pattern to be the bayer pattern of the color image. This can be seen from Fig. 6.

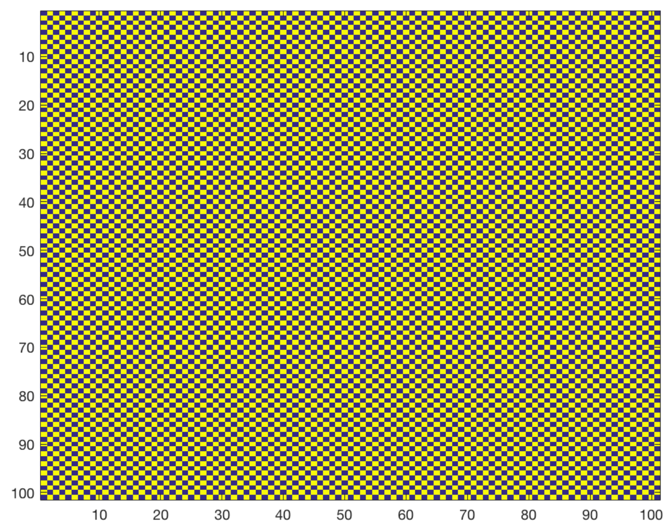
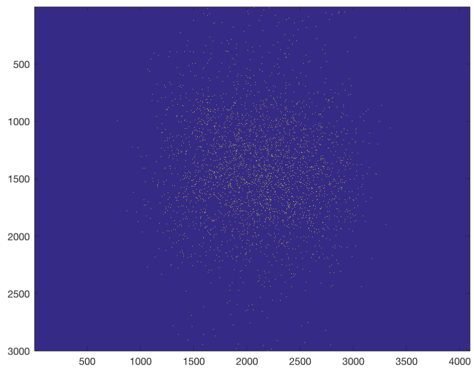


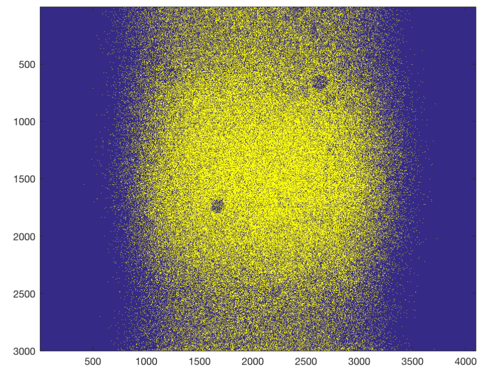
Figure 6: OBSERVED PATTERN

Additionally, I investigated if there is a general pattern of pixel saturation apart from the observed uniform pattern. For this,

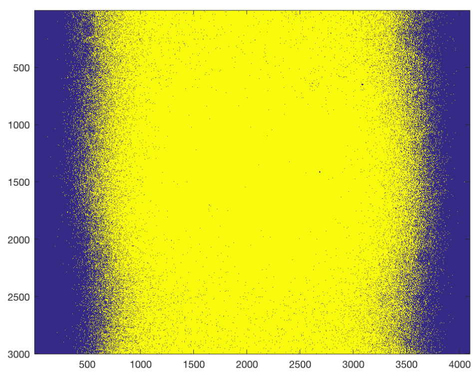
1. I took flat images in the green and yellow zone.
2. I converted the images into binary by thresholding at 0.95% of the maximum pixel saturation value (95% of 255).
3. I got an expected result: The pixel saturation begins at the center of the image and the edge pixels are the last to saturate completely (Vignetting).
4. Currently I am investigating ways to eliminate the effect of vignetting on the image noise. The saturation patterns can be seen from Fig. 7.



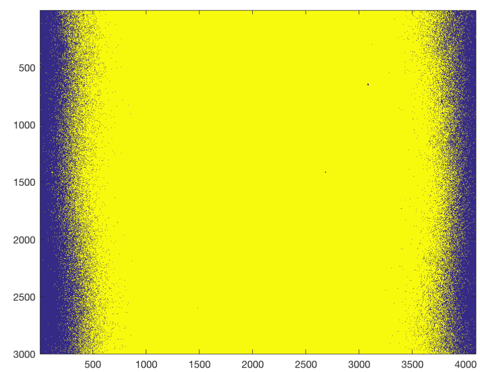
(a) Exposure: 52500



(b) Exposure: 55000



(c) Exposure: 57500



(d) Exposure: 60000

Figure 7: Pixel Saturation for Various Exposure Values.

3 TEAMWORK

1. **ABB ROBOT MODELLING AND SIMULATION: Peter** is currently working on the ABB robot arm. He has moved on from the simulation phase to working on the real robot and is trying to program the robot to follow given trajectories.

2. **COLOR CALIBRATION: Mandy** is currently working on the color calibration problem. Given the lighting conditions, she is working on mapping the observed color of the image to the actual color. She has used the data to create a linear and a polynomial fit and is working on the comparison between them.

3. **PATH PLANNING: Cece** is using the field of view of a system of cameras to calculate the ideal camera placement and an optimized path for the end effector of the robotic arm on which the calibration target is attached. She has assigned scores for different camera projections.

4. **IMAGE RENDERING: Sam** is currently working on the geometric calibration and on creating a simulation of the calibration target traveling in a provided trajectory. He has created a pipeline for image creation using blender.

4 FUTURE PLANS

The plan ahead is to investigate the effect of vignetting and bayer pattern on the read and shot noise. I plan to split the color channels of the image and repeat the above experiment. I will also be working on the PRNU measurement and on the aspects of integrating our project.