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# INDIVIDUAL LAB REPORT 7

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# 1 INDIVIDUAL CONTRIBUTION

## 1.1 DETAILED PLAN FOR MEASUREMENT OF NOISE

Based on the literature study I performed on the investigation of all the possible forms of noise which can degrade the image quality, I created a test plan for the measurement of noise. The test plan for each of the different types of noise is explained in the further sections.

## TYPES OF SENSOR NOISE

- SHOT NOISE
- READ NOISE
- THERMAL NOISE
- PIXEL RESPONSE NON UNIFORMITY

## MEASUREMENT OF NOISE

### TEST PLAN TO MEASURE SHOT NOISE AND READ NOISE

1. Take a set of 100 exposure values to consider $[E_1, E_2, .E_{100}]$ .
2. For each exposure value $E_i$ :
   (a) Take two consecutive images of uniform light using the integrating sphere.
   (b) Subtract two consecutive frames to cancel out the effects of thermal noise and PRNU.
   (c) Calculate the standard deviation of the noise(standard deviation of all the pixel values) from the resulting image.
   (d) As independent noise sources adds up in quadrature,

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

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

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

   (e) This would give us a datapoint $\{E_i, \sigma(N_i)\}$
3. Repeat steps above for all the exposure values to get 100 datapoints. The expected graph must look like figure 1.

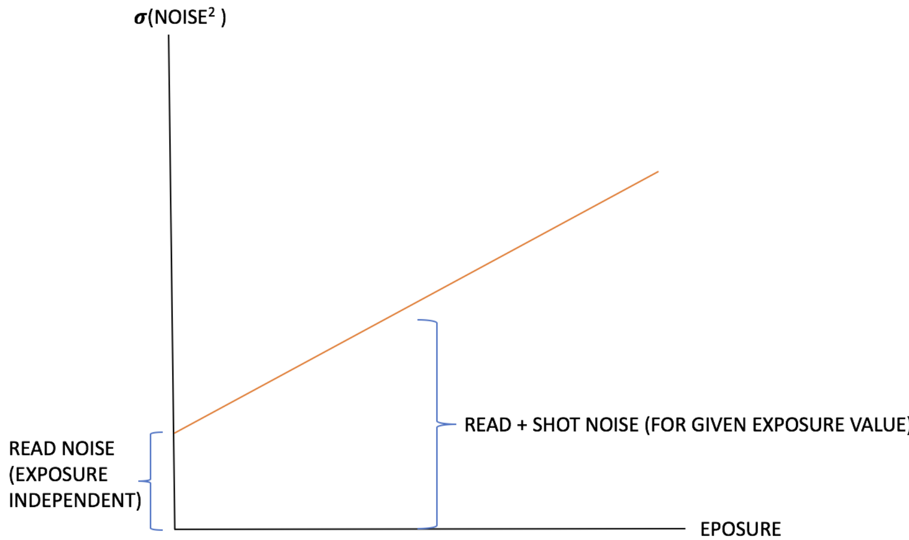


Figure 1: $EXPOSURE$ vs $\sigma(NOISE^2)$

An illustrative visualization of the measurement of read and shot noise can be seen in figure 2.

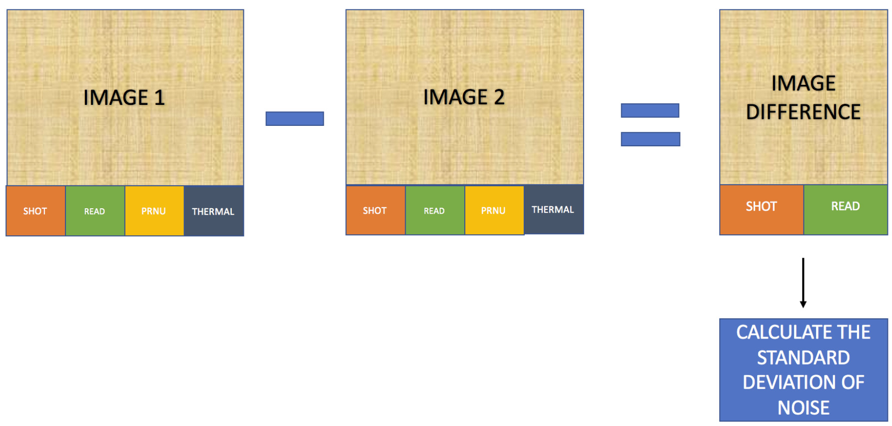


Figure 2: CALCULATING THE READ AND SHOT NOISE

## TEST PLAN TO MEASURE PIXEL RESPONSE NON UNIFORMITY

1. Take a set of 100 exposure values to consider $[E_1, E_2, .E_{100}]$ .
2. For each exposure value $E_i$ :
   (a) Take an images of uniform light using the integrating sphere.
   (b) subtract a dark frame from the image at that exposure value.
   (c) subtract in quadrature, the read and shot noise already calculated at this exposure.

$$\sigma(N_{total})^2 = \sigma(N_{read})^2 + \sigma(N_{shot})^2 + \sigma(N_{PRNU})^2$$

$$\sigma(N_{PRNU}) = \sigma(N_{total})^2 - (\sigma(N_{read})^2 + \sigma(N_{shot})^2)$$

   (d) This would give us a datapoint $\{E_i, \sigma(N_{PRNUi})\}$

3. Repeat steps above for all the exposure values to get 100 datapoints. The expected graph must look like figure 3.

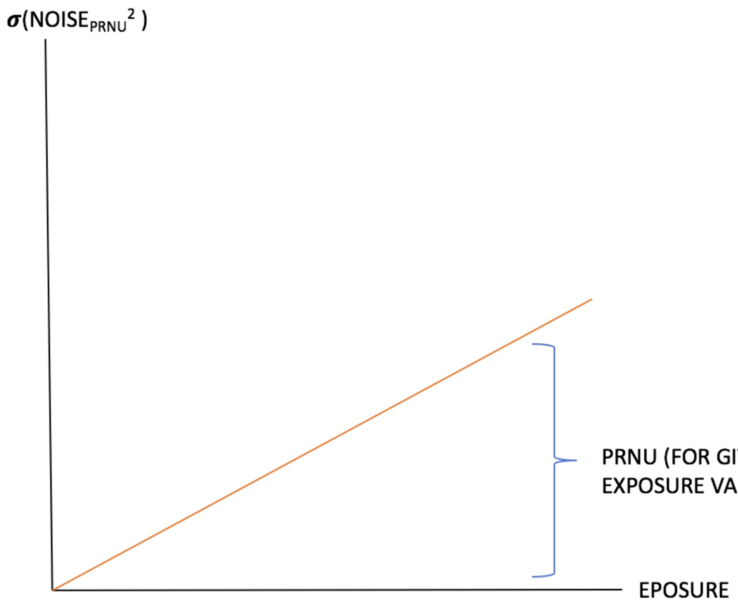


Figure 3: $EXPOSURE$ vs $\sigma(NOISE^2)$

An illustrative visualization of calculating PRNU can be seen in figure 4.

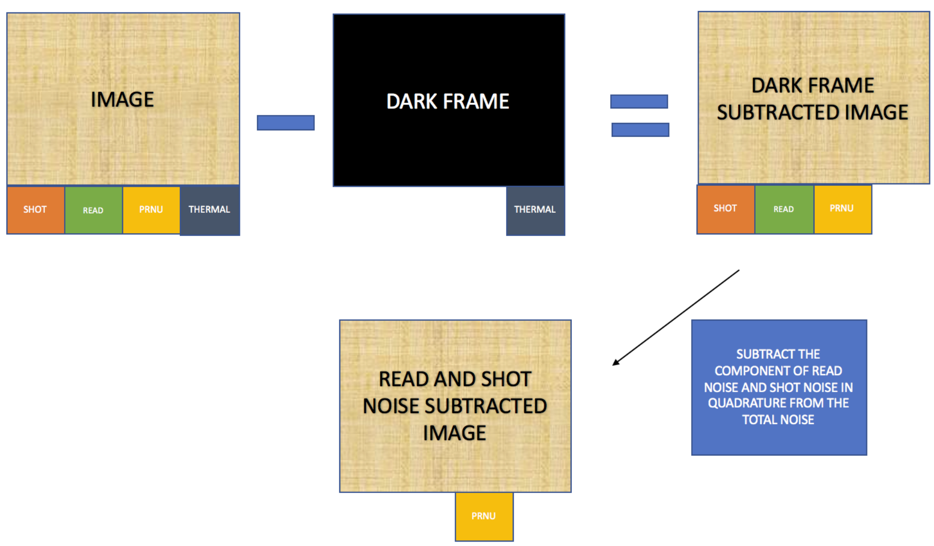


Figure 4: CALCULATING THE PIXEL RESPONSE NON UNIFORMITY

**THERMAL NOISE**

1. Take a set of 100 exposure values to consider $[E_1, E_2, .E_{100}]$ .
2. For each exposure value $E_i$ :
   (a) Take images by covering the camera lens.
   (b) This would give us a datapoint $\{E_i, \sigma(N_{THERMALi})\}$
3. Repeat steps above for all the exposure values to get 100 datapoints. The expected graph must look like figure 5.

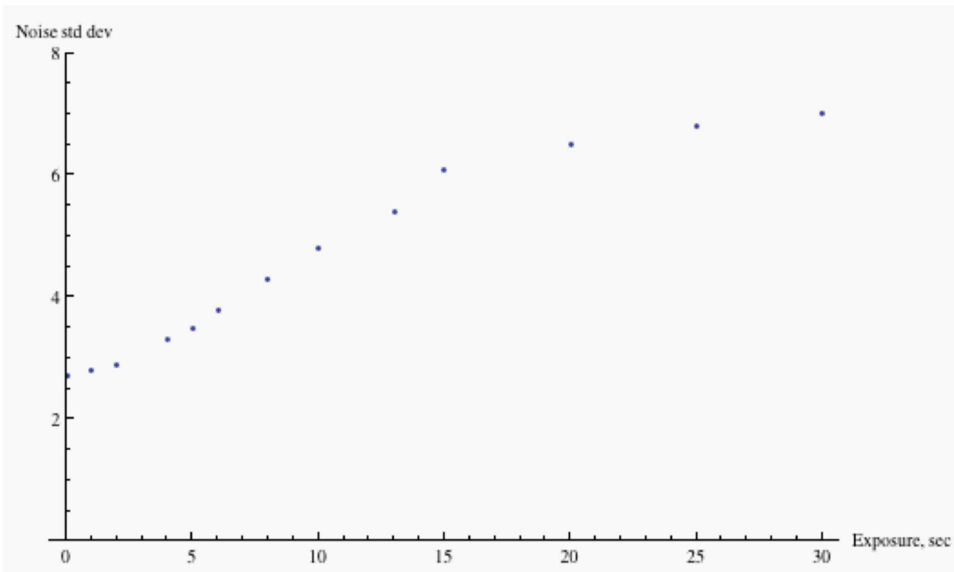


Figure 5: THERMAL NOISE
**Reference:** http://theory.uchicago.edu/ ejm/pix/20d/tests/noise/

An illustrative visualization of calculating THERMAL NOISE can be seen in figure 6.

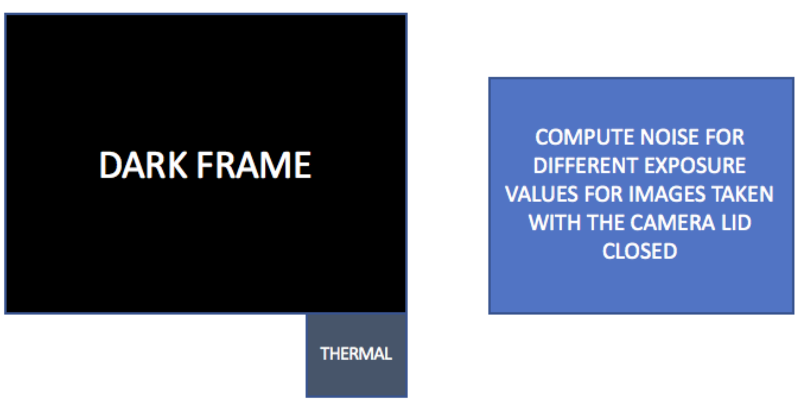


Figure 6: CALCULATING THE THERMAL NOISE

## 2 CHALLENGES

For each of the above test plans, I have to determine the exact set of exposures to be used for measurement. However, prior to this I have to calculate the maximum exposure for which the image does not saturate, as these test results are valid only uptill the image doesn't saturate. For this I would have to conduct an experiment to find out the maximum allowable exposure before the image saturates.

## 3 TEAMWORK

1. **ABB ROBOT MODELLING AND SIMULATION: Peter** is currently working on the ABB robot arm modeling and simulation. He is importing points to a configuration space and creating collision free paths for the ABB robotic arm.

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. Initially, she planned on using the Macduff Algorithm, but due to its disadvantages of not being detected if the color checkerboard is not a significant portion of the captured image, she is going forward with the CCFind Algorithm.

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 is calculating projections of the calibration target(on uniformly sampled points from the trajectory of the robot arm) from the field of view of 4 cameras. The projections which are redundant in all the camera frames are being removed.

4. **IMAGE RENDERING: Sam** is currently working on creating a simulation of the calibration target traveling in a provided trajectory. This would simulate the real motion of the calibration target and can be used to implement the geometric calibration on it.

## 4 FUTURE PLANS

The plan ahead is to use the test plan created to measure and if possible eliminate all the different types of noise listed above. I am going to use an integrating (calibrating) sphere which will give me precise information about the amount of light entering the camera and enable me to accurately calculate the amount of sensor noise being introduced in the captured images. I will measure the amount of noise and create plots for each noise type. I will then compare the characteristics of the plots obtained by me with the expected graphs in this ILR.