# Progress Review 8

## Individual Lab Report 7

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**Team E:**

Wholesome Robotics

**Teammates:**

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# Individual Progress

## Capstone Project

Team E is creating an organic monitoring robot which has to autonomously navigate through crop rows. For this phase of the project, I had two main tasks which can be summarized as follows:

1) Understand and develop a method to tackle the issue of under-exposure and over-exposure in images being captured as the robot traverses a row.

2) As the initial designer behind the software architecture for the plant health visualizer, I had to facilitate the integration of the GPS-Image association parser code with the Mask R-CNN detection and Matplotlib visualizer pipeline.

### Over-Exposed and Under-Exposed images

**Understanding the problem**

While processing the ROS Bags collected from our first field visit in September 2018, we realized that a good portion of images were severely under-exposed or over-exposed. This led to the images being unusable for the deep-learning network training process. Out of 26 ROS Bags, 2 ROS bags (2 rows of crops) were rendered totally unusable because of this issue. Hence, a mandatory requirement which stated that 75% of the images captured during a field run should be usable images. My task was to understand the scale of this problem and investigate ways to mitigate the under-exposure and over-exposure in images.

**Methodology and key steps**

The requirements for satisfying this work package can be summarized as follows:

1) Develop an image acceptance script to classify images as under-exposed, over-exposed or normal images. The results from this script will be discussed in the **Results** section.

2) Design strategies which change exposure of the camera in order to capture maximum information from the image. The methods used in this case can differ depending on the sensor used. These strategies will be discussed in detail in the **Proposed Solutions** section.

**General Concepts**

Before starting off on designing strategies, the initial steps were to get a general understanding of computational photography principles and how they would apply for our given camera. Some key concepts relevant to the camera have been summarized as follows:

1) **Exposure**- This is an important indicator of the image’s quality and generally refers to the brightness of an image. This value is generally controlled by the following three settings.

2) **Aperture**- This indicates the diameter of the opening of the lens. For the custom stereo camera in FRC, the aperture can be mechanically controlled. However, there is no software triggered method to change the aperture.

3) **Shutter Time**- This indicates the amount of the time the sensor is open/ exposed to light. More the shutter speed (less the shutter time), less is the amount of light hitting on the camera sensor. For our stereo camera, this was the **only parameter** which can be controlled using software.

4) **ISO-** This can be defined as the amplification of the electronic signal from the camera. Increasing ISO can increasing brightness, however, it generally amplifies noise as well. Hence, for our camera, this parameter was supposed to be kept fixed.

### Potential solutions

From the initial research, the following potential solutions were considered during the initial planning stage. The key principle was to change the camera exposure depending on geometric/ semantic information relating to the foliage present in the scene. The methods considered can be listed down as follows:

1) Depth-based methods- These methods aim to estimate the depth between the camera and the foliage. This can be done as follows:

    a. Use a fast stereo-disparity method from the custom camera to get an estimate of the depth. However, as the camera is also capturing image information, the robot will have to stop, adjust its exposure, take a good image and then move ahead.

    b. Use a Multi-Sense camera mounted on top of the custom stereo camera in order to estimate depth.

2) Gradient-based methods- This approach aims to adjust the camera exposure in such a way as to increase the gradient information in the image. Most of the deep-network (CNN-based) pipelines find edge information in the initial layers. Hence, increasing gradient information can potentially result in better detection results [1].

### Image acceptance script and results

The first step of the process was to develop the image acceptance script. This script aims to differentiate between images which are under-exposed, over-exposed and normal. As exposure basically leads to change in the intensity levels of pixels, a simple method of analyzing the histogram of images was utilized. The histograms for over-exposed images are shifted to the right (as shown in Figure 1b) and histograms for under-exposed images (as shown in Figure 1c) are shifted to the left.

However, Figure 1a and 1d are both for normal images. Figure 1d can be easily confused to be an under-exposed image. Hence, these edge cases need to be dealt with when setting thresholds for the histograms. Further evaluation of the thresholds will be done after a new ROS Bag of images is collected during a recent field visit.

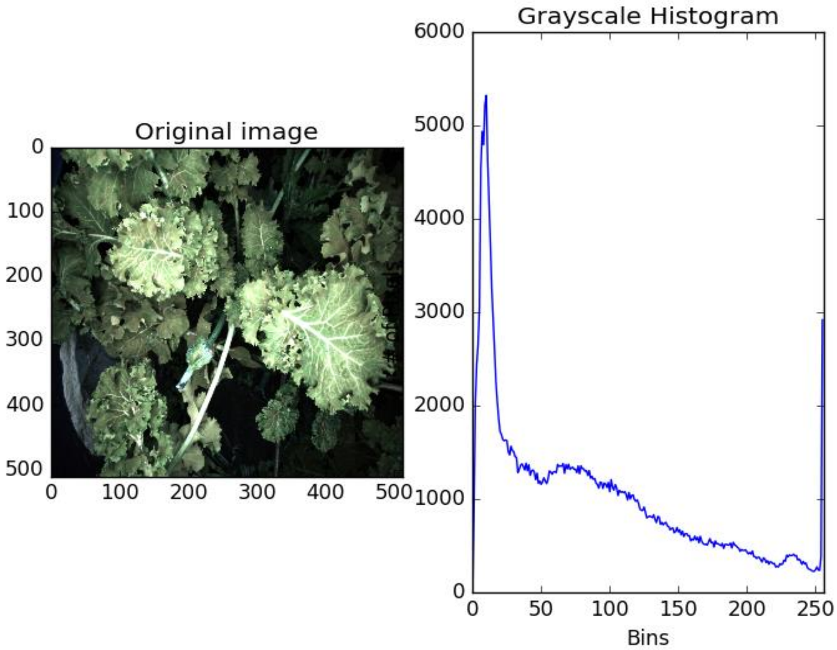


*Figure 1 (a): Histogram for a normal image*

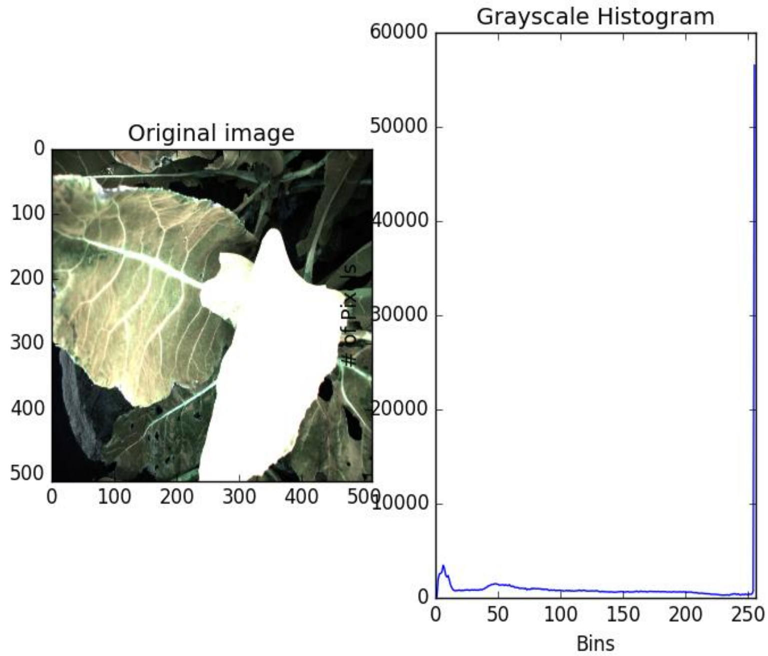


*Figure 1 (b): Histogram for an over-exposed image*

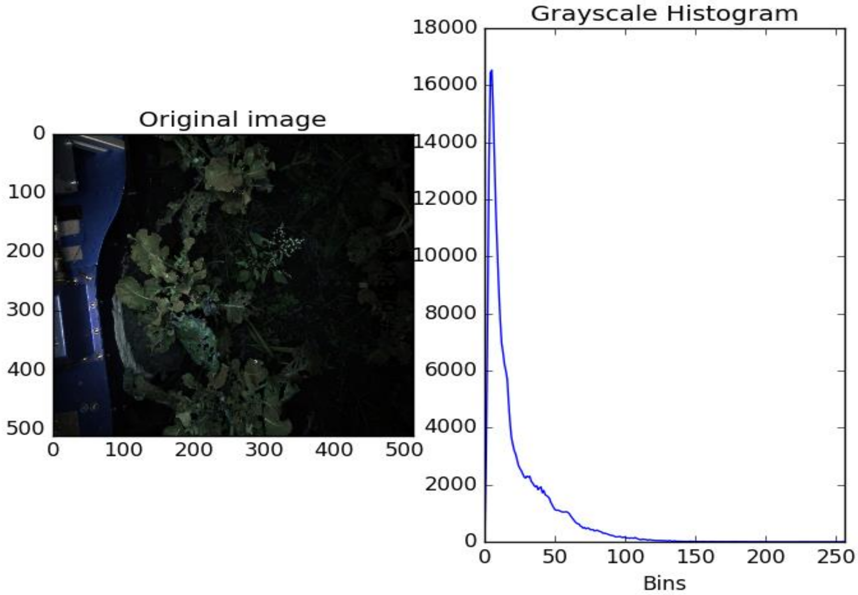


*Figure 1 (c): Histogram for an under-exposed image*

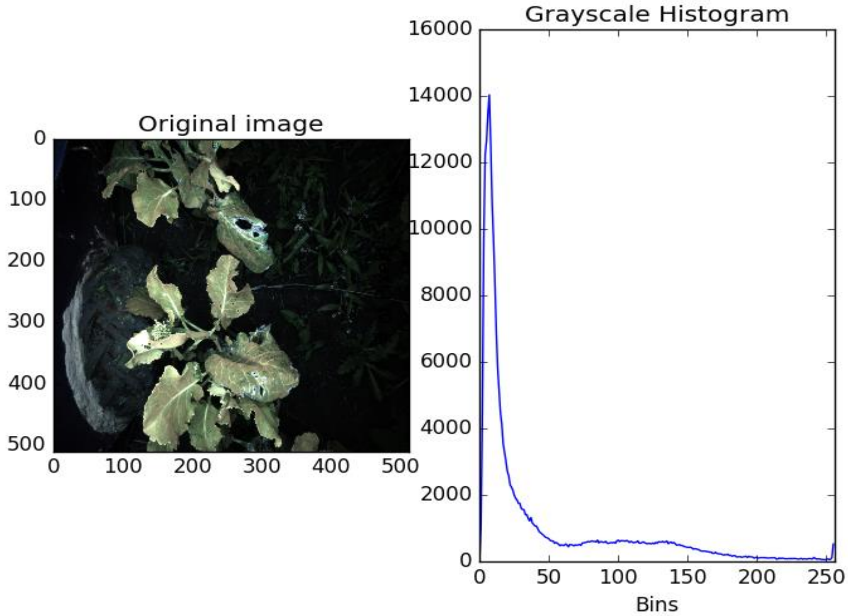


*Figure 1 (d): Edge case for a normal image*

## Latest Developments

In order to understand the scale of the problem, I sifted through 60k images from 26 ROS Bags from previous visits to find under-exposed and over-exposed images. The first version of the image acceptance script has been made using the data.

However, during our last field visit, we realized that some assumption made about the exposure problem from the September 2018 field visit need to be changed.

1) The plant layout has changed with the height of most of the plants being uniform and plant height remaining almost constant. Hence, fixed heights for the camera should be able to mitigate the exposure problem.

Hence, the conclusion is that exposure handling may not be as big of an issue as thought before due to the changes in the farm layout. The development efforts on auto-exposure side have been paused till new data is collected. Version 2 of the image acceptance script will be continued.

### Integration of the plant health visualizer tool

During the last progress review, the GPS-Image association parser as well as the MatplotLib visualizer were decoupled and working separately. The plant health detection pipeline based on the Mask-RCNN network had not been integrated into the visualizer. As a part of the system design process, I made sure that the correct interfaces for plugging in different parts of the pipeline exist. Hence, this process was made easy and I had to play a minor role in facilitating the integration task. This step involved active collaboration with Dung-Han Lee and Hillel.

## Challenges

The key challenges faced during this progress review include lack of information on the scale of the Exposure handling problem and software conflicts between different versions of the code for the integration process.

The exposure handing problem seemed like a considerable challenge when we started off with the sprint for this Progress review. Initial development effort and research was done in order to develop methods to solve this issue. However, after the recent field visit, the problem scale does not seem so large. Even though it was great researching and reading about computational photography principles, this time could have been spent in working on other aspects of the system.

The integration task for the plant health visualizer tool had issues with code integration as there were three people separately developing the code. Hence, it took multiple discussions from the involved members in order to reach a consensus. However, even after multiple discussions, we faced software compatibility issues at the end of the development. The plant health detection pipeline based on the Mask R-CNN used Python3, while the ROS based tools require Python2. Hence, the initial design of tightly integrating the whole system in one Python file was not possible. These issue will be dealt in the next iteration of the process. .

## Teamwork

### John Macdonald

John worked on creating an RTK GPS based node to perform in-field localization. He also did some initial work on performing IMU compensation to reduce the lateral drift in the current localization efforts.

### Aman Agarwal

Aman worked on completing the cleaning up process for the controls and planning code and integrating the code with the RTK GPS navigation node written by John.

### Hillel Hochsztein

Hillel worked on scaling the GPS coordinates onto image pixel level for the Matplotlib visualizer. He was involved with the process of debugging and fixing the hardware after the recent sparks issue in the field visit. He took the lead in collecting actionable feedback from the farmers during our field visit to add new features to the plant health visualizer.

### Dung-Han Lee

Dung-Han Lee worked iterated on the Mask-RCNN based detection pipeline in order to find the best metrics to quantify disease and pest in leaves. He also coordinated with Hillel and me for integrating the plant health visualizer with the detection pipeline.

## Future Plans

### Team

The future team goals for the upcoming weeks can be summarized as follows:

1) Testing the navigation pipeline with RTK GPS and the first version of the Map builder.
2) Version 2 of the Plant health visualizer pipeline with added features from suggestions from the farmer.
3) Add first version of the plant guards in order to brush off plants from the Robotanist.
4) Investigating methods to improve the accuracy of the deep learning pipeline. These include improving the estimate of depth accuracy from the stereo images to provide better methods to compare leaf areas and diseased area. End-to-end binary classification techniques will be explored.

### Individual

The future individual tasks which are planned for the coming weeks can be summarized as follows:

1) Work on improved depth estimation methods using stereo images for foliage extent estimation.
2) Integration of the ROS Bag visualizer for multiple rows of the field.
3) Adding new features into the plant health visualizer pipeline. These include clustering of multiple GPS points, tagging data according to rows, and support for multiple rows. This could involve restructuring the core data-structures at the heart of the visualizer pipeline.

## References

[1] I. Shim, T. Oh, J. Lee, J. Choi, D. Choi and I. S. Kweon, "Gradient-Based Camera Exposure Control for Outdoor Mobile Platforms," in *IEEE Transactions on Circuits and Systems for Video Technology*, vol. 29, no. 6, pp. 1569-1583, June 2019.doi: 10.1109/TCSVT.2018.2846292