Image Processing for a Point-of-Use Soil Health Assay

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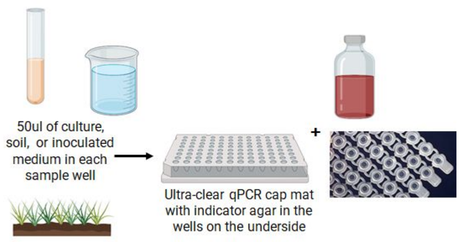
Abstract

This research provides real-time monitoring of soil health through the improvement of in-field soil health assays. This is accomplished through analyzing colorimetric assays that use pH cresol red to measure the CO_2 produced by microbial respiration from prospective soil samples in PCR tubes. We are building an iOS application that processes assay images, analyzes the data, and gives informative feedback on soil health, making it accessible to all via smartphone.

Introduction

- With population rates increasing and growing demands to provide food and energy crops to more people in sustainable ways, soil health has become a priority in solving these challenges
- Microbial Respiration, a biological indicator, is effective in determining soil health
- Comprehensive soil analyses are often limited to expensive laboratory equipment

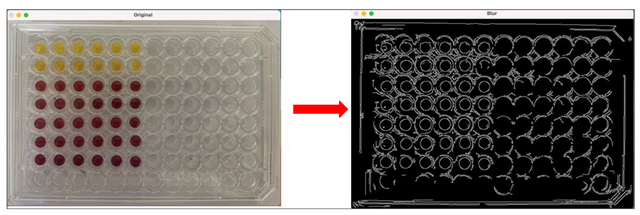
- We propose a solution with an inexpensive kit that measures soil health effectively



The Chakraborty Lab has previously developed an in-field assay to measure microbial activity by means of CO2 mineralization. The assay allows growers to add a small amount of soil into wells in a plate, and CO2 mineralization is measured via color change using cresol red indicator agar.

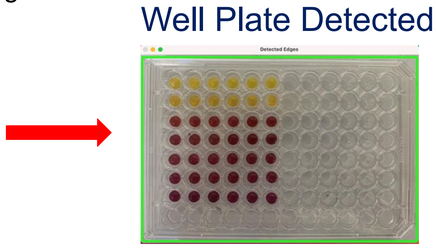
Methods: Object Detection

Sample Image → Blurred Image with Contours



To detect the location of the 96-well plate in an image, the Blur function and cv2.Canny function were used to expose image contour lines.

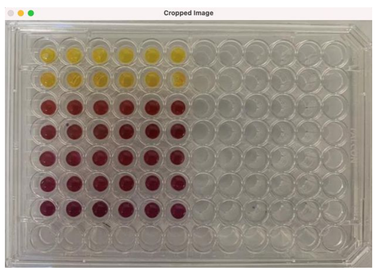
Well Plate Detected



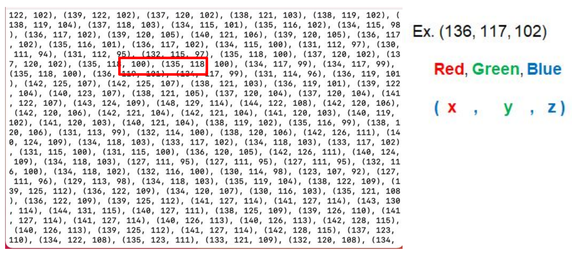
cv2.Rectangle function used to detect edges of well plate

Methods: Accessing Image Pixel Arrays / Data

Cropped and Resized Image



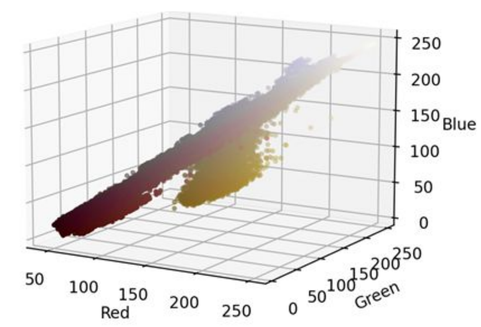
Pixel Arrays and Data Exposed



The cropped and resized sample image (top left) was converted into image pixel arrays using a NumPy array function (top right). These arrays came in groups of three numbers each representing its red, green, and blue color content and combination per pixel. These groups can also represent an x, y, and z coordinate system.

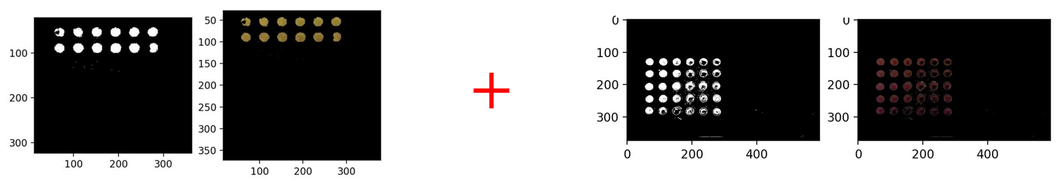
Results

3D Scatter Plot of RGB Pixel Decimal Values

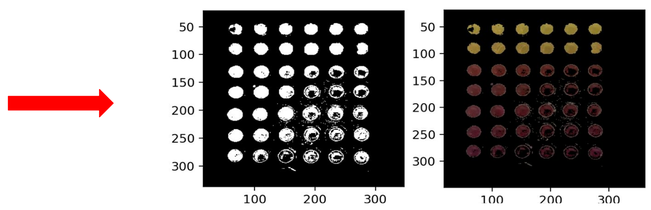


3D Scatter Plot of red, green, and blue decimal values from the sample image pixels. Sample image pixels were converted to numerical data and plotted to obtain pixel color averages and standard deviations.

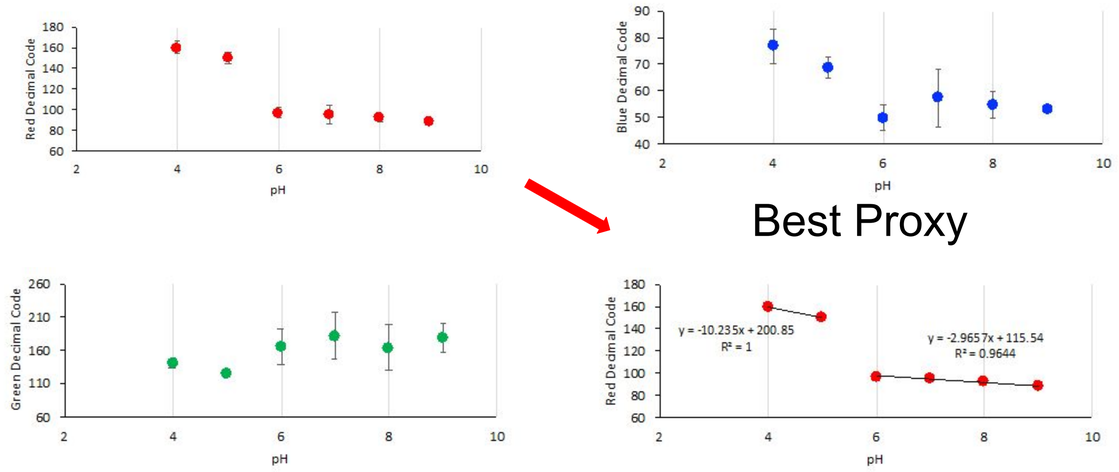
Yellow Mask + Red Mask



Sample Image Processed: Both Masks Combined



Standard Curves for RGB Channels



Standard curves for each of the red (R), green (G), and blue (B) color channels calculated from our test image. Each marker represents the mean of six experimental replicates. The error bars indicate one standard deviation of the six replicates. We determined that the red color channel is the best proxy for measuring CO2 mineralization due to the high R-squared value of the linear fits. However, there is missing information between pH 5 and 6, for which we need further analysis.

Future Work

- Test more 96-well plate images to increase accuracy in image processing and standard curve calculation.
- Future plates tested will include more values between pH 5 and 6 (e.g. 5.2, 5.4) to create an accurate standard curve between these values.

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