Monitoring strawberry plant wetness using color imaging and Artificial Intelligence for the Strawberry Advisory System (SAS)

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Summary

During the 2023-24 season, we developed a Time-of-Day classification model based on observed patterns of water droplet sizes, illumination conditions, brightness levels, and weather conditions from the acquired images. The model classified the images into five categories: blue, blurry, cloudy, day, and night. Then, these images of different categories were independently trained using artificial intelligence-based wetness detectors. A higher-resolution camera was employed for testing in a new location, Plant City, FL. The Time-of-Day classification and the higher resolution camera improved the overall detection accuracy. An overall accuracy of 95.8% was achieved for wetness detection. The new higher-resolution camera and Time-of-Day classification will be employed in the 2024-25 season.

Hardware Description

During the 2023-24 strawberry growing season, a higher-resolution camera (Raspberry Pi Camera Module 3, Raspberry Pi Foundation, Cambridge, UK) was employed and used to set up a new in-field wetness detection system in Fancy Farms, Plant City, FL. Figure 1 shows the new system.

The new camera acquired images of 4608 x 2592 pixels, whereas the other cameras (WYZE v2 color camera) had a resolution of 1920 x 720 pixels which were installed at the previous three locations, including (1) the Plant Science Research and Education Unit (PSREU), University of Florida (UF) in Citra, Florida, (2) Gulf Coast Research and Education Center (GCREC), UF, Wimauma, Florida, and (3) Florida Strawberry Growers Association Office, Dover, Florida.

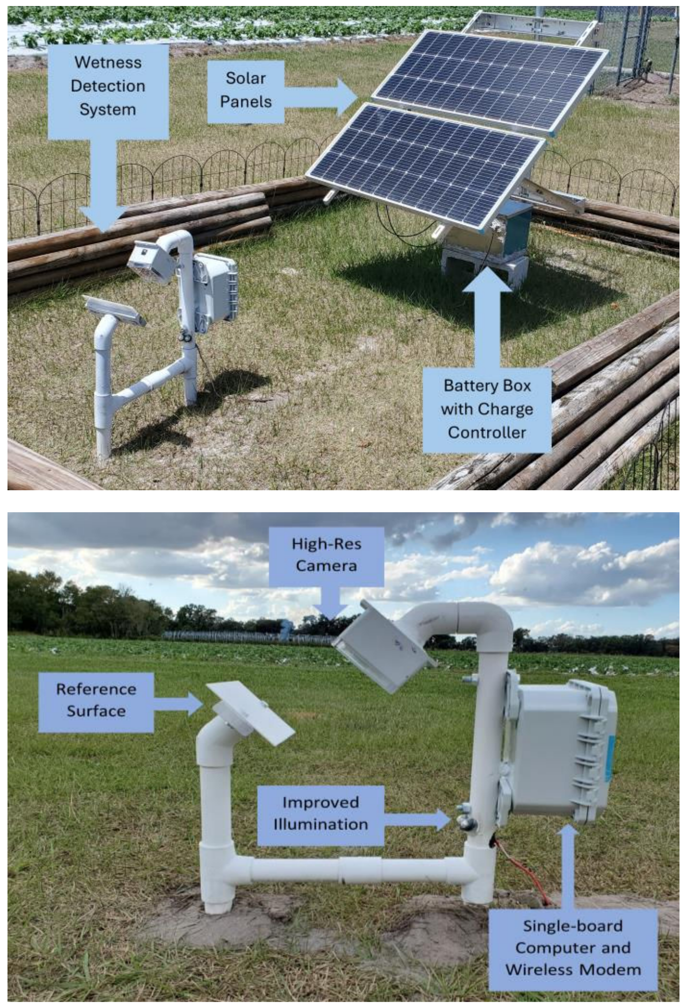


Figure 1. Wetness detection system installed at Fancy Farms, Plant City, FL.

These systems consisted of the following hardware components: a reference surface, a color camera, a single-board computer, a wireless cellular modem, and artificial illumination. The details of these components can be found in the 2022-23 report.

Figure 2 shows the system block diagram, providing an overview of the hardware components and their interconnections.

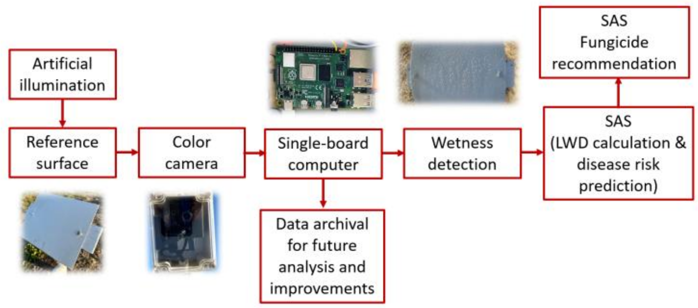


Figure 2. Wetness detection system block diagram.

Methods

The image data were collected from May 2023 to April 2024 at UF PSREU, GCREC, and Dover locations.

In October 2023, a new system with a new higher resolution camera (details below) was developed and installed at a commercial strawberry field (Fancy Farms) in Plant City, FL.

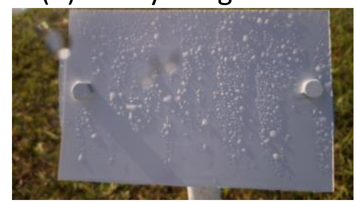
To improve the resolution of the images and facilitate the detection of droplets of smaller sizes, a switch to a high-definition camera was made. A Raspberry Pi Camera Module 3 (Raspberry Pi Foundation, Cambridge, UK) was used in the new system that took images at a resolution of 4608 × 2592 pixels, whereas the previous camera (Wyze Web camera v2, Wyze Labs, Seattle, WA, USA) only took images of resolution 1920 × 720 pixels. This huge improvement in the resolution enabled a better observation of smaller water droplets on the reference plate.

The entire dataset consisted of images of a wide variety of illumination conditions, droplet sizes, brightness levels, clarity levels, and weather conditions. The droplet appearances in all of these classes varied greatly. Using a single model to learn the features in all the conditions might not be the optimal solution. Hence, we implemented the Time-of-Day classifier, which first classified the images into five categories: Blue, Blurry, Cloudy, Day, and Night. Figure 3 shows examples of these categories. The training set for this model training included 9,429 images, and the test set included 944 images.


(a) Blue image


(b) Blurry image


(c) Cloudy image


(d) Day image

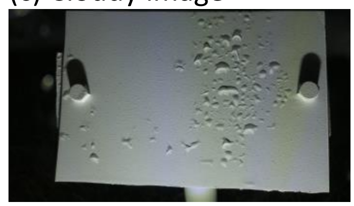

(e) Night image

Figure 3. Example images for the Time-of-Day classification.

After the Time-of-Day classification, wetness classification was conducted with a training set of 2,784 images, a validation set of 280 images, and a test set of 310 images. The wetness detection model was evaluated using detection accuracy.

Results

The model trained on the Time-of-Day classification outputted the following results: the training accuracy was 95.3%, the validation accuracy was 92.9%, and the test accuracy was 92.0%. The model excelled at classifying the Cloudy, Day, and Night class images. However, the model needs improvement in the Blue and Blurry classes.

Combining all the trained models into one algorithm, the overall result was calculated on a test set of 8,896 images, as shown in Table 1. The overall accuracy for the manual labels was 95.8%, and when compared to SAS data, it was 83.8%.

From these results, it can be concluded that there was a significant improvement in the model performance compared to the one presented by Patel et al. (2022). The new algorithm performed well, resulting in a correlation of 95.8% when compared to manual observations. This correlation dropped to 83.8% when compared to the SAS data, although the correlation between SAS data and the manual observations was 90.3%.

Upon careful inspection of the data from all three sources, the LWD (or wetness durations) in the Imaging System predictions and the manual observations was lower than that from the SAS data. The wetness durations were shorter in the Imaging System predictions, meaning the system was detecting wetness with a higher threshold.

Table 1. Accuracy scores of the overall algorithm.

Comparison	Accuracy Scores
Number of images	8,896
Manual observation vs. Image detection system	95.8%
Manual observation vs. SAS	90.3%
Image detection system vs. SAS	83.8%

Takeaways

- This study presented a significant advancement in precision agriculture with the development of a highly accurate leaf wetness detection system using high-resolution imaging and deep learning.
- An innovative divide-and-conquer approach was introduced that classified images based on different times of the day and weather conditions.
- The system achieved an overall accuracy of 95.8%, demonstrating its efficacy in detecting leaf wetness with high precision. The implementation of this advanced detection system within the SAS may improve decisions about fungicide applications and improve strawberry yield and profit.

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