Monitoring Strawberry Plant Wetness Using Color Imaging and Artificial Intelligence for the Strawberry Advisory System (SAS)

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Summary

This project aimed to develop an automated system to provide real-time wetness detection in strawberry fields replacing conventional leaf wetness sensors, aiding in disease management. This system utilized a camera, reference panel, and a single-board computer to capture images of the reference panel and analyze them using artificial intelligence.

Hardware Description

During the 2022-23 strawberry growing season, two new in-field wetness detection systems were set up in addition to the one at the University of Florida (UF) Plant Science Research and Education Unit (PSREU) in Citra, FL. These were located at the Florida Strawberry Growers Association office in Dover, FL, and the UF Gulf Coast Research and Education Center (GCREC) in Wimauma, FL. These systems consisted of the following hardware components:

1. *Reference surface:* An acrylic sheet painted with flat white paint served as the reference surface.
2. *Color camera:* A WYZE v2 color camera, featuring a resolution of 1920 x 1080 pixels, was employed, facing the reference surface to ensure optimal color image acquisition.
3. *Single-board computer:* Raspberry Pi 4 (Raspberry Pi Foundation, Cambridge, UK) was utilized as the central processing unit for the system. The Raspberry Pi received the images directly from the camera and ran the image analysis software, processed the captured images, and performed wetness detection using a deep learning model.
4. *Wireless connectivity:* The Raspberry Pi was linked to a Verizon MiFi 4G wireless cellular modem, which enabled the transfer of images to Google Drive, where they were accessed for further analysis.
5. *Artificial illumination:* An LED, controlled by the Raspberry Pi, was used to facilitate image capturing at nighttime.
6. *System setup:* Figures 1, 2, and 3 depict the physical arrangement of the wetness detection systems at Citra, Dover, and GCREC, respectively.

Figure 4 shows the system block diagram, providing an overview of the hardware components and their interconnections.

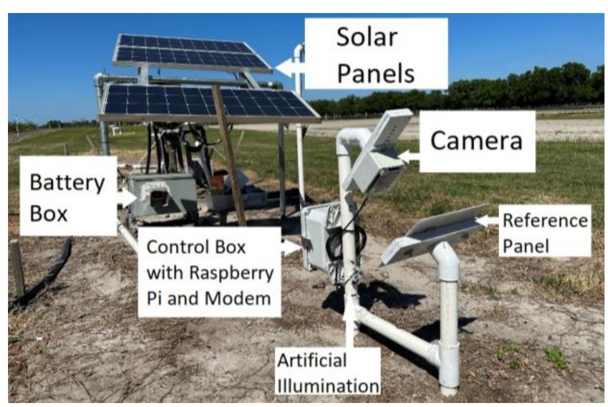

Figure 1. Wetness detection system at UF PSREU, Citra, FL.

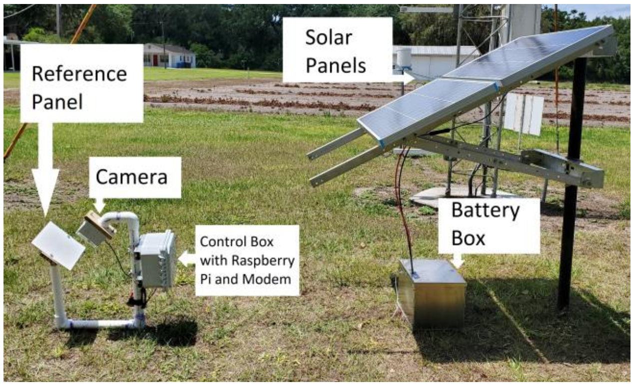

Figure 2. Wetness detection system at Florida AG Research, Dover, FL.

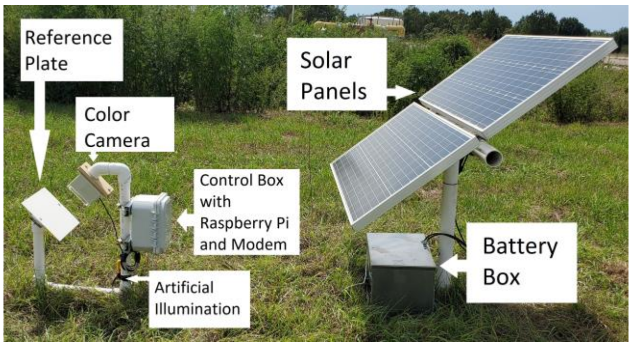

Figure 3. Wetness detection system at UF GCREC, Wimauma, FL.

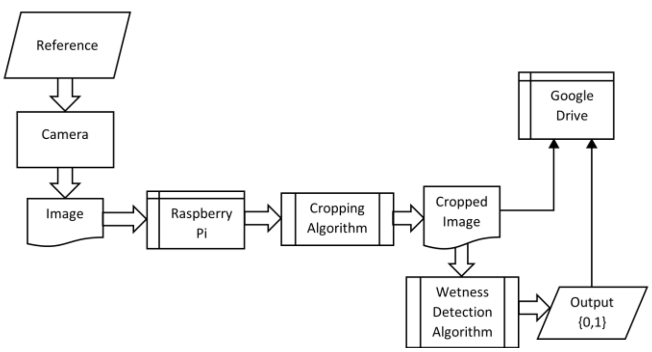

Figure 4. System block diagram.

Methods

The data were collected from January 2023 to June 2023 at UF PSREU and from April 2023 to June 2023 at UF GCREC and Dover. During this period, all the collected images were manually assigned into wet/dry classes to evaluate the deep learning model. Test set 1, which had images taken at PSREU, had 9,091 images. Test set 2, which had images taken at Dover, had 6,330 images, and Test set 3, from GCREC, had 3,288 images.

The camera images were cropped to the center of the reference panel. These images were pre-processed before sent through a trained deep neural network that outputted "1" for 'wet' or "0" for 'dry' conditions. These images were later cross-checked by manual inspection to determine the accuracy of the deep learning algorithm.

Results

The deep learning method yielded good accuracy when compared with manual observations, as shown in Table 1. Table 2 showcases the accuracy of the model compared to data from the SAS (Strawberry Advisory System). Table 3 shows the comparison between manual observations and the SAS data. Table 4 depicts the Leaf Wetness Duration (LWD) for the three locations.

The model's ability to accurately predict the wetness status is apparent through the high level of accuracy shown in Table 1. This suggests that the automated system can provide consistent and accurate wetness assessments, allowing the system to replace the current wetness sensors.

Some of the reasons that hindered higher accuracies include a temporary LED malfunction at Citra which reduced nighttime prediction accuracy. In Dover, dust accumulation on the reference panel caused false wet predictions at night. Challenging ambient lighting at GCREC led to difficulties in manual inspections and system predictions, resulting in some instances of misclassified dry conditions.

The wetness detection system has the potential for expansion across various Florida locations for optimizing disease risk prediction and enhancing strawberry production practices. It enables the measurement of leaf wetness duration (LWD), a crucial parameter for predicting strawberry disease risks. Integrating these results into SAS improves strawberry disease management.

Table 1. Results from the wetness detection system for the test set images, when compared with manual observations.

	Test set 1 at PSREU	***Test set 2 at Dover***	***Test set 3 at GCREC***	***Overall Acc.***
Accuracy	0.916	0.900	0.895	0.907

Table 2. Results from the wetness detection system for the test set images, when compared with the SAS data.

	Test set 1 at PSREU	*Test set 2 at Dover*	*Test set 3 at GCREC*	*Overall Acc.*
Accuracy	0.894	0.836	0.798	0.857

Table 3. Results from the SAS data, when compared with the manual observations.

	Test set 1 at PSREU	*Test set 2 at Dover*	*Test set 3 at GCREC*	*Overall Acc.*
Accuracy	0.895	0.756	0.760	0.824

Table 4. Average Leaf Wetness Duration (LWD) values at all three sites from the wetness detection system, manual observations, and SAS data *(in hours)*.

LWD	*Test set 1 at PSREU*	*Test set 2 at Dover*	*Test set 3 at GCREC*	*Overall LWD*
Wetness Detection System	~1.6	~3.4	~1.6	~2.2
Manual	~2.7	~2.5	~2.6	~2.6
SAS	~2	~1.9	~3.1	~2.2

Takeaways

The results obtained from the Wetness Detection System offer the following takeaways:

1. Real-time wetness monitoring: Implementing the automated wetness detection system allows growers to monitor wetness levels in real time

2. Replacing the current wetness sensors: The automated wetness detection system allows for replacing the current wetness sensors, which are difficult to calibrate and maintain. Plant wetness can be easily monitored and integrated with SAS.

3. Integration into disease risk models: By implementing the wetness detection system, growers can improve disease management strategies and enhance disease risk factor calculations.

By incorporating these takeaways into strawberry production, growers can leverage the Wetness Detection System's capabilities to make informed decisions, replace the current wetness sensors, and improve disease management.

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