Monitoring wetness of strawberry plants using color and thermal imaging for the Strawberry Advisory System (SAS)

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Summary

It is crucial to detect leaf wetness to prevent the occurrence of diseases like Botrytis and Anthracnose. This research is done to find a better alternative to widely-used leaf wetness sensors. This study utilized color and thermal cameras to capture images of a wetness sensor. The captured images were analyzed using image processing and computer vision techniques to detect the presence of water on the sensor surface. We compared image processing results with sensor readings. We were able to detect wetness with good accuracy and by replacing a wetness sensor with the camera, we can easily detect plant wetness without the difficulty of calibrating a wetness sensor.

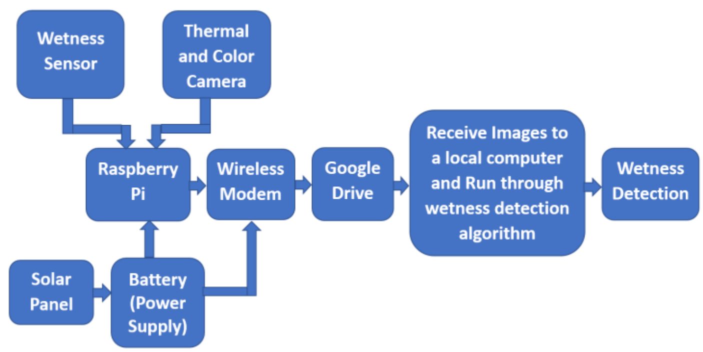

Figure 1. Block diagram of the system.

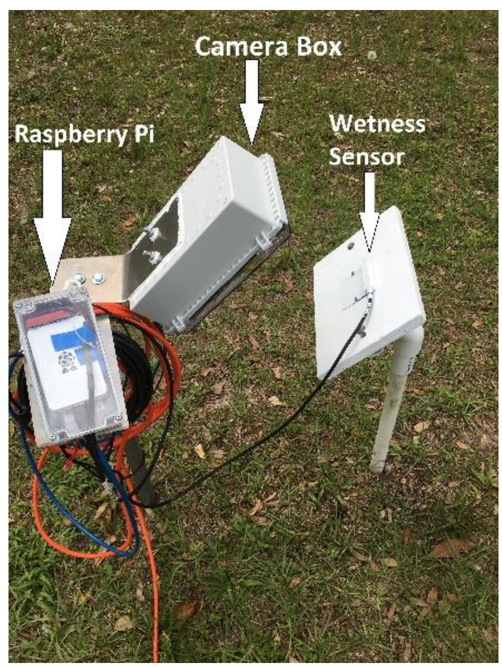

Figure 2. System setup for preliminary outdoor testing.

Hardware Description

We used a FLIR E8 thermal camera which had a resolution of 320 x 240 pixels and Imaging Source DFK 23U618 color camera which had a resolution of 640 x 480 pixels. Both cameras were connected to a microprocessor (Raspberry pi, The Raspberry Pi Foundation, UK) with a USB cable. Raspberry Pi was then connected with a Verizon MiFi 4G wireless modem to upload images to Google Drive. Those images will eventually be downloaded to a local computer for image processing and wetness detection. For plant wetness, we used a Campbell Scientific 237-L leaf wetness sensor to detect wetness. Thermal and color cameras were facing perpendicular to the wetness sensor so that the wetness sensor output could be compared with image processing results. The sensor was connected to the microprocessor via an analog to digital converter (MCP3008 ADC, Microchip Technology, Chandler, AZ).

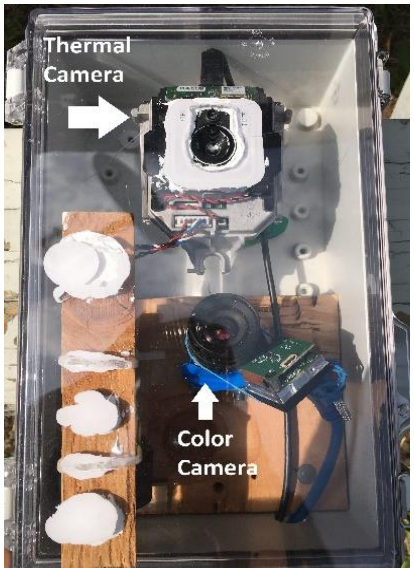

Figure 3. Camera box - thermal and color cameras enclosed in a waterproof box.

Methods

The system was set up indoors for testing, and it showed very promising results. We were able to identify water droplets with high accuracy. Then we set up the system outdoors for preliminary testing. We collected thermal and color images along with sensor data. Images were acquired every five minutes and at the same time also the wetness sensor data was collected. The results from images were compared with the wetness sensor results to check accuracy.

To detect wetness from thermal images, we used image processing and computer vision techniques. The water on the wetness sensor surface had a lower temperature than the surrounding area, so it had a different color in the thermal image as shown in Figure 4. Those wet spots as shown in Fig. 5 were detected using the temperature information.

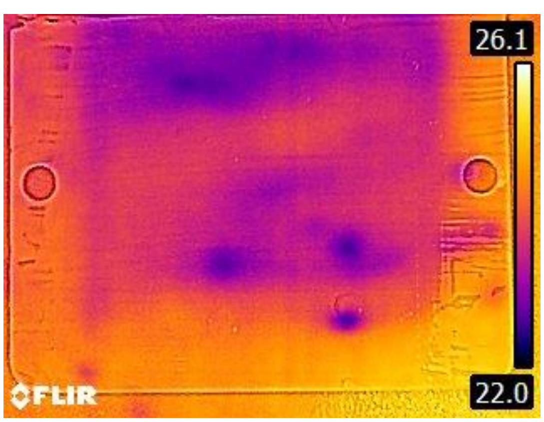

Figure 4. Thermal Image of the wetness sensor.

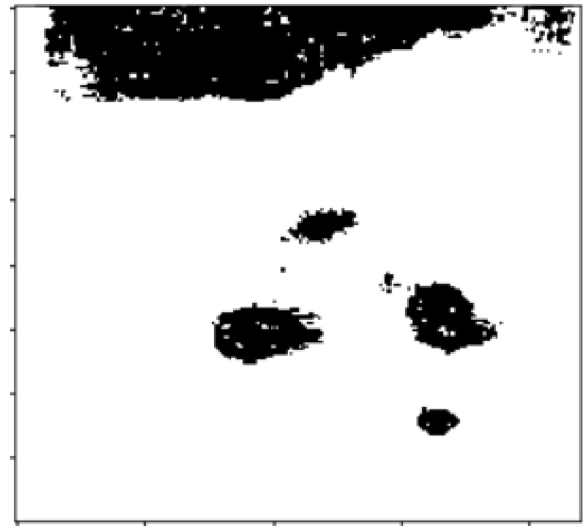

Figure 5. Thermal to binary image conversion. Black spots are water droplets.

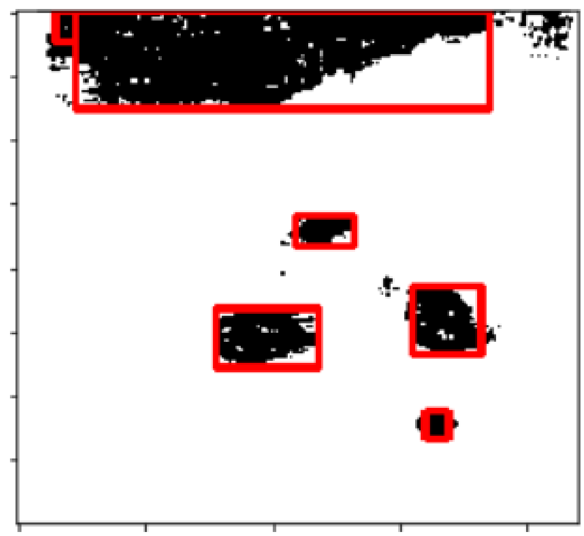

Figure 6. Wet spot detection using computer vision. We measured the area of red squares to get an estimate of the amount of wetness.

In Fig. 6, the areas of wet spots are shown in red squares, which in turn are used for estimating the amount of wetness.

Similarly, wetness can be detected from color images (Fig. 7). We first split the image into red, green, and blue channels. The blue channel provided a better result than other channels, so the blue channel images were converted to binary images.

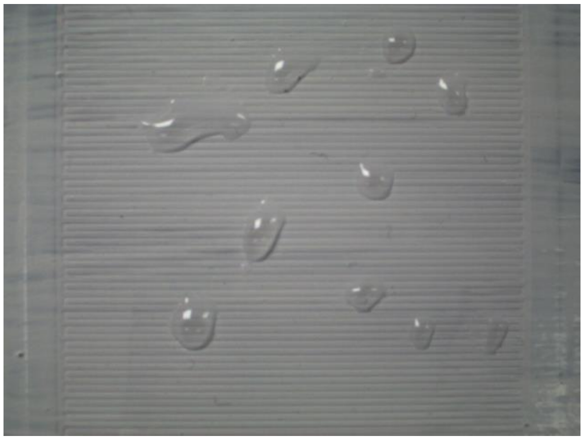

Figure 7. Color image of the wetness sensor.

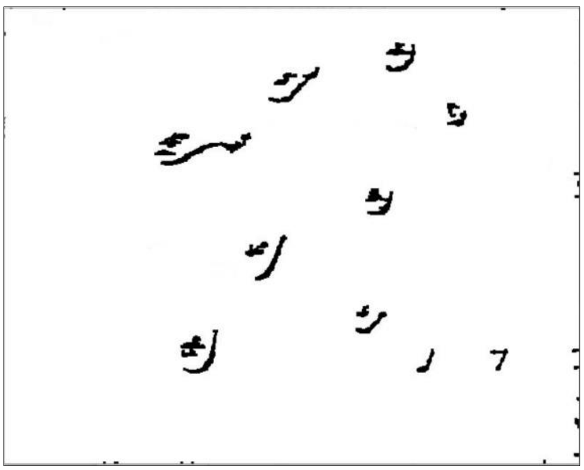

Figure 8. Color to binary image conversion. Black spots are water droplets.

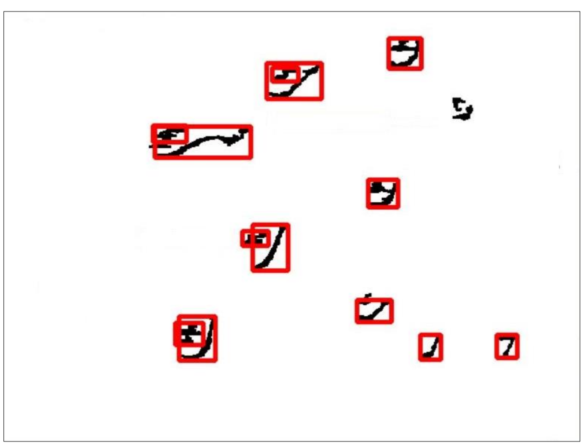

Figure 9. Wet spot detection using computer vision. We measure the area of red squares to get an estimate of the amount of wetness.

Figure 8 shows water droplets detected by the image processing algorithm and Fig. 9 shows area estimation of the droplets, which can be used to estimate the amount of wetness. After estimating the amount of wetness from the thermal and color images, we can decide a wet/dry threshold that can measure whether the wetness sensor is wet or dry. This result can be included in the Strawberry Advisory System (SAS). As this method does not require manual calibration for each sensor, it shows great potential to replace the current wetness sensor used in the Strawberry Advisory System.

Results

Wetness detection from thermal and color image was achieved with good accuracy. One of the main challenges is to take images without any distortion. During the indoor testing, the system worked very well and produced high accuracy. When the system was tested outdoors, the image quality varied which affected the overall accuracy of the system. However, when the image quality was good, we were able to detect wetness precisely. Due to varying illumination during the day, the color camera produced a low-quality image with a fixed iris and also was not able to acquire images at night.

To improve color image quality, we are planning to install an auto iris color camera with night vision capability. While we monitored the wetness sensor to determine wetness in the current study, strawberry plants will be directly monitored and compared with the wetness sensor to determine wetness in future studies.

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