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Mini Review

Design and Implementation of Low-Cost Thermal-RGB Camera for Remote Monitoring Crop

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Abstract

Commercial thermal-RGB camera is very expensive, and is a lack of suitable for periodic remote sensing. This study presents the design and implementation of a low-cost thermal-RGB camera for usage in agriculture crop monitoring applications. It consisted of an open-source single-board computer with thermal and RGB camera modules. The camera could be configured as a webserver to allow real-time data transfer to a client computer. It also could save periodic thermal and RGB data to a local disk. We additionally adopted video synchronization (VSYNC) mode so that video frames could be read out from the Lepton module. Also, power-saving strategies were utilized when the module was idle. Experimental results showed our camera collected remotely sensed images correctly.

Keywords: Lepton 3.5; CWSI; Irrigation scheduling

Introduction

Water is imperative to plant growth, but it is also a finite resource. Thus, irrigation scheduling is one of the major concerns in agriculture. The scheduling approach may be grouped into three main categories [1]: evapotranspiration-based, soil moisture-based, and plant-based irrigation.

The plant-based approach relies on the plant water status. The water status can be measured by the crop water stress index (CWSI) [2,3], which can be calculated by canopy temperature using thermal imagery. The thermal imagery can also indicate crop health [4]. Infrared thermometry-based irrigation scheduling has been shown to be comparable to soil-based irrigation scheduling, especially in terms of crop water use efficiency and crop yield [5].

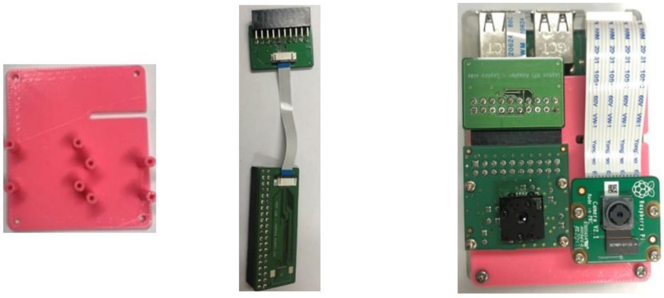
We can measure the canopy temperature of a crop by using a handheld camera or a drone thermal camera. However, the commercial handheld thermal imaging camera is expensive and has the disadvantages of not being able to shoot remotely. The commercial thermal drone camera is also expensive, and it can only be used by people who have a drone control license. Therefore, it is practically difficult for farmers to use such equipment.

Our objective was to design and implement a low-cost dual camera that allows remote monitoring crop by using RGB and thermal camera. The contribution of this study is that it can be used for research using crop growth status through remote sensing.

Thermal-RGB Imaging Camera Design

The imager is comprised of a Raspberry Pi 3 Model B, FLIR Lepton 3.5, and a Raspberry Pi Camera Module V2.1. The Lepton module [6] has an automatic shutter, a resolution of 160 x 120 pixels, and an effective frame rate of 8.7Hz. The radiometric accuracy is ±5° C in high gain mode, and the thermal sensitivity is 0.050° C. The accuracy of measured temperature in high gain mode is ±5 or 5% over a range of -10 to +140° C. The Raspberry Pi Camera Module [7] is based on the Sony IMX219 silicon CMOS backlit sensor and produces 8-megapixel images that are 3280 x 2464 pixels in size. In total, the completed thermal-RGB imager cost just under $500.

To anchor the two camera modules to the Raspberry Pi, a hardware attached on top (HAT) was designed with a 3D printer as shown in (Figure 1(a)). Also, a custom interface board with the pin map shown in table 1 was designed to connect the Lepton 3.5 breakout to Raspberry Pi general purpose input output (GPIO) pins easily, as shown in (Figure 1(b)).



(a) (b) (c)

Figure 1: Customized thermal-RGB camera: (a) Raspberry Pi HAT for two cameras, (b) Custom interface board, (c) Assembled thermal-RGB camera.

Table 1: Pin mapping.

Lepton Breakout Board	SIGNAL Name	Raspberry Pi
J2 Pin 8	SCL	GPIO3
J2 Pin 5	SDA	GPIO2
J2 Pin 12	SPI_MISO	GPIO9
J2 Pin 7	SPI_CLK	GPIO11
J2 Pin 10	SPI_CS	GPIO7
J2 Pin 15	VSYNC	GPIO17
J3 Pin 1	GROUND	Ground
J3 Pin 2	VIN	3.3V

Application Program Design

The Lepton processes 27 frames per second regardless of whether the frames read out successfully. If a host fails to synchronize to the beginning of a frame, the host might fail to read out all packets for the given frame. To read out an entire frame from the Lepton while reducing the failure, we adopted VSYNC (Video Synchronization) mode along with the VoSPI (video over SPI) mode to synchronize to the beginning of every frame. When the Lepton is idle for a certain period, its power switches from the On-state to the Shutdown-state to save power. When the Lepton is used again later, the power gets back to the On-state.

We developed Web Application Programming Interface (API) in order to periodically take images remotely using the camera. The API provides thermal image data in JSON format of data [120][160] array, and RGB image from Pi camera in JPEG format. The first index of the array data is the y-axis offset, and the second index is the x-axis offset. The value of each item is an absolute temperature in units of 0.01°C, which can be converted to Celsius by dividing by 100 and subtracting 273.15.

The experiment was conducted with our camera installed 40cm above on a plant pot of 70 x 40 x 50 cm indoors. (Figure 2) shows the images transmitted over the Web and the minimum and maximum canopy temperatures.

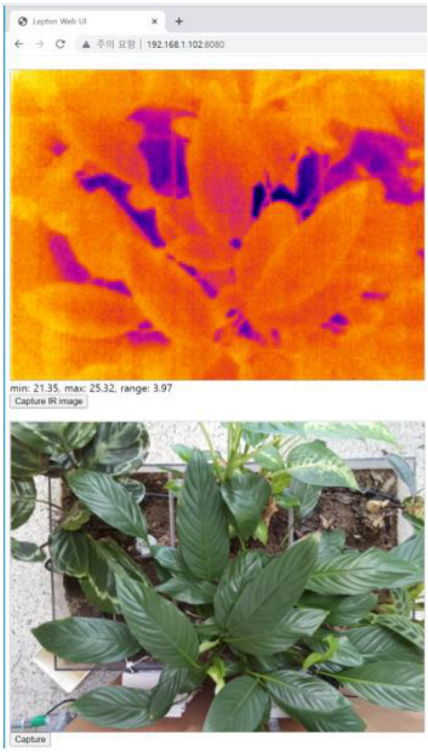


Figure 2: Experimental image.

Conclusion

In this study, we aimed to present the design and implementation of a low-cost thermal-RGB camera that are capable of getting thermal and RGB images remotely. We used VoSPI and VSYNC mode to read the Lepton's frames with more accuracy. The Lepton's power state was switched to the Shutdown-state when the Lepton was idle to save power. We believe that the dual camera can be used for agricultural researchers to develop a thermal-based irrigation algorithm and early pest diagnosis in crop.

Acknowledgement

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Conflict of Interest

The authors declared no conflict of interest.

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