

AFFORDABLE MULTI-ROTOR REMOTE SENSING PLATFORM FOR APPLICATIONS IN PRECISION HORTICULTURE

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ABSTRACT

Satellite and aerial imaging technologies have been explored for a long time as an extremely useful source of collecting cost-effective data for agricultural applications. In spite of the availability of such technologies, very few growers are using the technology in their agricultural practices for making informed management decisions. This is particularly the case for fruit and vegetable growers which are usually small to medium size growers. The major challenges that limit the agricultural applications of remotely sensed aerial images are the high cost and the lack of resolution of acquired data for certain applications. In this paper, we describe the utilization and implementation of an affordable, light weight, multi-rotor remote sensing (MRRS) system for various precision agriculture applications. The overall objective of this work is to test the feasibility of utilizing a cost-effective, reliable remote sensing tool for applications such as inventory management and stress detection in different specialty crops. The sensor used with the MRRS platform includes multispectral cameras with visible-near infrared reflectance imaging capabilities and a thermal camera. The MRRS platform also provides an opportunity to acquire high resolution stitched images for applications in tree counting and crop monitoring. The system has the capability of fully automated autonomous waypoints navigation and altitude control. It is capable of spatial-temporal data collection using the GPS navigation points and it can store the flight path for flying to the same point over time. The platform is very easy to operate and quite user-friendly. Our preliminary studies show that the MRRS system could identify stressed trees from those of healthy ones in citrus orchard. Such tool will enable growers to make better management decisions for better productivity and profitability.

Keywords: Disease detection, Huanglongbing, citrus greening, visible-near infrared spectra.

INTRODUCTION

Satellite or aerial remote sensing is emerging as an important component of precision agriculture for its ability to identify and define the cause of crop yield variability. For example, to identify the vegetation contribution in an image, the use of a vegetation ratio index is very common. The normalized difference vegetation index (NDVI) has been used to assess the health and condition of crops and natural vegetation over large geographical regions (Teillet 1992; Wade et al., 1994; Ramsey et al., 1995; Roderick et al., 1996a, b). With improvements in spatial, spectral and temporal resolution of satellite remote sensing, aerial imagery remains advantageous due to its real-time or near real-time availability of imagery for visual assessment (Everitt and Escobar, 1989; Mausel et al., 1992; Everitt et al., 1995). In spite of the usefulness of remote sensing, this technology was not used by small growers due to its cost. There are a number of companies that are offering small UAV (e.g. SenseFly or Draganflyer from Draganfly Innovations Inc.) that can be used for precision agriculture applications; however, they are often either too expensive or have a very limited payload capabilities. In addition, some of them required a trained RC pilot to operate them or they are not sophisticated enough to get high quality, geometrically corrected and geo-referenced images that can be used for precision agriculture applications. The resolution of aerial images depends on the resolution of the sensor and location of the sensor platform. Therefore, there is a need for a simple, low-cost, field-based sensing tool that can benefit the growers.

In recent years, the development of miniaturized, light-weight unmanned aerial platforms, with better flight control, have enabled the acquisition of very high resolution images for various remote sensing applications in agriculture. Many of these remote sensing applications can be yield predictions, crop status mapping, weed detection, and disease and nutrient deficiency detection that would use optical sensing for acquiring aerial images of the desired target. Nebikar et al. (2008) used two different unmanned aerial platforms (WeControl –Zurich, Quadcopter md4-200 microdrones) with visible-near infrared sensors to identify damaged leaves using NDVI values. Their preliminary studies reported that there was a good similarity between the NDVI values as predicted by remote sensing with that of ground truth. Similarly, Berni et al. (2009a, b) found good potential from thermal and multispectral imaging sensors from unmanned aerial platforms for stress detection in different crops. They found that there was a good relationship between the predicted and validated values of leaf area index (LAI) in corn and olive ($r^2 = 0.5, 0.88$) plants. Similarly, chlorophyll a and b concentration could be validated with r^2 of about 0.89. These studies show good use of this technology for other crops.

In this work, we propose to implement and assess a multi-rotor remote sensing (MRRS) system for precision agriculture application in specialty crops. This sensing technology will aid in improving the resolution of aerial images, thereby allowing the high-quality image acquisition for desired application. Scouting or visual inspection is a common practice for stress or disease detection in specialty crop production. This process is expensive, time-consuming and prone to human errors. The aerial remote sensing application can help the scouts to focus on a specific area for better scouting efficiency, lower scouting costs, and

better disease management efficiency. The MRRS system will help in monitoring the plant health, enabling the growers to apply pesticides or fertilizers on a needed basis. Similarly, inventory management (tree count and characterization) is a labor-intensive process, where the workers have to account for the number of plants or trees present in a block of specialty crop production area. In this paper, we present proof of concept of few potential precision agricultural applications of MRRS system based on high resolution imaging.

Potential applications

The main advantages of MRRS over existing aerial imaging systems are the ability to collect images at a desired time (timeliness), at a lower cost and higher resolution. This system is more suitable for taking aerial images of small to medium-size fields. Most high value crops will fall under this category. In general, this system can be used in the small field for the following applications:

- **Crop Scouting:** Aerial images can be used for disease and stress detection and mapping crop damage caused by pests. This is a particularly valuable tool for inspecting disease symptoms on the leaves of tall trees such as date palm or oil palm or for use with diseases whose symptoms show up on the top of the canopy where they are not visible from ground level.
- **Bare soil imagery:** The bare soil images, if taken at the right time, can be used for identifying soil type and potentially be used for delineating management zones.
- **Irrigation and drainage planning:** A multi-band aerial image can be used for identifying irrigation and drainage problems.
- **Yield estimation and monitoring:** For certain crops, especially fruits and vegetables, it is possible to use high resolution aerial images for yield estimation and yield monitoring.
- **Inventory:** For orchards and open field nurseries, it is possible to use aerial images and some image processing software to count the number and type of trees.
- **Academic and extension education:** Aerial images from research plots can be very useful educational tools. For example, in a fertility trial of a sugarcane crop, it is impossible to show the performance of different research plots from the ground level due to the height of the sugarcane.

METHODOLOGY

Sensor platform and sensors

A low-cost, unmanned aerial vehicle (Fig. 1) termed as multi-rotor remote sensing (MRRS) system was used in this work. This MRRS platform was developed by purchasing and assembling different components at the Precision Agriculture Laboratory, Citrus Research and Education Center, Lake Alfred, FL. This platform has the capability of flying at a wide range of altitudes (2-300 m) and is

capable of carrying a payload of up to 1.5 kg for 10 to 30 minutes. It also has an automatic GPS waypoint navigation and altitude control. This platform can provide higher resolution images than those taken from a helicopter. Also, it is possible to obtain aerial images multiple times during the growing season or when is necessary. Preliminary evaluation using a regular digital camera with the MRRS platform showed that a resolution as high as 2 cm can be achieved from an altitude of 100 m altitude.



Figure 1. Multi-rotor remote sensing platform with six-band sensor.

Visible, near infrared and thermal infrared sensors were used to acquire high resolution images using the MRRS platform. These sensors include: (i) Specialized light weight agricultural digital camera (ADC-Lite, Tetracam, Inc., Chatsworth, CA) with a 3.2 megapixel Complementary Metal Oxide Semiconductor (CMOS) sensor. The camera provides information on the red, green, and near-infrared bands of electromagnetic spectra, which can be used for extracting information such as NDVI, soil adjusted vegetation index (SAVI), canopy segmentation, and NIR/Green ratio, the image size is 2048×1536 ; (ii) Six-band multispectral camera (MCA, Tetracam, Inc., Chatsworth, CA) has CMOS sensors that are sensitive to six spectral regions of 10 nm range in visible-near infrared region, the images have a 1.3 MP resolution and are 1280×1024 pixel size. Our lab possesses two such sensors with 12 spectral bands covering 440-900 nm wavelength range; and (iii) Thermal camera (Tau 640, FLIR Systems Inc.) which is sensitive in the thermal infrared region (7.5-13.5 μm). The image size is 640×512 .

Data collection and analysis

Different sensors were used to collect the images from the citrus orchards for various applications. Images were collected from citrus orchard for citrus canopy characterization using simple camera. In addition, the visible-near infrared and thermal data were collected from healthy and stressed (water stressed and Huanglongbing, HLB-infected) trees using a retractable mast that mimics the MRRS platform to establish a proof-of-concept. The reflectance data from the top of the citrus canopies were compared. Images were processed manually and

electronically to determine if individual plants or patterns can be detected beyond background variation inherent in imagery.

RESULTS AND DISCUSSION

Inventory characterization

The crop characteristics will be used to estimate the volume and density of citrus canopy, which can be related to yield information. Yield estimation is a critical process in citrus orchard management. Moreover, the chemical application and irrigation can be scheduled based on the crop requirements, which will reduce significant production costs as well as reduce pollution. Figure 2 summarizes the diameter estimation procedure using image processing and relationship between the estimated and actual measurements.

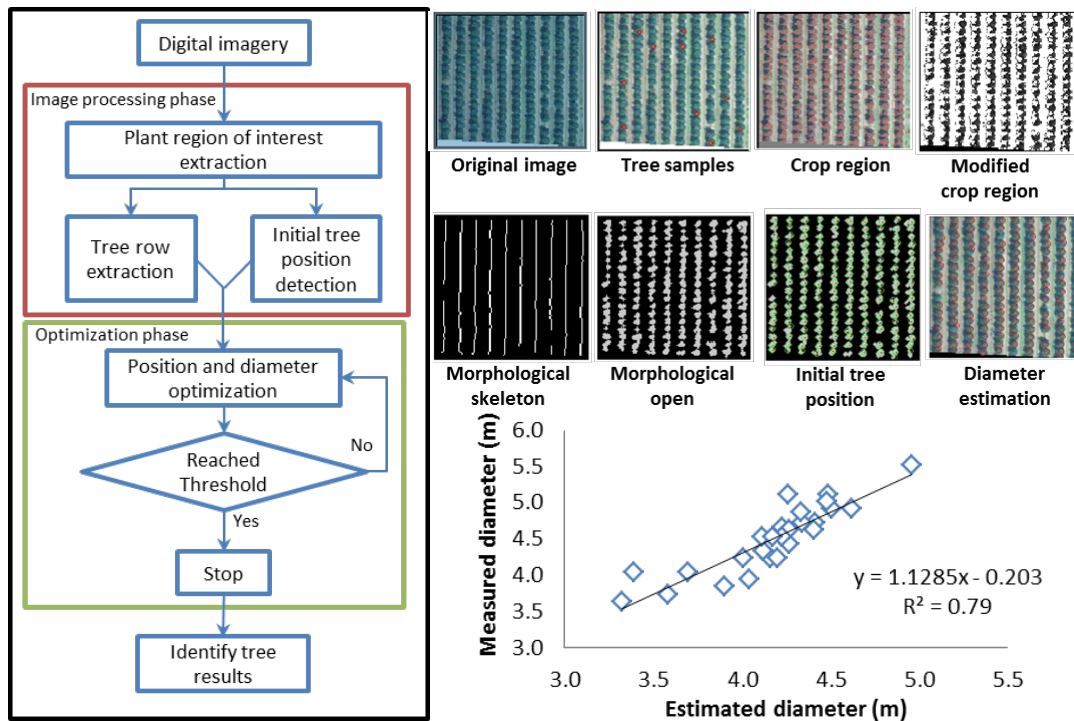


Figure 2. Estimating citrus tree diameters using image processing technique

Results indicated that diameter of citrus tree could be estimated with a regression coefficient (R^2) of about 0.79. Unlike plant width or diameter, estimates of canopy volume from aerial images were made indirectly. A R^2 of 0.70 was achieved.

Plant stress detection

We evaluated the capabilities for remotely sensing HLB-infected and water-stressed trees using hyperspectral and thermal imaging. Figure 3 represents the

thermal images of individual trees under different conditions and the average pixel values of the healthy and stressed trees. We found that the average pixel values were higher in stressed trees than those of healthy ones (thermal camera). Similar results were found using multispectral camera.

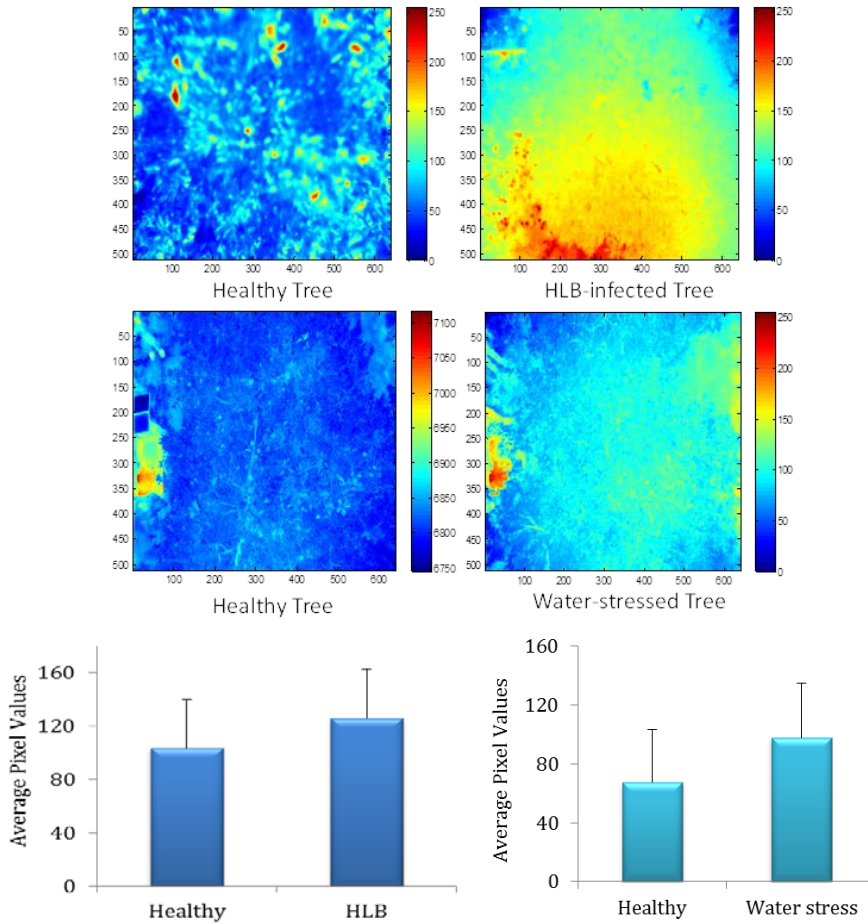


Figure 3. Thermal images and average pixel values of HLB-infected and water stressed-trees and their comparison with the healthy tree reflectance.

Normalized difference vegetation index (NDVI), red-edge normalized difference vegetation index (RE-NDVI), modified simple ratio index (mSR) and simple ratio index (SRI) showed that there was a significant difference between the healthy and HLB-infected canopy (Figure 4). Thus, the aerial high resolution images show good potential in precision agricultural application for specialty crops.

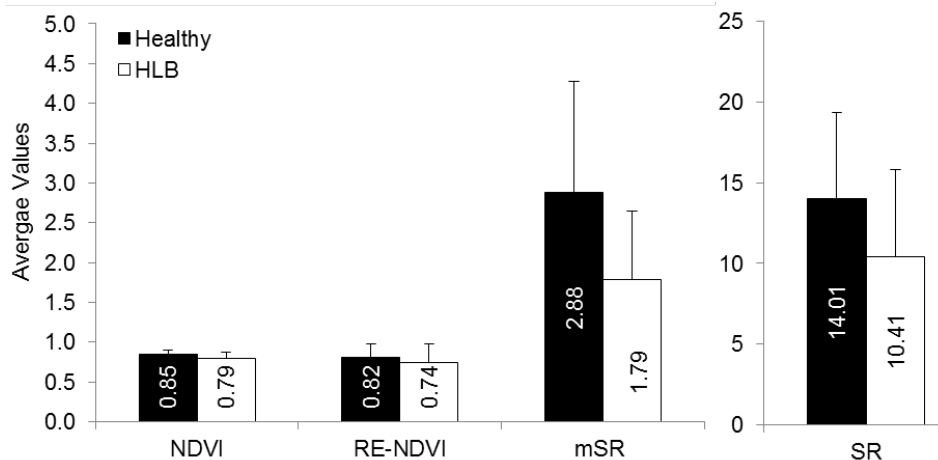


Figure 4. Vegetation indices computed from healthy and HLB-infected tree canopies.

CONCLUSION

A low-cost aerial sensing system can benefit growers to accomplish various critical agricultural operations. Ease of operation and ability to obtain very high resolution aerial images over time by growers can potentially be a very attractive tool for precision agriculture. Also high resolution aerial imaging can provide opportunity to explore new applications that are not available today with current aerial imaging systems. In this work, we present few potential applications of a reliable, robust multi-rotor remote sensing system that is capable of acquiring high resolution aerial images (1 inch or better). Results from our preliminary work indicate that such remote sensing technology can aid in improving the management efficiency in citrus orchards. Thus, we can further improve the adoptability of technology in agricultural practices.

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