CAFEi2012-135

APPLICATIONS OF A LOW-COST MULTI-ROTOR REMOTE SENSING UAV IN AGRICULTURE

Reza Ehsani, Joe Mari Maja, Sindhuja Sankaran

Citrus Research and Education Center, University of Florida, 700 Experiment Station Road, Lake Alfred, FL 33850.
Email: ehsani@ufl.edu

ABSTRACT

Satellite images along with other aerial images acquired using aircrafts have long been investigated for various agricultural and environmental applications. Aerial imaging offers a rapid, cost-effective means of acquiring data from a larger area, and evaluating the conditions for implementing various management strategies. A few of the limitations of satellite and aircraft imaging are high cost, lack of desired resolution and on-demand capability, and effect of atmospheric conditions on the image quality. Considering these aspects, a low-cost multi-rotor remote sensing system (MRRSS) UAV can be used as a reliable sensing tool for various agricultural applications. This work describes the potential applications of a MRRSS system that has been used for inventory management, canopy characterization, yield estimation and stress detection in specialty crops. The MRRSS platform can be integrated with a number of sensors such as visible-near infrared multiband sensors, and thermal sensors. based on the desired application. The MRRSS provides features that are well suited for growers who don't have the experience in flying a UAV, e.g. waypoint navigation, hover capability and safety. Such a system provides an opportunity to small- and medium-sized growers to use aerial imaging as a part of their orchard/farm management strategy.

Keywords: *UAV, precision agriculture, plant disease detection, specialty crops.*

INTRODUCTION

Satellite or aerial remote sensing has been 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 [1-5]. 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 [6-8]. In spite of the usefulness of remote sensing, this technology has not been widely adopted by growers largely due to its cost. There are a number of companies that are offering small UAVs 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 Remote Control (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 the distance of the sensor from the object of interest. Therefore, there is a need for a simple, low-cost, field-based sensing tool that addresses the problems associated with satellite and aircraft imaging and benefits 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 such as yield predictions, crop status mapping, weed detection, and disease and nutrient deficiency detection. The main advantage is the ability to collect images at a desired time (timeliness), at a lower cost and higher resolution. In this work, we propose to implement and assess a multi-rotor remote sensing system for precision agriculture application in specialty crops. This sensing technology will help to improve the resolution of aerial images, thereby allowing high-quality image acquisition for a desired application. The system will help in monitoring plant health, enabling the growers to apply pesticides or fertilizers on an as needed basis. Similarly, inventory management (tree count and characterization) is a labor-intensive process, where the workers have to count 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 same potential precision agricultural applications of our system based on high resolution imaging.

MATERIALS AND METHODS

A low-cost, unmanned aerial vehicle (Fig. 1) termed as MRRSS was used in this work. This MRRSS platform was developed by purchasing and assembling different components at the Citrus Research and Education Center, Lake Alfred, FL. It has the capability of flying at a wide range of altitudes (2 to 300 m) and is capable of carrying a payload of up to 2.5 kg for 10 to 30 minutes. It also has an onboard GPS navigation, on demand telemetry information, altitude control, and the ability to hold on a particular location making it easy to acquire higher resolution images.

Fig. 1: Multi-rotor remote sensing system

Imaging sensors such as a specialized light weight agricultural digital camera (ADC-Lite, Tetracam, Inc., Chatsworth, CA), a six-band multispectral camera (MCA, Tetracam, Inc., Chatsworth, CA), and a thermal camera (Tau 640, FLIR Systems Inc.) were used to acquire high resolution images using this system. Different sensors were used to collect the images from the specialty crops for various applications. Visible-near infrared and thermal images were acquired from healthy and stressed specialty crops using a telescopic mast platform as well as the MRRSS. Images were processed off-site to identify healthy and stressed crops.

RESULTS AND DISCUSSION

Inventory and Crop Characterization

A remote sensing tool is critical to inventory management, especially for high density cropping such as nurseries. The MRRSS was used to estimate the inventory and crop characteristics. Nursery crops and citrus were used as a model crops. The citrus crop characteristics were used to estimate the volume and density of the 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. Fig. 2 represents object-based image analysis of ornamental pear trees for inventory management. Preliminary evaluation indicated that an inventory accuracy of up to 90% can be achieved using images taken by our system.

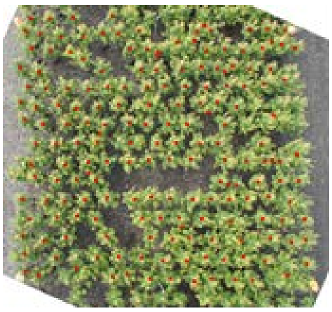

Fig. 2: Tree counting in nurseries using object-based image analysis**.**

With regard to counting citrus trees, the tree diameters and tree heights were estimated from the aerial images acquired using the MRRSS system. Results indicated that the diameter of citrus trees 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. An R^2 of 0.70 was achieved.

Plant stress detection

We evaluated the capability of the MRRSS for remotely sensing HLB-infected and water-stressed citrus trees, and water-stressed nursery crops using hyperspectral and thermal imaging and found that pixels from healthy and infected trees are different. The average pixel values were higher (20-40 pixel values) in stressed trees (HLB and water stress) than those of healthy ones (thermal camera) in citrus. Similar results were found using multispectral camera. The vegetation indices such as 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.

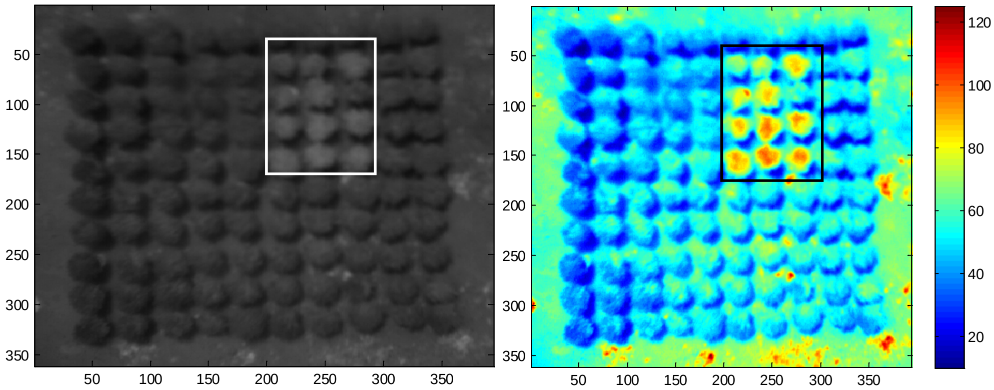

Fig. 3: Thermal image of healthy and water-stressed nursery crops.

The thermal images of healthy and water-stress nursery crops (Fig. 3) also indicated a clear identification of stressed crops, which were otherwise not visible in the RGB image. Thus, the aerial high resolution images show good potential for precision agricultural applications of the specialty crops.

CONCLUSIONS

A low-cost aerial sensing system can benefit growers to accomplish various critical agricultural operations. The ease of operation and ability to obtain very high resolution aerial images over time by growers is a very attractive tool for precision agriculture. Also, high resolution aerial imaging can provide the opportunity to explore new applications that are not available today with current aerial imaging systems. In this work, we present some 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 farms and orchards.

ACKNOWLEDGEMENT

This research was funded by the Citrus Research and Development Foundation (CRDF) and the U.S. Department of Agriculture - National Institute of Food and Agriculture (USDA-NIFA). We would like thank Ms. Sherrie Buchanon and other colleagues for their help during this study.

REFERENCES

[1] Teillet, P.M. (1992) An algorithm for the radiometric and atmospheric correction of AVHRR data in the solar reflective channels. Remote Sensing of Environment, 41, 185-195.

[2] Wade, G., Mueller, R., Cook, P., Doraiswamy, P. (1994) AVHRR map products for crop condition assessment: A geographic information systems approach. Photogrammetric Engineering and Remote Sensing, 60, 1145-1150.

[3] Ramsey, R.D., Falconer, A., Jensen, J.R. (1995) The relationship between NOAA-AVHRR NDVI and ecoregions in Utah. Remote Sensing of Environment, 53, 188-198.
[4] Roderick, M., Smith, R., Cridland, S. (1996) The precision of the NDVI derived from AVHRR observations. Remote Sensing of Environment, 56, 57-65.
[5] Roderick, M., Smith, R., Cridland, S. (1996) Calibrating long term AVHRR derived NDVI imagery. Remote Sensing of Environment, 58, 1-12.
[6] Everitt, J.H., Escobar, D.E. (1989) The status of video systems for remote sensing applications. In: Proeedings of. 12th Biennial Workshop on Color Photography and Videography in the Plant Sciences and Related Field (American Society for Photogrammetry and Remote Sensing, Bethesda, Maryland USA), pp. 6-29.
[7] Mausel, P.W., Everitt, J.H., Escobar, D.E., King, D.J. (1992) Airborne videography: Current status and future perspectives. Photogrametric Engineering and Remote Sensing, 58(8), 1189-1195.
[8] Everitt, J.H., Escobar, D.E., Cavazos, I., Noriega, J.R., M.R. Davis. (1995) A three-camera multispectral digital video imaging system. Remote Sensing of the Environment, 54, 333-337.