

Sensors and sensing technologies for

DISEASE DETECTION

By Reza Ehsani and Sindhuja Sankaran

Citrus health monitoring is a critical part of citrus orchard management. Citrus health monitoring is often performed to detect and assess the presence of biotic (diseases) and abiotic (nutrition) stress in a tree. In recent years, citrus-devastating diseases such as citrus canker and citrus greening (Huanglongbing/HLB) have spread to various parts of Florida and are threatening the Florida citrus industry. The detection of HLB infected trees in the early stages is imperative to eliminate trees as sources of inoculum and to prevent further spread of the disease. Currently, grove scouting by a trained scouting crew is the most widely used technique for disease detection. A recent study on survey methods indicated that scouting efficiency for detection of HLB can range from an average of 47 percent to 61 percent, depending on the survey techniques used. Thus, the scouting efficiency can be further improved by the development of field-based sensors to monitor tree health and detect diseased trees.

Direct methods of disease detection include molecular techniques such as polymerase chain reaction (PCR) and enzyme-linked immunosorbent assay (ELISA), where symptomatic leaves are analyzed to confirm the presence of a disease (e.g., HLB). These leaves are collected by the scouting crew during the scouting process. The PCR analysis involves an elaborate laboratory-based sample preparation and testing protocol. Therefore, there is a demand for the development of new field-based, real-time, accurate sensing technologies for rapid plant-disease detection.

An optical sensor operates on the principle of spectral reflectance. Reflectance (from the tree canopy) in the visible and infrared regions of the electromagnetic spectra is known to provide information on the physiological stress levels in plants. Some of these wavebands have been demonstrated to be specific to a disease/stress condition, which can then be used in the field to identify plant diseases and nutrient deficiencies.

OPTICAL SENSORS

Differences in the reflectance of a healthy and diseased tree in the visible-infrared region can be detected using spectroscopic and imaging opti-

cal sensors. Various optical sensors are being developed and evaluated to detect diseases and other plant stress. Some of the sensors being used for disease or stress detection are spectroradiometer, multi-band sensors, and hyperspectral cameras. These portable optical sensors offer opportunity for real-time detection of plant diseases.

A spectroradiometer is an optical sensor that can measure reflectance from the tree canopy (healthy or diseased) in the visible-near infrared range. The resolution of the spectroradiometer depends on the wavelength range and the type of detector used.

Similarly, the hyperspectral camera is another optical sensor that has the ability to collect reflectance in two dimensions (preferably in x-y direction). An advantage of hyperspectral camera-based imaging is that if a specific region within a tree canopy is showing diseased symptoms, this region can be isolated and identified using mathematical models.

Recently, multiband sensors (Fig. 1) have been used for disease detection, as they are robust, rugged, economical and specific for different applications. In addition, these sensors can be developed as an active sensor (light source within a sensor) or passive sensor (natural light source), unlike spectroradiometer and hyperspectral camera, which are passive sensors. The multiband sensors can also be customized to support a GPS system and possess self-calibration capabilities. At Citrus Research and Education Center (CREC), these portable systems are being developed and/or evaluated for field-based detection of various diseases such as HLB, phytophthora, root rot and blight-infected citrus trees. There are very few commercial optical sensors available for disease detection. One such instrument, the Dualex leaf-clip chlorophyll fluorescence meter (<http://www.force-a.eu/an/dualex.html>),

exhibits a potential for fungal disease detection in plants.

In spite of significant developments in sensor technologies, there are still challenges that need to be addressed for practical applications. Since optical systems are very sensitive to light conditions, incidental light plays an important role in determining the reflectance spectra from the plant. Changes in natural light conditions may limit its application. This could be resolved by using an artificial light



Figure 1. Optical sensors used for disease detection: (top) four-band active sensor; and (left) five-band passive sensor.

source and conducting disease-detection surveys during the night time. In addition, variations in appearance of tree-disease symptoms also need to be considered in any disease-detection system during field-based disease monitoring.

Other factors that can influence the performance of optical sensors are statistical algorithms used for data analysis (type of algorithm will influence the accuracy and required computational speed), field of view of the sensor (narrow or broad depending on the extent of symptoms within a tree canopy), and suboptimal environmental conditions (changes in natural

light intensity, wind and humidity may affect the sensor performance). At CREC, efforts are being made to further improve the optical-sensing technologies to customize sensors for desired applications. With some improvements, these sensor/sensor systems could be integrated with ground- or aerial-based sensor platforms to continuously monitor plant diseases (Fig. 2).

SENSOR PLATFORMS

The selection of a sensor platform is a key factor that determines the cost and accuracy of optical sensor-based disease detection. An agricultural tractor, an autonomous agricultural vehicle or an unmanned aerial vehicle (UAV) (Fig. 2) could be used as a sensor platform to support sensors during disease detection. An agricultural tractor could be used for monitoring tree canopy health from the sides of a tree, while UAV could be used to monitor the top canopy of the tree. At CREC, an advanced low-cost UAV (shown in Fig. 2) with a capability of complete automated waypoint navigation is currently being tested. The UAV could be a fast, low-cost sensor platform for disease detection. Multiple platforms (side, overhead) with optical sensors could provide a comprehensive evaluation of the disease status in a tree which might be present in just a branch of the tree (HLB). The additional benefit of combining these different sensor platforms is that they can be coupled with GPS systems to locate the exact position of a tree in a large orchard within a tree canopy. Both the sensors and the sensor platform can also be remotely controlled.

Much attention has been drawn toward utilizing optical-sensing technology for plant-disease detection in precision agriculture-based applications. The optical-sensing technology currently under development for citrus can also potentially be extended

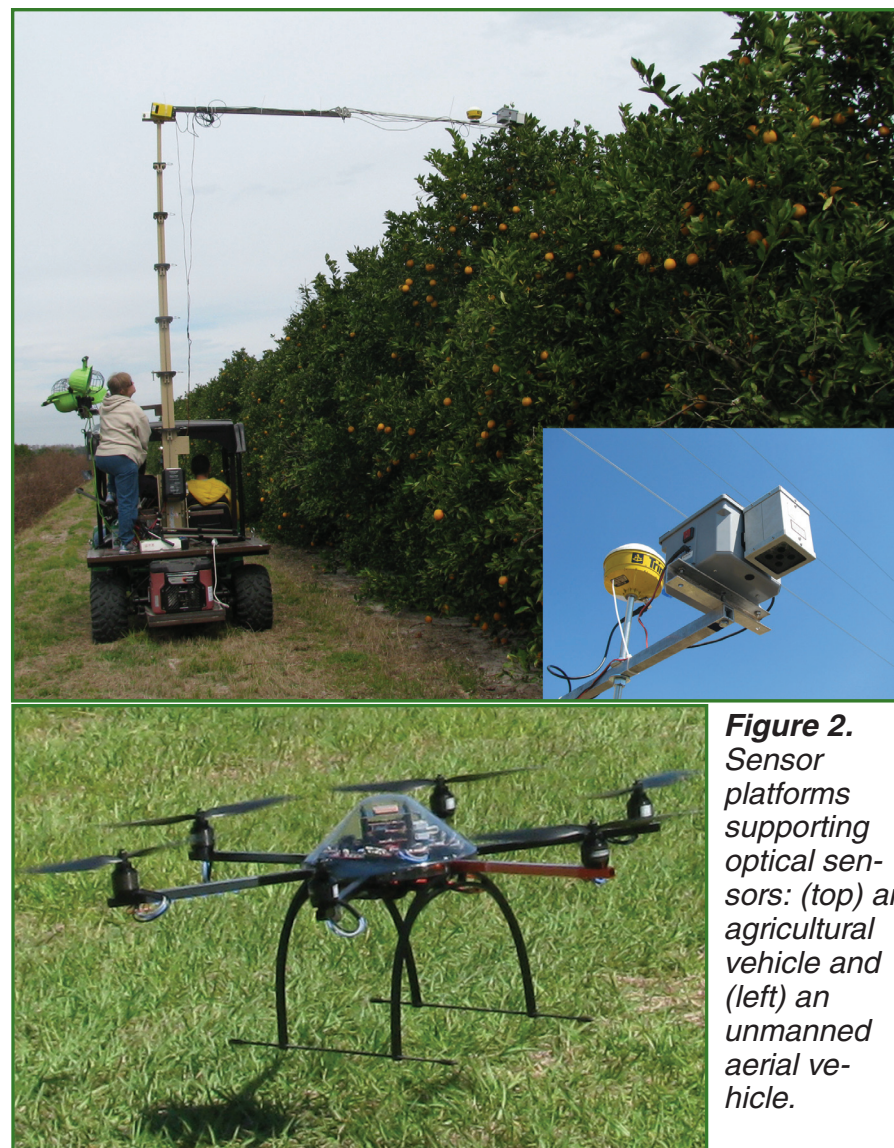


Figure 2. Sensor platforms supporting optical sensors: (top) an agricultural vehicle and (left) an unmanned aerial vehicle.

to multiple diseases and other specialty crops. In the future, these sensor systems could also be integrated with an autonomous vehicle for monitoring diseases in large citrus orchards. This technique demonstrates potential for efficient, rapid, non-invasive field detection of plant diseases for disease control and management, thus providing economical, production, and agricultural benefits. An ideal method of

disease detection could be the integrating of optical sensors for preliminary screening with further confirmation using molecular methods.

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