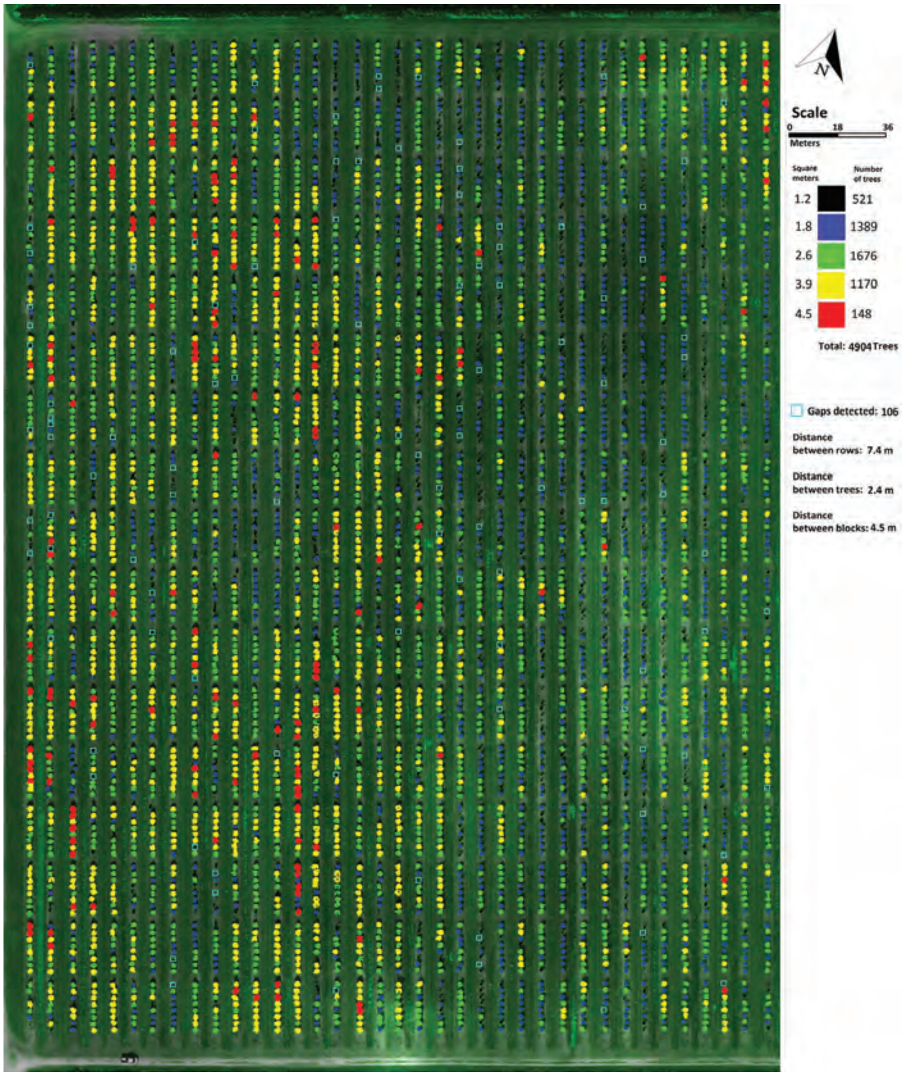

Figure 1. This map was produced using unmanned aerial vehicle technology with artificial intelligence. The map shows tree and gap detection, canopy size categories and other field analytics. Each color represents a canopy size category.

Precision agriculture technologies in citrus

By Yiannis Ampatzidis

Citrus growers face issues from an increasing number of pests and diseases. Rapid and accurate tools for early pest and disease detection are needed to improve precision and timely management.

Almost all agrochemicals (e.g., pesticides) applied in specialty crop production are made uniformly with conventional spraying equipment, despite the fact that pathogen distribution is typically patchy. Uniform applications result in the use of agrochemicals where no diseases, weeds or pests occur. This unnecessary use of agrochemicals leads to increased costs, risk of crop damage, environmental pollution and contamination of the edible products.

The rapid development of new technologies and the changing landscape of the online world (e.g., Internet of Things, cloud-based solutions) provide a unique opportunity for developing intelligent agricultural systems for precision applications. Technological advances in machine vision, artificial intelligence (AI) and machine learning enabled the development of intelligent agricultural technologies for precision applications. These technologies can optimize weed, pest and disease identification and management. In this article, several examples of emerging technologies in citrus are presented.

UAV APPLICATIONS

Conventional sensing techniques for evaluation of plant phenotypes (e.g., rootstock varieties) rely on manual sampling and are often labor intensive and time consuming. Field surveys utilized for weed and disease detection, to assess plant health status and to create a plant inventory are also expensive and labor intensive. Small unmanned aerial vehicles (UAVs) equipped with several sensors have recently become available. They are cost-effective solutions for rapid and precise high-throughput phenotyping and sensing.

UAVs can provide growers with a low-cost tool to constantly monitor crop health status, estimate plant water needs, and even detect diseases. They offer a rapid method for high-resolution image acquisition and have been increasingly studied for agricultural applications. For example, we developed a UAV-based technique this year utilizing multispectral imaging and artificial intelligence. It can:

- Detect, count and geo-locate citrus trees and tree gaps (locations with dead or no trees)
- Categorize trees based on their canopy size (plant inventory)
- Develop individual tree health status maps (health index maps)
- Evaluate citrus varieties and rootstocks

Figure 1 presents a generated tree detection map from this technique. This map presents the number of detected trees and their canopy size, number of trees belonging to a specific tree-canopy-size category and tree gaps. It also includes field analytics (e.g., distance between rows, between trees and between blocks of trees). All these parameters are produced by the developed algorithm automatically.

This method detected trees with

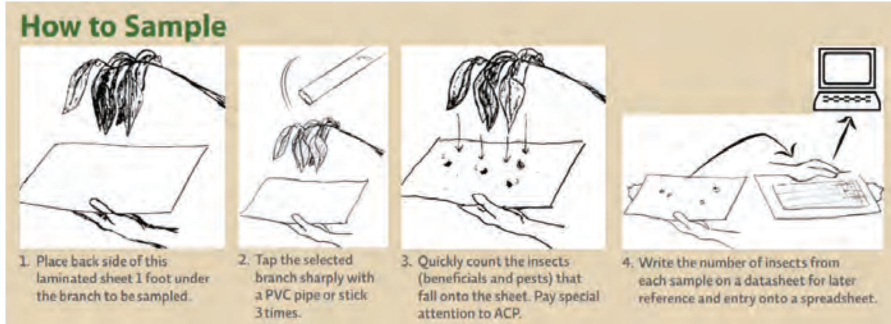

Figure 2. Traditional (manual) Asian citrus psyllid monitoring is performed with the tap sample method.

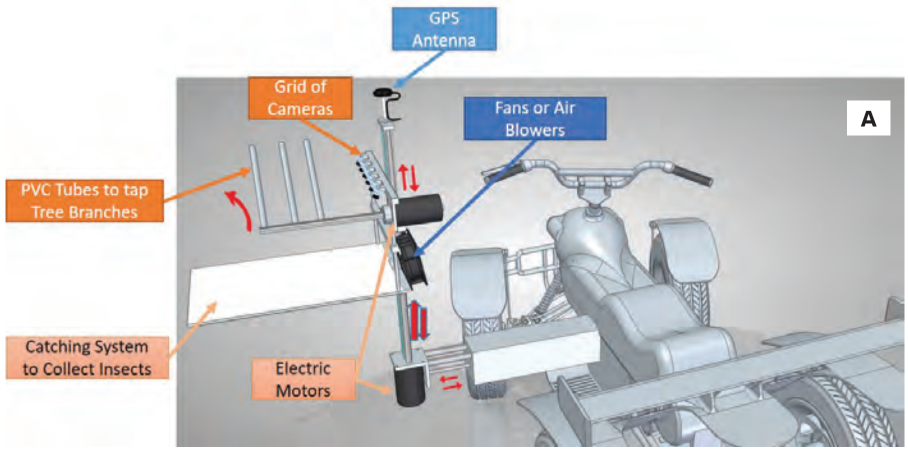

Figure 3. A) This is an example of an initial design of an automated and mobile system for monitoring and mapping Asian citrus psyllids (ACP) in groves. Red arrows indicate all moving components of the system. B) The artificial intelligence-based vision system detects and counts ACP.

an overall accuracy of 99.8 percent and tree gaps with an accuracy of 94.2 percent. It estimated individual tree-canopy area with more than 85 percent accuracy when compared to manual measurements.

AUTOMATED ACP MONITORING

Smart agricultural technologies for precision applications can be used to optimize pest and disease identification and management. For example, we developed an automated system, utilizing machine vision and AI, to monitor Asian citrus psyllid (ACP) in groves.

There are several methods to monitor ACP populations in order to determine the need to spray. Of all these methods, the tap sample technique has proved to be a fast and reliable tool for assessing ACP numbers in the tree canopy. This technique was adopted by the Florida Department of Agriculture and Consumer Services Division of Plant Industry as an integral part of the Citrus Health Response Program.

Tap sampling requires striking a randomly selected branch with a stick and counting ACP adults falling onto a laminated sheet held below (Figure 2, page 12). We automated this method by developing an intelligent and cost-effective system to detect, distinguish, count and geo-locate ACP populations in citrus groves.

This novel and mobile system includes a tapping mechanism to strike a tree's branches so that insects fall over a board with a grid of cameras used for image acquisition and processing (Figure 3, page 12). A unique AI-based algorithm was developed to distinguish and count adult ACPs. A video demonstration of this technology can be found at https://twitter.com/i/status/1110151596770500608.

DATA MAPS

This system can generate a map of scouted trees (detected ACP numbers per tree) for a better visualization of the collected data (Figure 4). The collected ACP detection data can be used to generate prescription maps compatible with precision equipment for variable rate applications in order

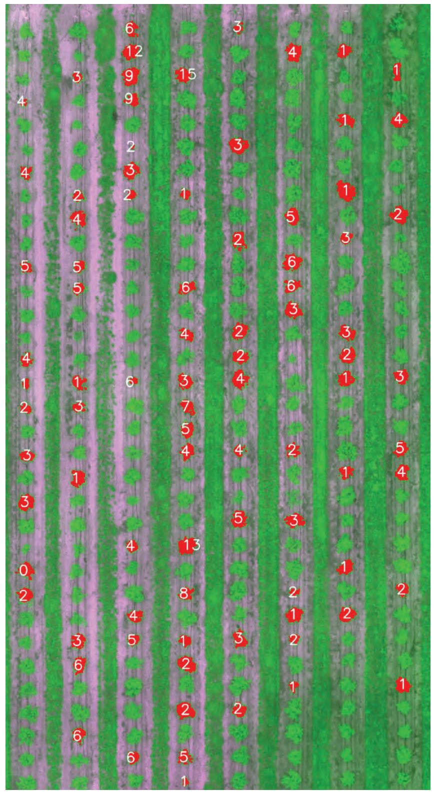

Figure 4. An aerial map shows visualization of automated Asian citrus psyllid detection (ACP numbers per tree) for each randomly selected tree. Segments in red were used to measure each tree canopy size.

Figure 5. Real-time citrus detection uses artificial intelligence in immature (green) fruit.

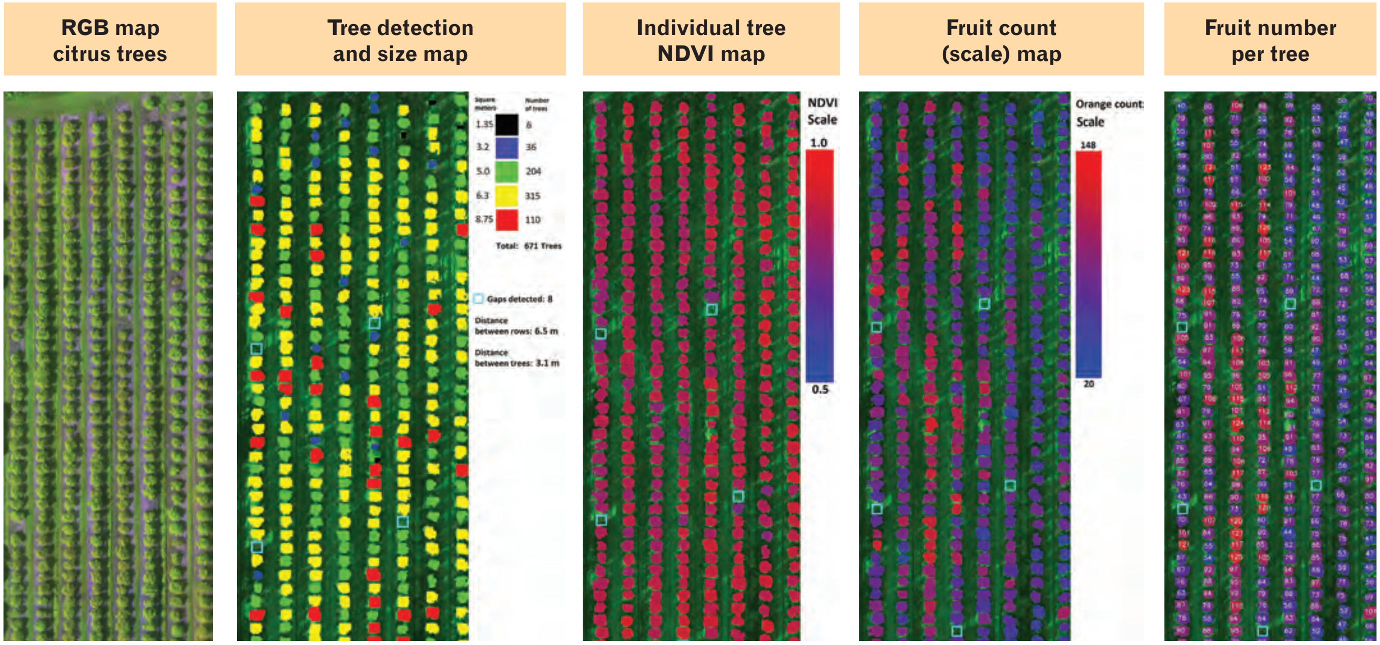

Figure 6. An automated system using UAV- and ground-based systems counts trees, tree gaps, tree size and fruit number per tree, and produces individual tree stress maps.

to apply the right amount of pesticides only where needed.

Machine vision and AI-based technologies can be used to detect and count citrus (immature and mature) fruit, too (Figure 5, page 14). A video demonstration of the real-time fruit detection system can be found at https://twitter.com/i/status/1042058065481269248. Figure 6 presents citrus maps developed by the integrated ground- and UAV-based systems that can count trees, tree gaps, tree size, fruit number per tree, and produce individual tree stress indices.

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