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Citrus Huanglongbing disease identification using computer vision and machine learning

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Extended Abstract

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The insect-spread bacterial infection known as Huanglongbing (HLB) or citrus greening is a very destructive citrus disease and has caused massive losses in Florida's citrus industry. No effective cure for this disease has been reported yet, and the HLB-infected tree will eventually die. Therefore, the infected tree must be detected and removed immediately to stop the spread of the disease. Early, easy, and less expensive HLB detection based on particular symptoms, such as starch accumulation in the citrus leaf, would increase the chance of preventing the disease from being spread and causing more damage. The ability of narrow-band imaging and polarizing filters in detecting starch accumulation in symptomatic citrus leaf was evaluated in this dissertation. Two custom-made image acquisition systems were developed for this purpose. In the first prototype, leaf samples were illuminated with polarized light using narrow-band high-power light emitting diodes (LED) at 400 nm and 591 nm, and the reflectance was measured by two monochrome cameras. Two polarizing filters were mounted in perpendicular directions in front of the cameras so that each camera acquired an image with reflected light in only one direction (parallel or perpendicular to the illumination polarization). Overall average accuracies of 93.1% and 89.6% in HLB detection were obtained for the 'Hamlin' and 'Valencia' varieties, respectively, using a step-by-step classification method. The second prototype was a vision sensor that included a highly sensitive monochrome camera, narrow band high power LEDs, and polarizing filters. The sensor was first tested and calibrated in a simulated field condition in a laboratory. Then, it was tested in a citrus grove. HLB detection accuracies which ranged from 95.5% to 98.5% were achieved during the laboratory and field experiments. The vision sensor images were compared with the images captured by a color camera to demonstrate the improvement achieved in this method. Also, the starch accumulation identification was studied for citrus leaves before and after being ground. The results showed an enhanced HLB identification performance using the developed vision sensor.

1. Chapter 1 : Introduction

This dissertation is about the identification of a major citrus disease called citrus Huanglongbing (HLB), also known as citrus greening, at the early stages using computer vision and machine learning techniques toward the development of on-the-go diagnosis systems. HLB disease symptom is very analogues to some types of nutrient deficiency symptoms such as zinc or manganese deficiencies. In order to differentiate the HLB infection from nutrient deficiency, a customized image acquisition prototype was developed and improved later to be employed for an on-the-go application.

A brief review of precision Agriculture and citrus industry in Florida is given. Also an introduction of computer vision and its applications in agriculture is discussed in this section. The HLB disease is presented and the diagnosis methods are reviewed in the next section. Then the computer vision based methods and machine learning approaches used in this research are presented and the results are discussed and concluded. Some future enhancements are recommended in the final section as well.

2. Chapter 2 : Literature Review

Using computer vision techniques in food and agricultural industries has increased extremely during the past few decades. In some cases, quality assessment of foods and agricultural products is still conducted subjectively by trained experts. Subjective assessment is an uncertain, labor Intensive, and time consuming process. In addition, subjective methods are mostly destructive, for example, to evaluate the taste of fruit, some portion of the product should be used (or wasted) for the assessment. These disadvantages caused an excessive interest in objective methods such as machine vision techniques. Objective methods resolve the uncertainty and judgment incompatibility problems and they are usually non-destructive

approaches. Because of these advantages, computer vision methods are getting very popular in agriculture and they are considered as a potential alternative for human vision based decision making.

3. Chapter 3 : Citrus Huanglongbing Detection Using Narrow-Band Imaging and Polarized Illumination

The ability of narrow-band imaging and polarizing filters in detecting starch accumulation in symptomatic citrus leaf was evaluated in this study. A custom-made image acquisition system was developed for this purpose in which leaf samples were illuminated with polarized light using narrow-band high-power LEDs at 400 nm and 591 nm, and the reflectance was measured by two monochrome cameras. Two polarizing filters were mounted in perpendicular directions in front of the cameras so that each camera acquired an image with reflected light in only one direction (parallel or perpendicular to the illumination polarization). Four groups of textural features, including gray, local binary pattern, local similarity pattern, and gray-level co-occurrence features, were extracted and ranked using several feature selection methods. Seven classifiers (support vector machine, linear, naive Bayes linear, quadratic, naive Bayes quadratic, Mahalanobis, and k nearest neighbor) were evaluated, and the best classifiers and sets of features were selected based on their accuracy. The leaf samples were collected from the 'Hamlin' and 'Valencia' varieties of citrus. Three classes of samples (magnesium-deficient, HLB-positive zinc-deficient, and HLB-negative zinc-deficient) were considered in the classification process to confirm the starch detection ability of the system. Overall average accuracies of 93.1% and 89.6% in HLB detection were obtained for the 'Hamlin' and 'Valencia' varieties, respectively, using a step-by-step classification method. The results of this study showed that the starch accumulation in HLB-symptomatic leaves rotated the polarization planar of light at 591 nm, and this property can be effectively used in a fast and inexpensive HLB detection system.

4. Chapter 4 : An Optimum Method for Real-Time In-Field Detection of Huanglongbing Disease Using a Vision Sensor

It was shown in the previous section that the unique capability of starch to rotate the polarization planar of light can be employed to identify the HLB-infected citrus leaves and differentiate them from zinc or magnesium deficiency. In this section, a vision sensor (the second image acquisition prototype) is introduced for the purpose of real-time HLB detection for use under field conditions. The sensor included a highly sensitive monochrome camera, narrow band high power LEDs, and polarizing filters. The sensor was first tested and calibrated in a simulated field condition in a laboratory. Then, it was tested in a citrus grove. Two simple image descriptors; mean and standard deviation of gray values, were used for the purpose of classification. The results showed that the sensor clearly highlighted the starch accumulation in the HLB-infected leaf and differentiated it from visually analogous symptoms of zinc deficiency. HLB detection accuracies which ranged from 95.5% to 98.5% were achieved during the laboratory and field experiments.

5. Chapter 5 : An Evaluation of a Vision Based Sensor Performance in Huanglongbing Disease Identification

The images of the customized vision sensor (which was introduced in the previous section) were compared with the images captured by a color camera to demonstrate the improvement achieved in this method. Also, the starch accumulation identification was studied for citrus leaves before and after being ground. The results showed an enhanced HLB identification performance using the developed vision sensor.

6. Chapter 6 : Summary and Conclusion

Computer vision and machine learning were utilized to develop a system which could detect Huanglongbing in citrus at an early stage of infection. The system successfully could detect the disease without excessive false positives, even when there were magnesium or zinc nutrient deficiencies.

Final remarks concerning the competition benchmarks and strength points

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HLB is a devastating disease that has reduced Florida's very important citrus production by 70% and is having similar effects in some other worldwide locations. This research develops original and innovative hardware and software technologies to detect the disease at an early stage without false detections due to nutrient deficiencies, thereby allowing appropriate actions to be taken in a timely manner. The practical system is sufficiently accurate and economical to be commercialized.