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[F] PhD Extended Abstract Form

DEVELOPMENT OF INTELLIGENT VISION SENSING SYSTEMS TO SUPPORT PRECISION AGRICULTURE PRACTICES IN FLORIDA CITRUS PRODUCTION

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Extended Abstract

Reducing production cost and producing a better quality of crops have always been fundamental goals for the Florida citrus industry. Especially, it is applicable in recent years due to the widespread of an exotic disease, Huanglongbing (HLB). Precision agriculture technology is one of the solutions to the agricultural challenges by adopting the site-specific crop management of agricultural fields. With advanced sensing technologies, various field data can be collected to analyze in-field spatial variability of different cropping factors. This research is focused on developing intelligent sensing systems to improve the capacity of current sensing technologies in agricultural applications and to support precision agriculture practices in the Florida citrus industry. Recently, more advanced sensors are in demand, which additionally provide information processing capabilities such as classification and prediction. Four vision vision-based sensing systems were developed as a non-destructive measurement to monitor crop health, diseases, and future yields in the various agricultural fields. The overall goal of this research was to develop intelligent vision sensing systems using economical and affordable devices to support precision agriculture practices in Florida citrus industry for various crop growing stages; early fruit development stage, pre-harvest to harvesting period, and post-harvest process. Specific objectives were: to

1. develop an immature green citrus detection system for yield forecasting at early fruit development stage,
2. develop fruit drop detection systems for evaluation of the severity of fruit tree diseases such as Huanglongbing (HLB) from pre-harvest to harvesting season,
3. determine decay stages among dropped fruit for additional information in pre-harvest to harvesting season, and
4. develop a fruit inspection system for HLB and other common citrus defects in Florida for the post-harvest process.

Below is a summary of the chapters of the dissertation explaining the motivation and technical details of four intelligent vision sensing systems developed in this research.

1. Chapter 1 - Introduction

Chapter 1 introduces current challenges that Florida citrus industry is facing. According to United States Department of Agriculture, Florida was an incomparably dominant citrus producer in the United States by producing more than 80% of the entire orange production until the 2003-2004 season. However, a bacterial disease HLB, also known as citrus greening, has spread widely throughout Florida. In the 2013-2014 season, more than 11% of citrus production in Florida was lost due to the early drop caused by HLB. In 2014-2015, citrus production in the United States was estimated at 5.8 million tons which were 350,000 tons lower than the previous season, mainly due to the decreased production in Florida. For the 2015-16 season, Florida accounted for 59% of orange production in the United States. Precision agriculture technologies have been considered important solutions to current challenges by adopting advanced sensing technologies, analyzing in-field spatial variability of various cropping factors, and allowing site-specific field management. Chapter 1 shows that machine vision is commonly used as an automatic nondestructive inspection tool to achieve timely measurement of in-field spatial variability without significant investment in the development of technology.

2. Chapter 2 - Immature Citrus Detection for Yield Forecasting under Extremely Varying Illumination

Yield forecasting is an important process to help growers plan operations and increase farming efficiency. A novel machine vision system using a Kinect v2 sensor was developed to detect immature green citrus fruit in various illumination

conditions. Using the Kinect v2 sensor, Chapter 2 introduces an innovative method for 2D representation of the geometrical shape of a sphere using gradient vectors of depth images. Using vorticity and divergence of the gradient vector field of depth, CHOI's Circle Estimation ('CHOICE') algorithm was developed to find spherical objects in depth images. The proposed machine vision algorithm included pre-processing of near-infrared (NIR) and depth images, detection of sphere objects, feature extraction, and classification. The developed algorithm is a new approach utilizing NIR and depth images to detect immature green citrus at a very early season. This algorithm showed significantly improved performance compared to algorithms which used only color images. The average rate for correctly identified fruit was 89.2%, and the false positive rate was 6.3%. An accurate method of fruit count at an early stage of development can improve citrus yield forecasts and provide site-specific management strategies to increase yields and profits.

3. Chapter 3 - Quantification of Citrus Fruit Drop on the Ground

Premature fruit drop is a serious concern that negatively affects crop yield. The overall goal of Chapter 3 was to develop a machine vision system to quantify dropped citrus fruits on the ground. The image processing algorithm consisted of: (1) illumination enhancement using retinex theory, (2) classification, (3) watershed algorithm with the h-minima transform and (4) ellipse fitting for the citrus count and mass estimation. The average correct identification rate was 88.1%, 83.6%, and 82.9% for logistic regression, k-nearest neighbor (kNN), and Bayesian classifiers, respectively. False positive errors were 13.7%, 40.9%, and 17.9% for logistic regression, kNN, Bayesian classifiers, respectively. The results demonstrate the system's ability to quantify dropped fruits with specific geo-referenced location information. Spatially varied fruit drop maps plotted from the results can assist growers in finding problematic areas in their citrus groves more efficiently while reducing inspection and treatment costs. Such maps can also facilitate treatment of citrus Huanglongbing (HLB) disease in combination with HLB intensity data, psyllid counts, fertilization programs, and other block-specific management practices.

4. Chapter 4 - Evaluation of Decay Stages of Citrus Fruit Drop

The machine vision system developed in Chapter 3 was extended to evaluate decay stages of dropped fruit: recently dropped fruit or rotten fruit. A novel method for image brightness correction using a contrast limited adaptive histogram equalization was developed to produce constant image brightness levels between and within images. The result shows all processed images had desired brightness levels (152 out of 255) with a standard deviation of 1.0. Correct identification of fruit and false positives were measured as 89.6% and 5.0%, respectively. False classifications of decay stages of fruit were as low as 4.2% and 18.5% for recently dropped fruit and rotten fruit, respectively. By estimating citrus fruit drop and creating a fruit drop map, block specific management can be achieved to provide better fertilization and irrigation programs that can help to treat the HLB infected trees in order to delay tree death and prevent infection within a tree. Also, differentiating recently dropped fruit from decayed fruit can improve accuracy of citrus yield estimation.

5. Chapter 5 - Evaluation of Decay Stages of Citrus Fruit Drop

Among the defected fruit, the market values depend on symptoms of endocarp or exocarp of fruit. For instance, the HLB damages the outer surface and inner fruit. Due to its bitter taste, the HLB-infected fruit is not suitable for both fresh market and value-added products and discarded. Whereas, other citrus defects in Florida such as rust mite and wind scar only damage the outer surface. An automatic post-harvest citrus inspection system was developed to distinguish HLB, rust mite, and wind scar using the visual symptoms of each defect with regular RGB cameras. The primary focus of this system was to achieve the practical processing speed and performance that can be used in commercial citrus packinghouses. Parallel computing technique using a graphical processing unit (GPU) was implemented for the accelerated processing speed. Furthermore, a convolutional neural network, a deep learning algorithm, was adopted to overcome the limitation of traditional machine learning methods for big data analysis; irregular shapes of defect symptoms can be well characterized using only large data set. The overall accuracy was 86.7, 98.8, 91.8, 94.5, 97.4, 94.4 percent for canker, HLB, healthy, melanose, rust mite, and wind scar, respectively. Also, the processing speed was 12.0 oranges/second. The developed system can increase the efficiency of the post-harvest process, and quantify the severity of each citrus defects for better management of citrus groves to improve the crop quality.

Final remarks concerning the competition benchmarks and strength points

My research focuses on improving upon the capacity of current vision sensing technologies for precision agriculture. Uncontrollable agricultural field conditions create unique challenges for current sensing technologies. To overcome the challenges, my research maximizes leverage from the low-cost but effective devices through the newest data processing techniques such as deep learning and parallel computing to provide practical sensing solutions for all citrus farming stages.