Giuseppe Pellizzi Prize

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INTELLIGENT VISION SENSING SYSTEMS FOR PRECISION AGRICULTURE PRACTICES IN FLORIDA CITRUS PRODUCTION

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1 Motivation

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.

<u>The overall goal of the research</u> 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.

<u>Specific objectives of the research</u> were to develop:

1. An immature green citrus detection system for yield forecasting at early fruit development stage,

2. An fruit drop detection system for evaluation of the severity of fruit tree diseases such as HLB from pre-harvest to harvesting season,

3. An evaluation system for citrus decay stages among dropped fruit for additional information in pre-harvest to harvesting season, and

4. A fruit inspection system for HLB and other common citrus defects in Florida for the post-harvest process.

2 Immature Citrus Detection for Yield Forecasting

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 (Fig. 1). 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.

Fig. 1. Image acquisition hardware in the developed citrus detection system.

Using vorticity and divergence of the gradient vector field of depth (Fig. 2), CHOI's Circle Estimation ('CHOICE') algorithm was developed to find spherical objects in depth images. The developed algorithm is a new approach utilizing NIR depth images to detect immature green citrus at a very early season.

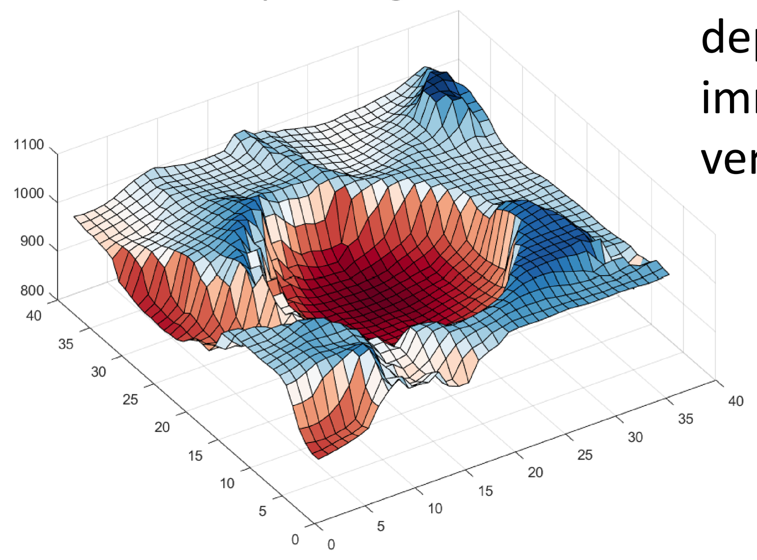

Fig. 2. Depth map of a citrus surface. The shape of the citrus fruit in the 3D is spherical regardless of maturity stages.

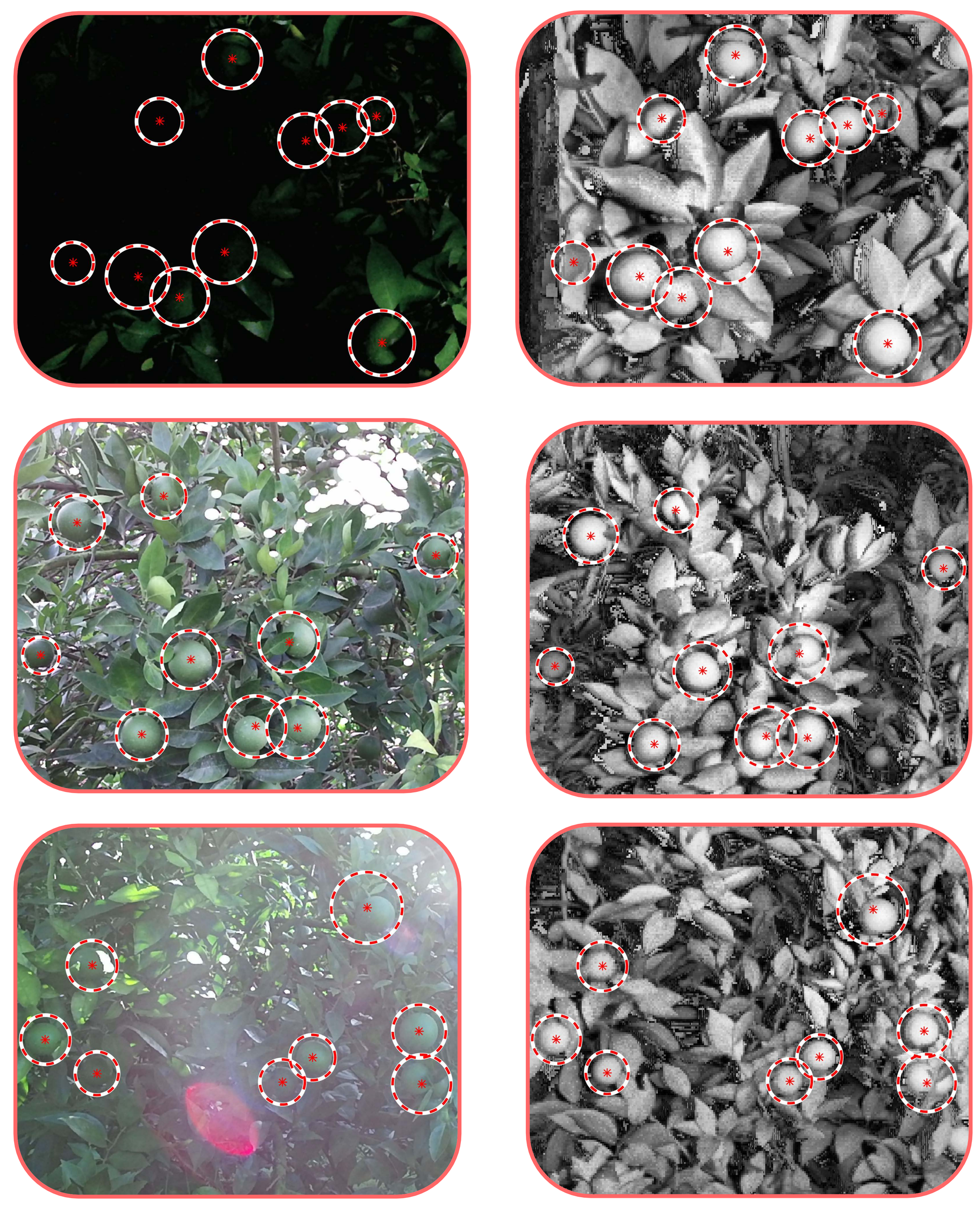

Fig. 3. Detection results under extremely varying illumination conditions

The algorithm (Fig. 3) 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%.

3 Quantification of Citrus Fruit Drop

An exotic citrus disease, HLB, causes unhealthy fruit as well as excessive early fruit drop. According to United States Department of Agriculture, the estimated amount of citrus production in the US dropped ten percent within a year. Two RGB cameras (720*1080, CMOS sensor) with own GPS receiver were installed under metal shields on moving vehicle (Fig. 4). to detect citrus fruit drop under a tree canopy. Pre-processing using contrast limited adaptive histogram equalization (CLAHE) was applied to keep average brightness constant among images. This process reduced effects of varying illumination conditions (Fig 5).

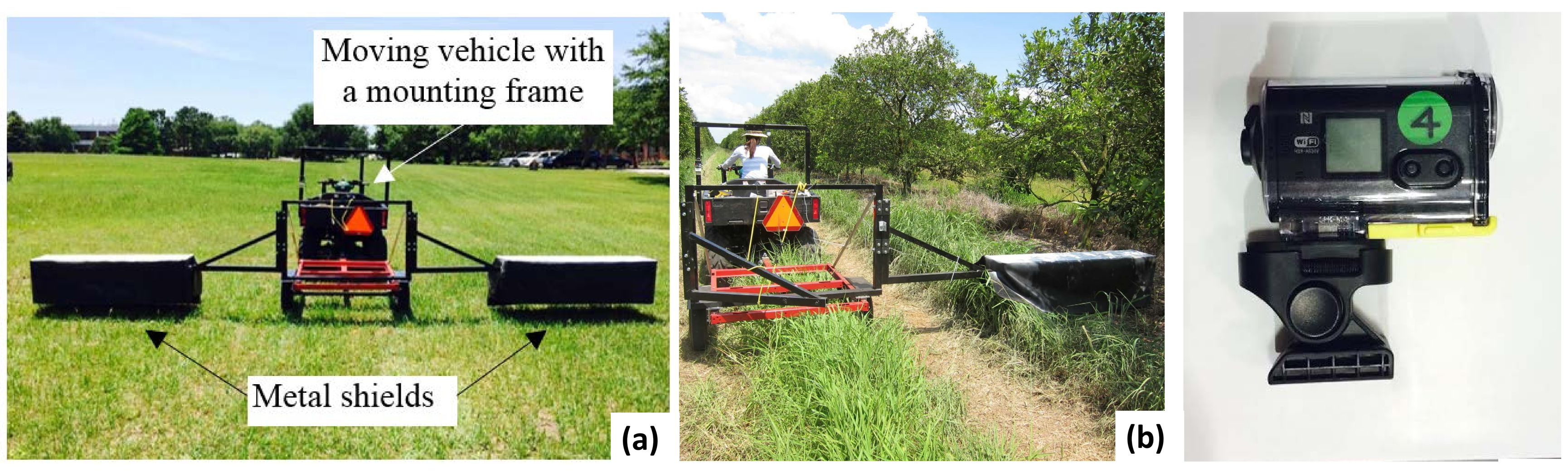

Fig. 4. Image acquisition system. (a) an off-road vehicle with trailer and metal shields for cameras, (b) vehicle moving a long with a tree row at 45cm/s, and (c) a camera used in experiment (HDR-AS30V, Sony, Japan).

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.

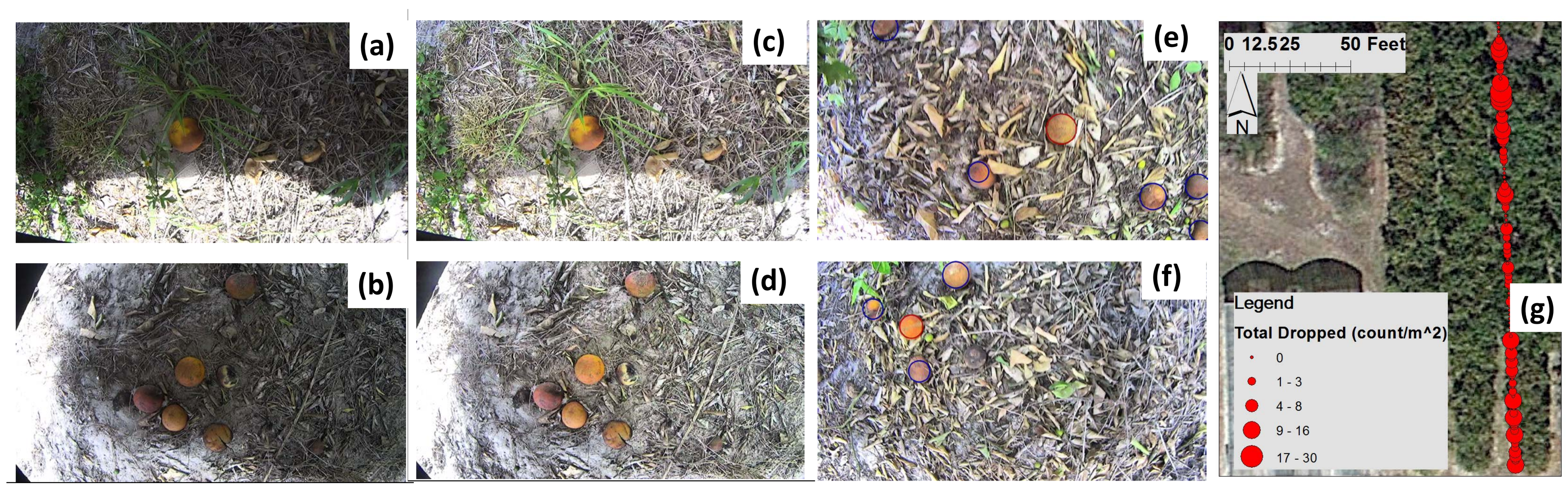

Fig. 5. Machine vision algorithm of the developed system. (a)&(b) original images with varying illumination, (c)&(d) enhanced images using CLAHE, (e)&(f) detection results using a random forest, and (g) a fruit drop map combined with GPS coordinates.

4 Postharvest Fruit Defect Inspection

The majority of the harvest citrus in Florida is used for juice processing, which requires post-harvest fruit inspection to separate fruits for the fresh market or value added products. The HLB infected tree produce the low-quality fruits. Some infected fruit is harvested along with other healthy fruit. 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 (Fig. 6). The primary focus of this system was to achieve the practical processing speed and performance that can be used in commercial citrus packinghouses.

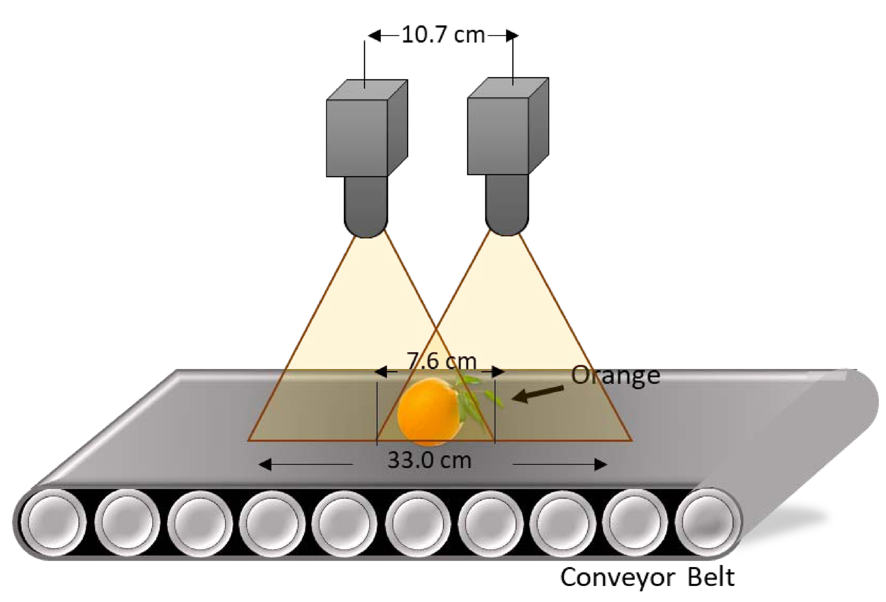

Fig. 6. The hardware setup of the prototype. The distance between the centers of the two cameras was 10.7 cm.

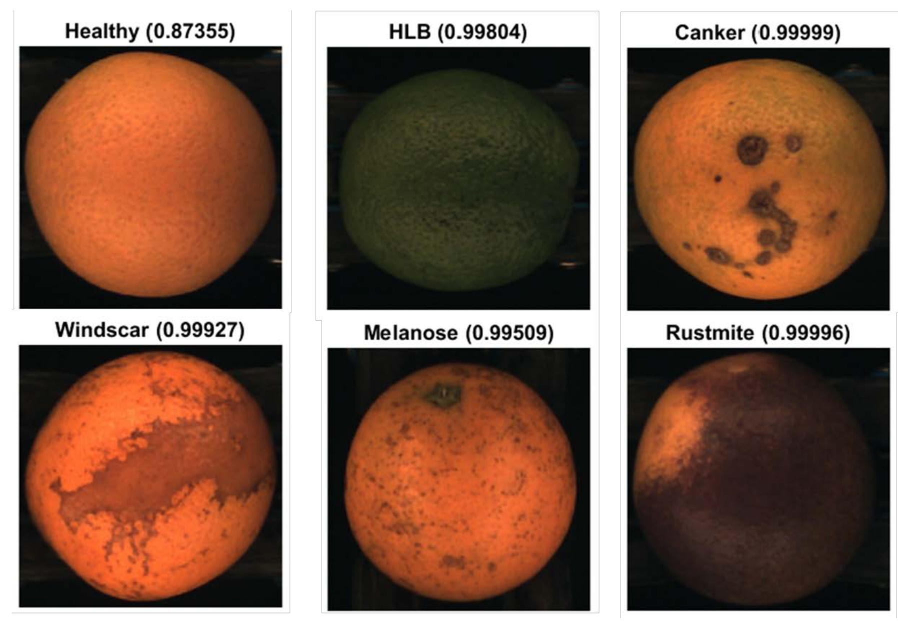

Fig. 7. Result images after the classification. The fruit with obvious symptoms had a score close to 1 .

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 handle large amount of data containing irregular shapes of defect symptoms. 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.

5 Final Remark

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.