Real-Time Grading System for Orange Citrus Fruits Using Multi-Spectral Imaging

By/ Mohammed S. Sayed
Department of Electronics and Communications Eng.
(mohammed.sayed@ejust.edu.eg)

Presentation Outline

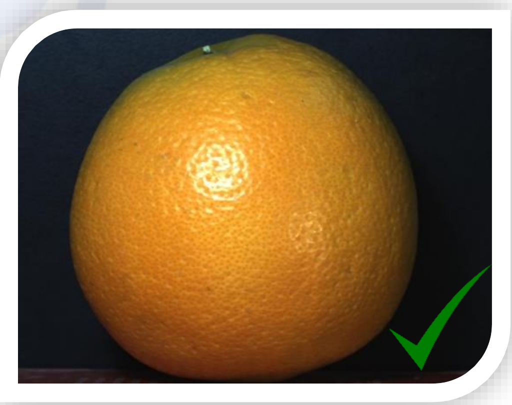
- Overview of defects detection systems for orange fruits
- The proposed defects detection system
- Results and Discussion
- Grading System Prototype

Orange Citrus Fruit Market

- Citrus fruits are the leading fruit crop in the international market → 48 million tons and $23 billion US annually.

- In 2010 → International Standard for Vegetables and Fruits (Citrus Fruits Section) was developed by the Organization for Economic Co-operation and Development (OECD).

- This standard defines specific quality requirements for citrus fruits at the export control stage based on :
  a. Size
  b. Shape
  c. Color
  d. Maturity

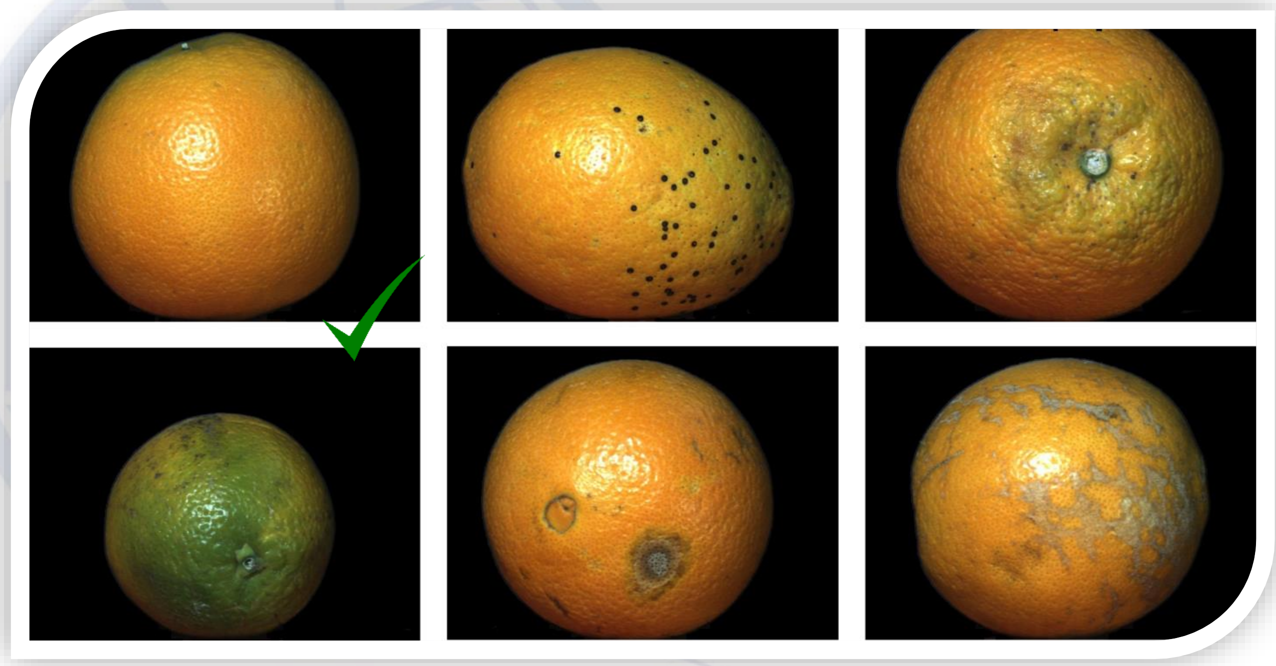


- **BUT FIRST**, the citrus fruit has to be free of diseases that cause surface defects.

Orange Citrus Fruit Defects

- According to the standard, there are five types of diseases that cause surface defects. These diseases are:

  a. Anthracnose
  b. Stem-End
  c. Unripe
  d. Green Mold
  e. Scarring.



- The defects have different sizes, textures and even colors, and citrus fruits widely vary in terms of size, shape and color as well.

Current Defects Detection Techniques

- Some recent research attention has focused on how to detect the defects of orange citrus fruits based on :

  a. Color images (RGB) → check the color value of each pixel and compare it with the natural sense of orange fruit color → **highly depends on the lighting system.**

  b. Neural network classifiers → based on the mean and variance of the red, green and blue components → **highly depends on the training set**.

  c. Different imaging modalities → use the Ultraviolet and Fluorescence computer vision system → **expensive solution.**

The proposed defects detection system

- The stages of the proposed system are
  1. Image Acquisition → single camera with RGB and NIR image sensors
  2. Citrus Fruit Segmentation
  3. Image Pre-Processing
  4. Thresholding Techniques
  5. Classification.

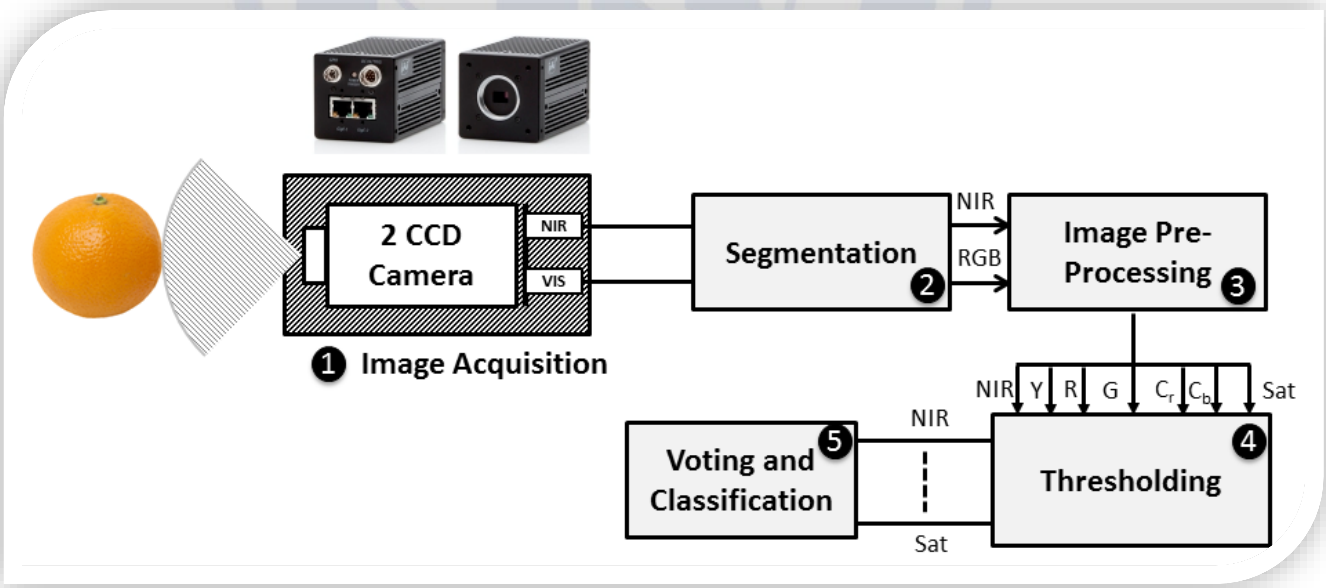
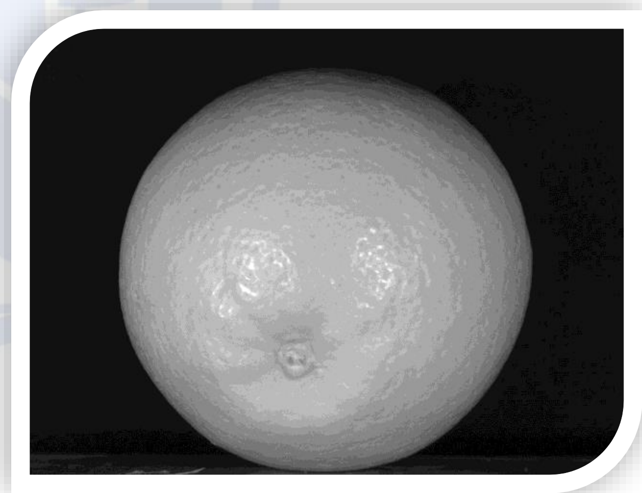


Image Acquisition

- The image acquisition system consists of two CCD scan camera that acquires visible Red Green Blue (RGB) and NIR images simultaneously and showing the images on two different channels.

- The NIR sensor is sensitive to wavelengths from 760 nm to 960 nm.



Citrus Fruit Segmentation

- Both RGB and NIR images are captured using the same camera sensor position.
- Orange fruit segmentation algorithm is applied only on one channel (NIR) and the same generated mask is used to segment the other image.
- Segmentation is based on:
  1. Sobel edge detection
  2. Thresholding → Binary Image
  3. Closing Morphological
  4. Filling Holes → get the final Region of Interest (ROI)

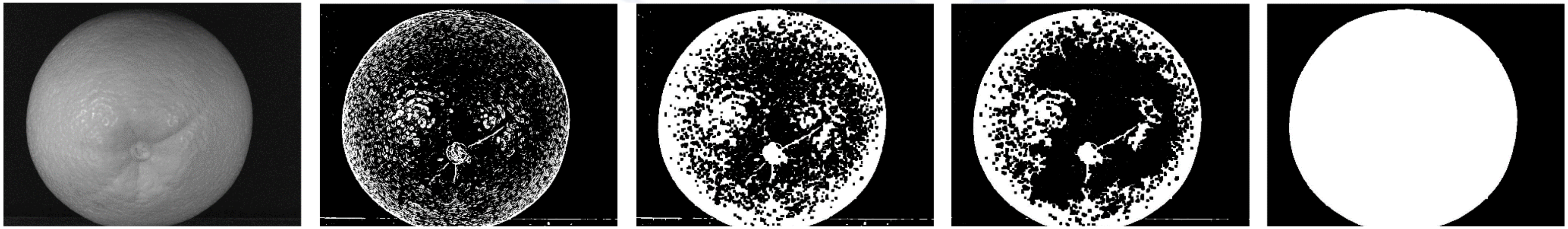
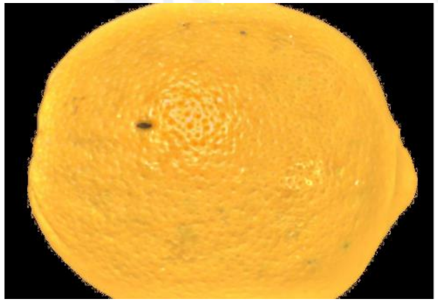
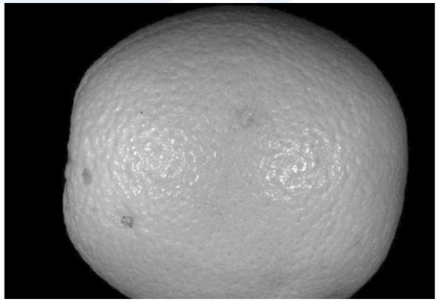
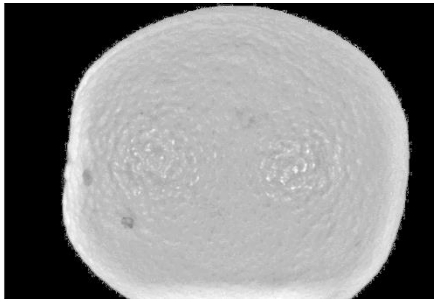


Image Pre-Processing

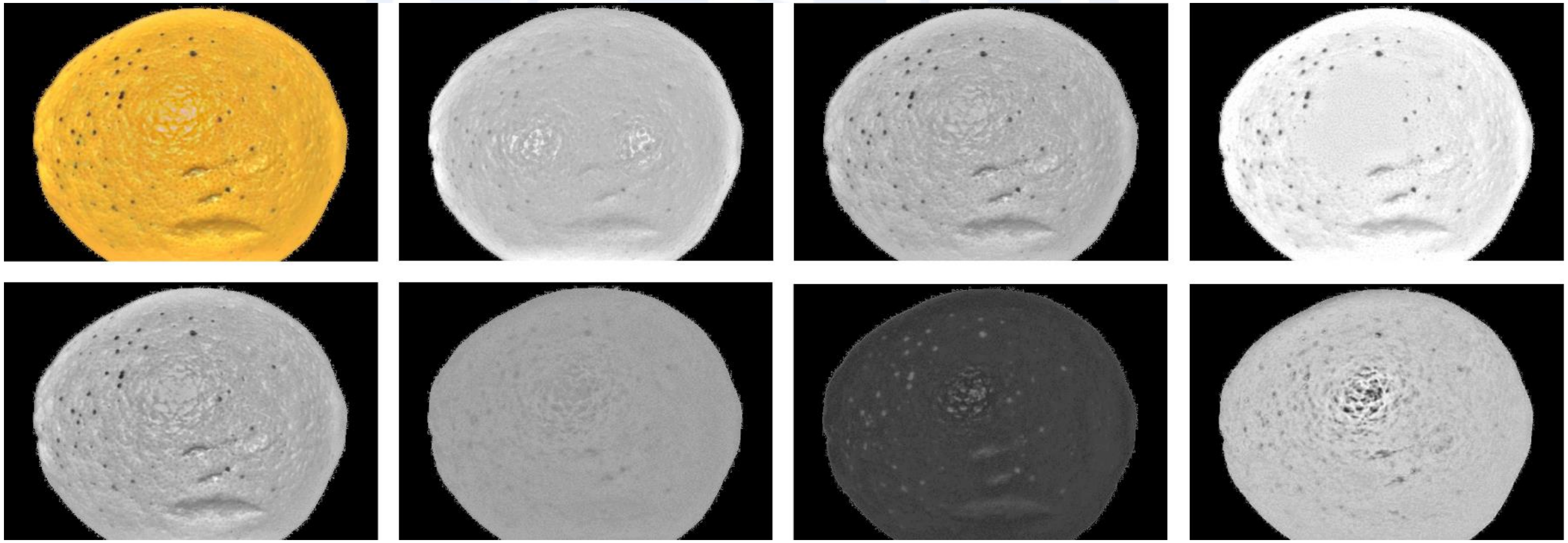
- The illumination of the citrus fruit is often non-uniform due to the reflection of the light sources.
- Orange fruit images are variable in terms of color, size and quality.
- Therefore the image pre-processing applies:
  1. Illumination Equalization
  2. Contrast Equalization
  3. De-noising

Thresholding Techniques

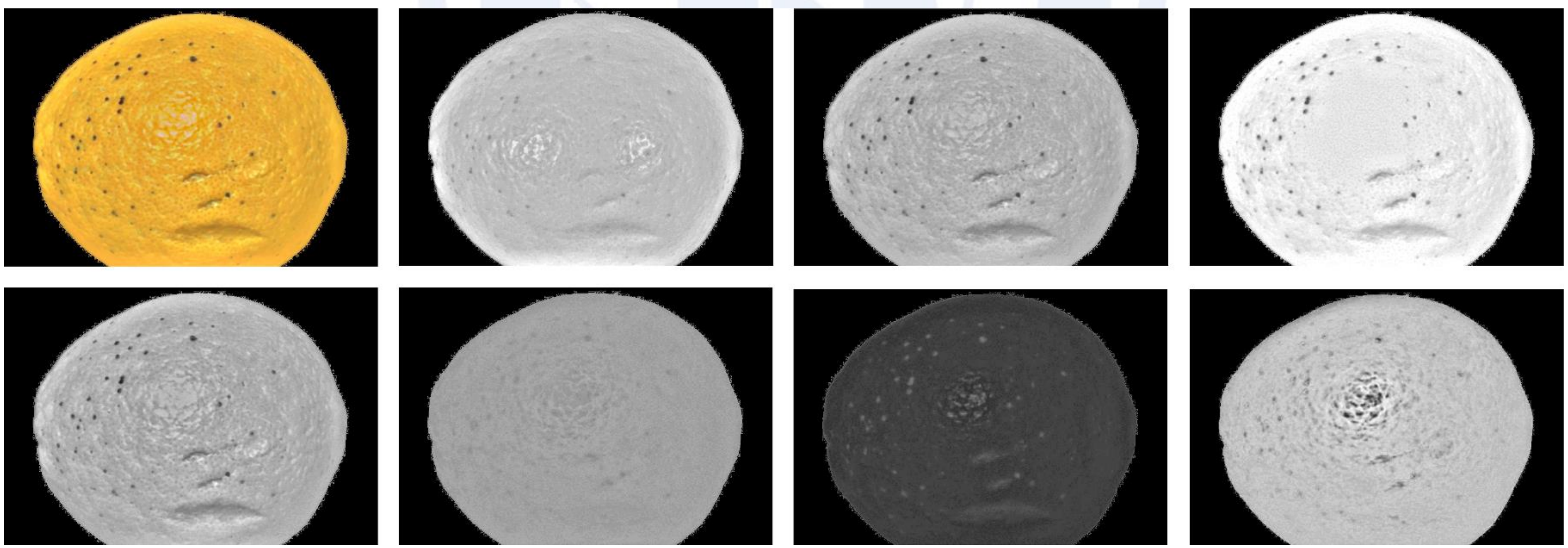
- We propose using Sauvola adaptive thresholding techniques on different color components of each input image → based on (mean and STD).

- The proposed adaptive thresholding techniques are applied on seven different color components in order to achieve higher accuracy of defects detection (NIR, R, G, Brightness (Y), Cr, Cb and Saturation).



Thresholding Techniques cont.

- NIR → defects that are not affected by visible light or color change.
- Brightness (Y) → defects that cause image intensity change.
- Red, Cr → defects if the orange fruit color tends to red color.
- Green → defects if the orange fruit color tends to green color.
- Cb → monitor the orange fruit through the whole color space.
- Saturation → confirm the defects in R, Cr, G, Cb and Y components.



Classification

- We propose a voting technique that exploits the idea of using seven different color components and assigns number of credits to each defected color component based on its importance.

Color Comp.	NIR	Y	R	G	Cr	Cb	Sat	Total
Credits	6	4	3	3	2	2	1	21

- The voting technique assigns ZERO credit to each defect free color component.

- The orange fruit image is considered defected if it has more than 12 credits as the total number of credits (experimentally found). → **at least one of the two most important color components (NIR and Brightness) must be defected.**

Results and Discussion

- All the simulations were performed using **OpenCV 3.1** library on Windows 7 OS platform with Intel Core i7 at 1.87 GHz CPU and 8 GB RAM.
- A dataset of 143 orange citrus fruits image was captured in order to carry out the experiments.
- The 143 image dataset contains 43 defect free image and 100 defected image.

Results and Discussion cont.

- The quality of any classifier is usually measured by calculating: **Sensitivity** and **Specificity** as follows:

$$Sensitivity = \frac{TP}{TP + FN}, Specificity = \frac{TN}{TN + FP}$$

- where:
  - True Positive (**TP**) is the no. of defected images and classified as defected.
  - False Positive (**FP**) is the no. of defect free images and classified as defect free.
  - True Negative (**TN**) is the no. of defected images and classified as defect free.
  - False Negative (**FN**) is the no. of defect free images and classified as defected.

Results and Discussion cont.

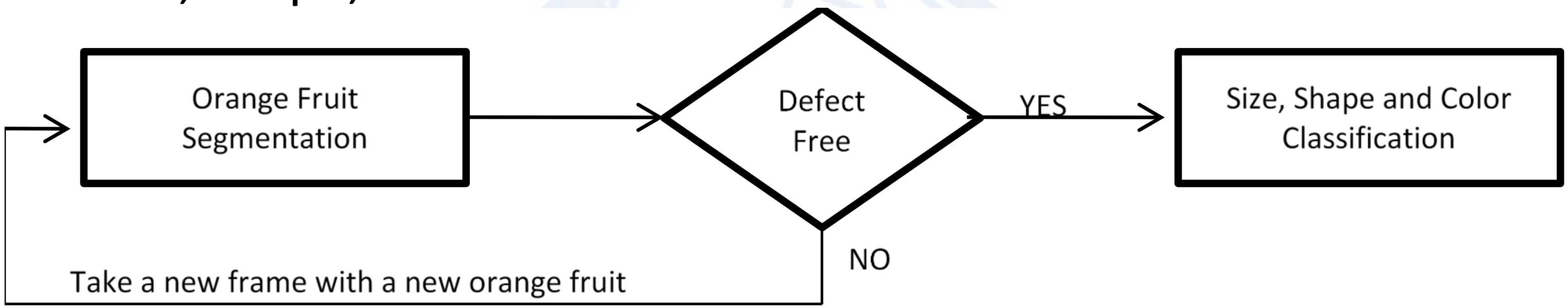
- The proposed algorithm achieved about 95% in both sensitivity and specificity.

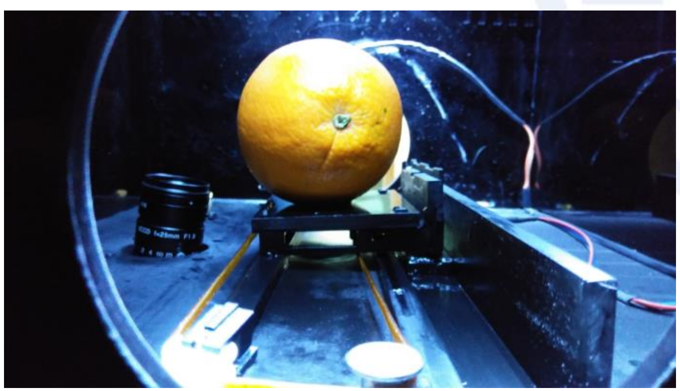
- The overall accuracy of the algorithm is about 95% and the system achieves grading speed of 3 fruits/s.

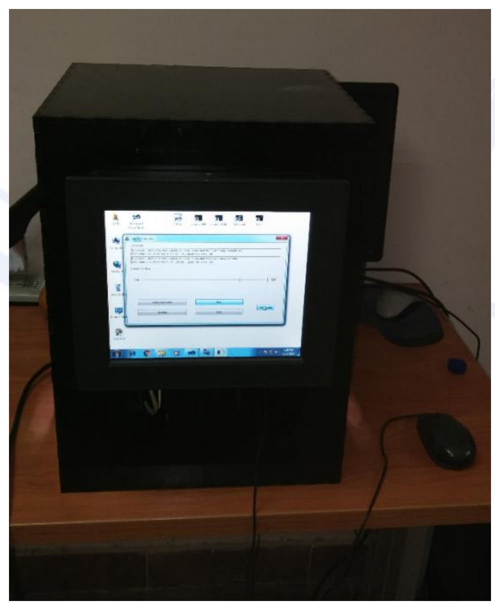
	Percentage
Sensetivity	(95/100) 95 %
Specificity	(41/43) 95.4 %

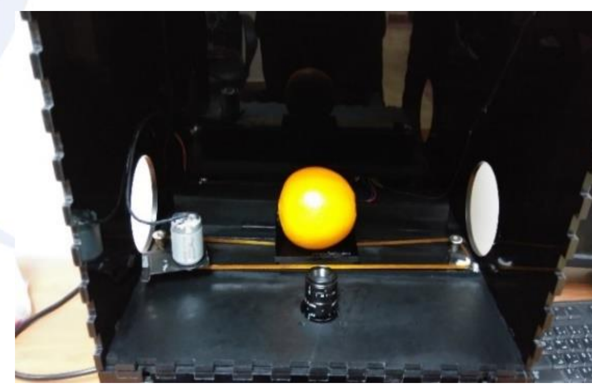
Grading System Prototype

- A full grading system was built based on defects existence, size, shape, and color.









Startup Company

QEYE

Smart Vision Systems

www.qeyeco.com

STARTUP OPEN

Among the top 10 startup open finalists at 2016 Global Entrepreneurship Congress

Thank You