

DEVELOPMENT OF A COMPACT QUALITY SORTING MACHINE FOR CHERRY TOMATOES BASED ON REAL-TIME COLOR IMAGE PROCESSING.

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Abstract

Even though cherry tomato is one of the major vegetables consumed in Asian fresh-cut markets, its quality evaluation process is only dependent on mechanical size-based sorting methods that employ drum or bar shaped-sorting machines. Consumers are increasingly demanding high quality products to satisfy their standards. The application of the non-destructive sensing technologies for quality measurement of individual cherry tomatoes has rarely been attempted due to high-throughput sorting in limited time frame. In this study, a compact non-destructive quality sorting machine was developed using a real-time color image processing method for rapid quality measurement of individual cherry tomatoes. Color, deformity, and defects on cherry tomatoes were rapidly inspected by the sorting machine. Following the overall quality evaluation, individual cherry tomatoes were sorted into the designated quality groups with a novel mechanical sorting unit implemented at the end of the machine. Results show that cherry tomatoes were successfully graded with an accuracy of above 80% and a maximum sorting rate of about 360 kg per an hour.

Key words: cherry-tomato, sorting-machine, image-processing, quality-measurement

1. Introduction

Due to market expansion, the cherry tomatoes sorting technique requires non-destructive, effective, less time consuming and higher quality standards. Nevertheless, cherry tomato quality grading is usually performed on employ drums or bar shaped-sorting equipments, which are based on size sorting. Size sorting techniques are deficient in satisfying consumer demands in Asian countries. Consumers always demand higher quality products. Color, size, surface defects, firmness, and sugar/acid contents of cherry tomatoes are important factors in evaluating the overall quality and market value of the vegetable. In particular, the color of the cherry tomatoes is a major decision factor for consumers in choosing what product to purchase.

During the exporting process, the color of the cherry tomatoes develops through the green, the breaker, the turning, the pink, and the light red or red phases as time passes. So it is necessary to export the red cherry tomatoes to nearby countries and the green cherry tomatoes to further countries. Thus, this is the reason why the process of determining the color of the cherry tomato is so imperative to the market operation.

Selection and inspection of the color of cherry tomatoes with human resources is problematic because of fatigue and inconsistencies. Undoubtedly, there is great difference between computer vision grading systems and human eye sight. So, eye sight inspection system cannot be considered quantitative analysis. But CCD camera offers the sensitive quantitative color grade methods and the obtained image shows detailed views of cherry tomato's color properties.

In this study, the obtained color images from a CCD camera were used to investigate the feasibility of a compact ripening stage sorting system for cherry tomatoes based on real-time image processing.

2. Material and methods.

2.1. Whole cherry tomato samples

In this experiment 'yoyo' Cherry tomatoes were harvested from a farm in Nonsan, Chungnam, South Korea in April 2012. The total number of cherry tomatoes used in this experiment was 360. The harvested tomatoes were divided into six different categories of ripeness. The different ripening stages of each were characterised according to the USDA standards (Table 1). Each cherry tomato was measured and classified into 3 stages, and these are provided in Figure 1.

TABLE 1: USDA ripening classes of tomatoes (USDA, 1991)

| Ripeness Stage | External Color ^a |
|----------------|---|
| Green | All percentages refer to both color distribution and intensity. |
| Breaker | There is a definite break in color from green to tannish-yellow, pink or red on not more than 10% of the surface. |
| Turning | 10% to 30% of the surface is not green; the aggregate, shows a definite change from green to tannish-yellow, pink, red, or a combination thereof. |
| Pink | 30% to 60% of the surface is not green; the aggregate, shows pink or red color. |
| Light red | 60% to 90% of the surface is not green; the aggregate, shows pinkish-red or red. |
| Red | More than 90% of the surface is not green; the aggregate, shows red color. |

^a All percentages refer to both color distribution and intensity.



FIGURE 1: Photos of the tomato samples

2.2. Image acquisition system

Interface software to control the imaging acquisition system was developed by using visual studio (version 2008, Microsoft, Seattle, Washington, U.S.A) operating in a Microsoft Windows platform.

Figure 2 shows a compact quality sorting machine for cherry tomatoes. The sorting system was composed of three charge coupled device (CCD) colour camera (HCC-640, Honeywell, Seoul, Korea) and a frame grabber (Cronos plus, Matrox, Cannada), which were connected to a personal computer to display the captured image. The CCD camera captures color images in 640 x 480 pixels. Compact fluorescent lamp lighting (4EA) was used as light sources for color imaging. The frame grabber digitized the acquired analogue signals and provided three user-defined buffers in red, green and blue channels (RGB). When the tomatoes were not arranged in a row or a line, the camera was unable to capture a single tomato image. Therefore, arranging the tomatoes in a line was a very important process. To arrange cherry tomatoes in a row, two conveyors belt parts were used. The velocity of the two belts was set differently from one another. Figure 5 shows part of the system that sorts for color.

TABLE 2: Specification of the prototype of color sorting system

| Item | Specification |
|------------------|---|
| Color CCD camera | Color 1/3" 768(H) × 494(V), NTSC signal format, 10 bit digital signal processing, 480 TV Lines, Internal or External Sync System |
| Frame grabber | Video capture board for PCI form factor, Captures from NTSC, PAL, RS-170 and CCR video sources, Connect up to 4 CVBS or 1 Y/C trigger input |
| Lens | 8 mm manual focusing lens |
| Lighting | 25 W compact fluorescent lamp × 4 |

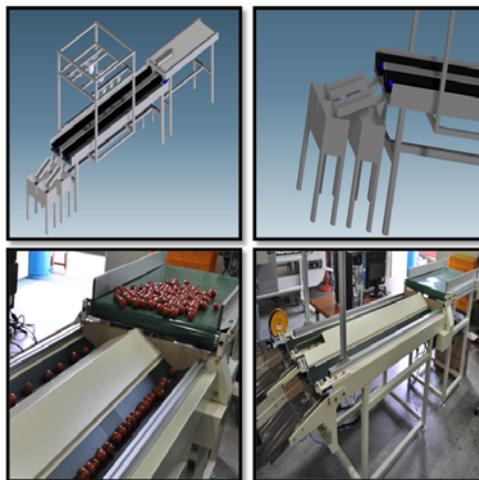


FIGURE 2: Schematics and photo of the prototype of the color sorting system

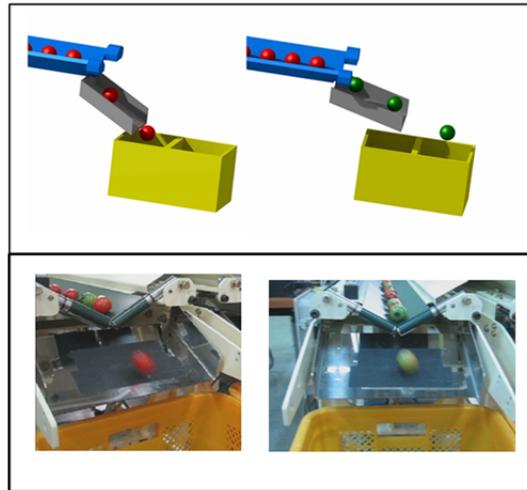


FIGURE 3: Schematics and photos of the sorting part

2.3. Image analysis

The real time operation started with the acquisition of the original image of cherry tomatoes (RGB color). Then, the original image's RGB color space was converted to L, a*, b* color spaces respectively. After this process, the background was removed from b value thresholding image and eventually, the final a value and b value image were acquired. Figure 4 shows the detection of cherry tomato surface.

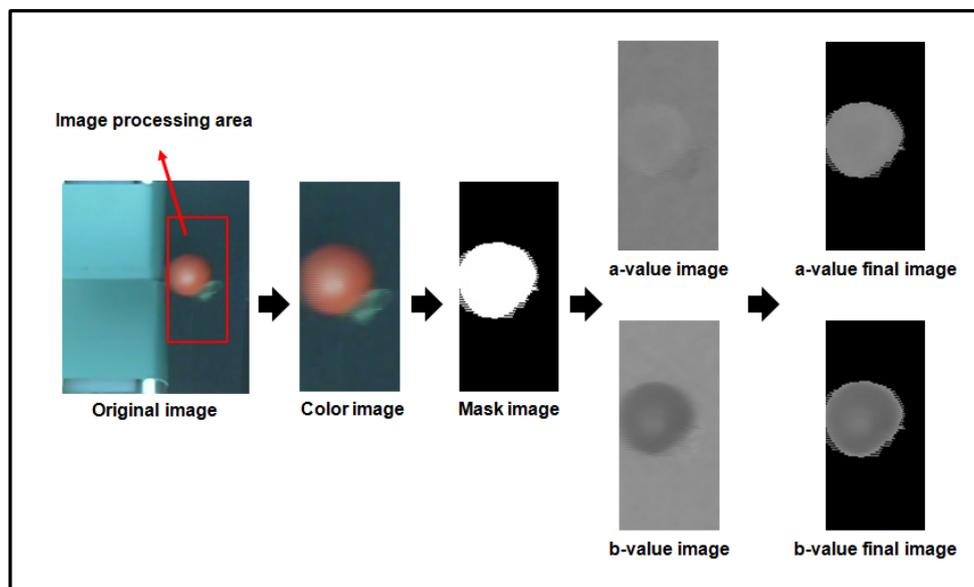


FIGURE 4: Image processing procedures for sorting cherry tomato

3. Results and Discussion

The $L^*a^*b^*$ color spaces were characterized according to a^* ranging from green to red, and b^* ranging from blue to yellow. It provided effective color discrimination. Therefore, the a^* and b^* value of cherry tomato colors were applied for color evaluation. The resulting distinction results are shown in figure 5. The a^*b^* of cherry tomatoes are used to develop the

boundary equation. The boundary equation could clearly divide each ripening stage into three groups. Two boundary equations are shown below in Equ. 1 and 2.

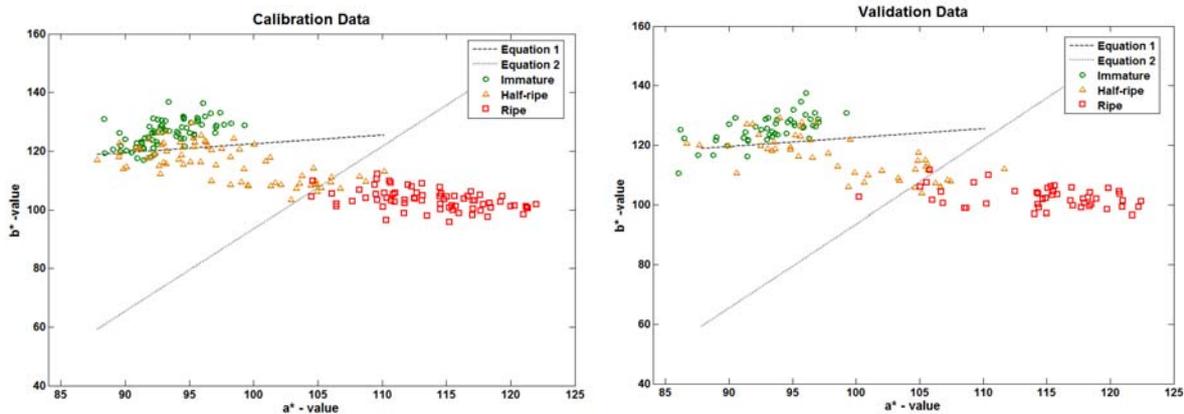


FIGURE 5: Classification using boundary equation according to ripening stages

$$f_1(a^*, b^*) = -0.0959a^* + 0.3222b^* - 29.8878 \dots \dots \text{Equation 1}$$

$$f_2(a^*, b^*) = -0.5540a^* + 0.1971b^* + 36.9351 \dots \dots \text{Equation 2}$$

$$f_1(a^*, b^*) > 0 \dots \dots \text{Immature}$$

$$\begin{cases} 0 > f_1(a^*, b^*) \\ f_2(a^*, b^*) > 0 \end{cases} \dots \dots \text{Half-ripe}$$

$$0 > f_2(a^*, b^*) \dots \dots \text{Ripe}$$

Figure 6 shows the real-time pictures of cherry tomatoes without their stems. The resultant images show that most of the tomato surfaces were effectively removed from the background and stem. These images were used to detect the surfaces of cherry tomatoes. After removing the background and the stem, the a^* and b^* values of the picture were collected to calculate the average and then, the color stages were graded by average a^*b^* values. The result for the accuracy deciding the stage of ripening can be seen below in Table 3.

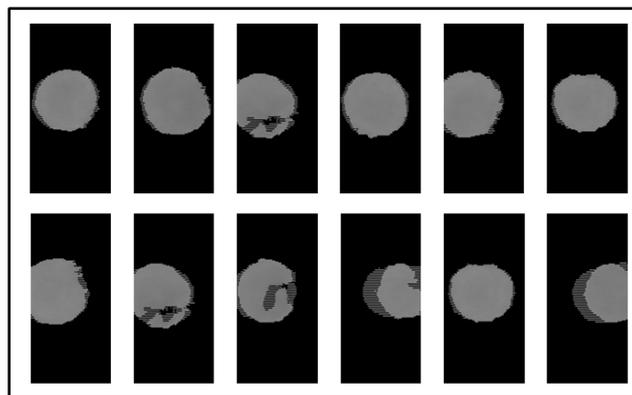


FIGURE 6: Resultant images for real-time detection of cherry tomatoes surface.

TABLE 3: Calibration and validation results of classification using boundary equation

| Calibration | Classification results | | |
|------------------------------|------------------------|-----------|--------------|
| | Correct | Incorrect | Accuracy (%) |
| Ripe (Light red, Red) | 71 | 1 | 98.61 |
| Half-ripe (Turning, Pink) | 46 | 26 | 63.89 |
| Immature (Green, Breaker) | 67 | 5 | 93.06 |
| Total | 184 | 32 | 85.19 |
| Validation | Classification results | | |
| | Correct | Incorrect | Accuracy (%) |
| Ripe (Light red, Red) | 46 | 2 | 95.83 |
| Half-ripe (Turning, Pink) | 26 | 22 | 54.17 |
| Immature (Green, Breaker) | 44 | 4 | 91.67 |
| Total | 116 | 28 | 80.56 |

4. Conclusion

In this study, computer vision was presented as a method of detecting the ripening stage of cherry tomatoes. Color images of cherry tomatoes moving in the conveyor belt was taken by a CCD camera. Then, the cherry tomatoes' images were isolated from the background through mask image. Following this process, two characteristics of a^*b^* values were extracted from the color iamges of one cherry tomato. Eventually, the optimal boundary equation was used to decide the ultimate ripening stageFurthermore, the grading speed of the color sorting system attained 360 kg per hour. As this experiment demonstrates and suggests, it is possible to develop a color sorting system for online measurement that can be applied to other industrial usage.

5. ACKNOWLEDGEMENT

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6. REFERENCES

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