Walailak J Sci & Tech 2006; 3(2): 195-205.

Automated Chokun Orange Maturity Sorting by Color Grading

Yaowarat SIRISATHITKUL, Naphasorn THUMPEN and Weerayut PUANGTONG

School of Informatics, Walailak University, Nakhon Si Thammarat 80161, Thailand

ABSTRACT

An image processing technique is developed in order to guide Chokun orange maturity sorting. The objective of this research is to assess the fruit maturity by color grading. The process is divided into two major steps, the training step and the testing step. In the training step, images of 90 Chokun oranges of three different degrees graded by an experienced farmer are collected by a color digital camera under the normal illumination conditions with white fluorescent lamps. Then, the original RGB (Red, Green and Blue) color image of an orange is transformed into an ISH (Intensity, Saturation and Hue) image. From the hue images, the hue colors are analyzed and then used to form decision rules. A classifier is implemented using these decision rules. In the testing step, the degree of maturity of 50 Chokun orange samples is tested. The Chokun orange maturity sorting is done by using the classifier obtained from the training step. The experimental results show that the method of grading the Chokun oranges could be a feasible alternative with a success rate of about 98 %.

Keywords: Chokun orange maturity sorting, decision rule, classifier, image processing, ISH color model

INTRODUCTION

Color grading is an important process for the agriculture industry especially in food processing, fruit and vegetable grading. The color of products is often used to determine quality and price. Consumers have developed distinct correlations between color and the overall quality of a specific product. Industries use machine vision technology to grade the products based on their surface colors for maintaining quality and price of products. Moreover, color grading is used to determine the time to market. This is necessary for commercial reasons because a rotten fruit placed among good ones can deteriorate the whole lot. In the agriculture industry, color grading applications are implemented by using color image processing. The advancement of color grading is based on the development of color charge coupled device (CCD) camera. Since food products can be graded by their color, color grading for peaches [1-3], apples [4,5], potatoes [5], cucumbers [6], tomatoes [7], mangoes [8] and oranges [9,10] have been developed. The peach grading system is used for maturity classification by comparing each color to the reference to determine the degree of maturity [3]. A machine vision system using the ISH (Intensity, Saturation and Hue) color model is highly effective for color evaluation [5,11]. The ISH space is compatible with human intuition and hue attribute is also independent on intensity changes. Thus, hue color is widely used to determine the level of skin color.

All the above machine vision systems utilize the color information for quality control or maturity estimation of products. Color space conversion from RGB (Red, Green and Blue) to ISH is the most common technique. Instead of high accuracy, speed of processing and repeatability of measurements are of major interests in this context. Thus, a simple and easy color grading technique for Chokun oranges has been developed in this paper. Generally, the Chokun orange is a green colored fruit. The level of maturity for Chokun oranges can be represented by external appearance such as color. For example, Chokun oranges with dark green, light green and yellowish color represent raw, ripe and overripe respectively.

In this project, we propose a computer vision system that can analyze surface color of the Chokun oranges from their images. There are 90 Chokun orange samples in three different degrees graded by an experienced farmer's eyes and hands. First, the original RGB color image of each orange is captured and transformed to an ISH image. From the hue images, the hue colors are analyzed, collected and then used to form decision rules for a classifier. Chokun orange maturity is sorted by using the classifier and tested with 50 Chokun oranges of

three different degrees. The next section describes image acquisition and our proposed methods in analyzing the colors of orange images, building a color classifier and a Chokun orange maturity sorting.

MATERIALS AND METHODS

In this section, we describe in detail our methods in processing and analyzing Chokun orange images. The section is divided into four parts: Chokun orange images acquisition, Chokun orange images color analysis, Color classifier building and Chokun orange maturity sorting.

1. Chokun orange images acquisition

All Chokun orange samples for training and testing were obtained from Veawphet's Chokun orange farm in Surat-Thani. The Chokun oranges were harvested at the same time for selling. There were three different grades (raw, ripe and overripe) 30 Chokun oranges of each grade for training and 50 samples for testing. The Chokun oranges were graded by an experienced farmer's eyes and hands.

The image acquisition set-up is shown in **Figure 1**. Color images of Chokun orange fruits were collected using color camera with 640×480 pixels (SONY, DSC-P100) and saved in JPEG format. The digital camera was 20 cm away from the orange and used to capture the front-view image of the orange. The orange was placed in front of a white background. The images were taken under normal illumination conditions with white fluorescent lamps in the factory. **Figure 2** shows an example of the obtained image.

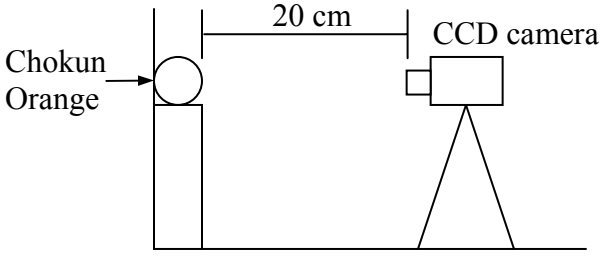
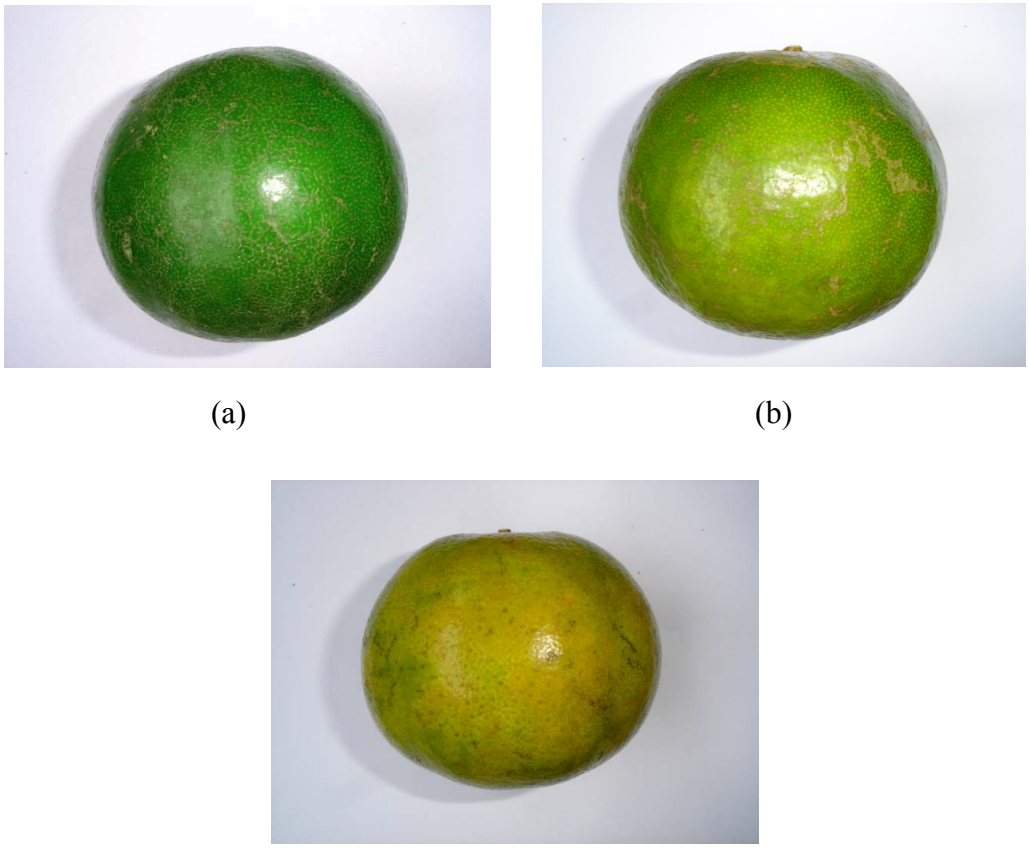


Figure 1 Image acquisition set-up.



(a) (b)

(c)

Figure 2 Acquired input images of Chokun orange: (a) raw (b) ripe and (c) overripe.

2. Chokun orange images color analysis

After acquiring 90 Chokun orange images, an image was picked sequentially and used as a training set. First, the color image in JPEG format was converted into 24-bit RGB format using TJPEGImage Class provided in Borland C++ Builder. The 24-bit RGB color image was transformed to the ISH color model for evaluating the hue value, H, according to the following equations [12].

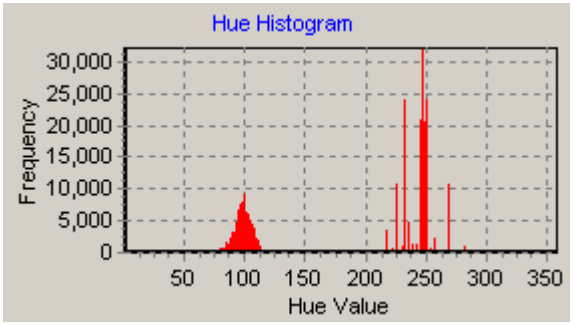
$$H = \begin{cases} \theta & \text{if } B \le G \\ 360\text{-}\theta & \text{if } B > G \end{cases} \quad (1)$$

where

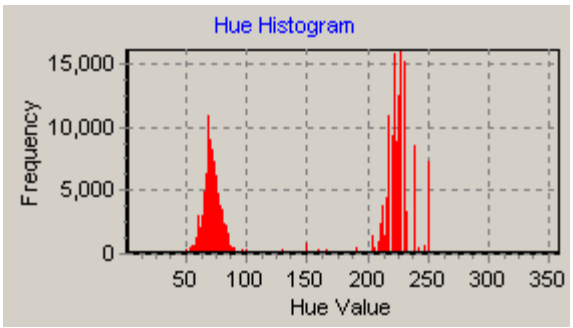
$$\theta = \cos^{-1}\left\{ \frac{\frac{1}{2}\left[(R-G)+(R-B)\right]}{\left[(R-G)^2+(R-B)(G-B)\right]^{1/2}} \right\} \quad (2)$$

and RGB values have been normalized to the range [0,1].

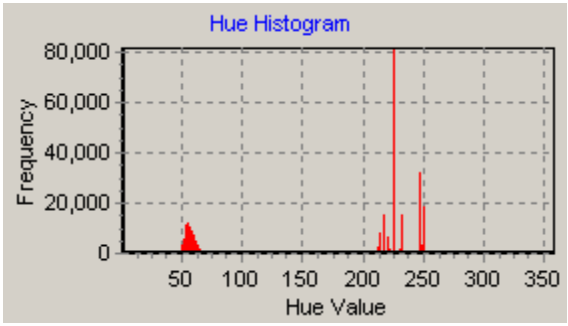
A basic analysis method for the color distribution of a fruit is the evaluation of the hue histogram. Thus a Chokun orange's surface hue histogram was constructed using hue values computed from all pixels. **Figure 3** shows the hue histogram of an input image.



(a)



(b)



(c)

Figure 3 Hue histograms of an input image: (a) raw (b) ripe and (c) overripe.

3. Color classifier building

After obtaining the hue histograms of all input images, the hue histograms were then further analyzed to obtain a color interval for the Chokun orange grading: raw, ripe, and overripe. The hue histogram implemented in the training was decidedly bimodal. Two mode values were evaluated and assigned for each Chokun orange. The values for 30 oranges in each grade were then plotted as exemplified in **Figures 4, 5** and **6**. According to these graphs, the decision rules to classify orange grade are established from the mode value of hue. The algorithm for classifying Chokun orange is as follows:

if h246+h248+h250 is the maximum value
{
if (h214+h217 = 0) then grade is Raw
else if (h217+h222+h225 > h222+h225+h239) and (h217+h222+h225>=15 then grade is Overripe
else grade is Raw
}
else if h222+h225+h239 is the maximum value
{
if (h61to70 =0 and h71to80 = 0) then grade is Overripe
else grade is Ripe
}
else if h217+h222+h225 is the maximum value

```
{
        if (h61to70 =0 or h71to80 = 0) and (h214+h217 !=0) then grade is
Overripe
        else if (h61to70 !=0 and h71to80 != 0) then grade is Ripe
        else if (h246+h248+h250 >= 10) then grade is Raw
        else grade is Overripe
}
```

where h246 is an aggregated percentage of hue value at 246 degree, h61 to 80 is a summation of aggregated percentage of hue values from 61 to 80 degree, and so on.

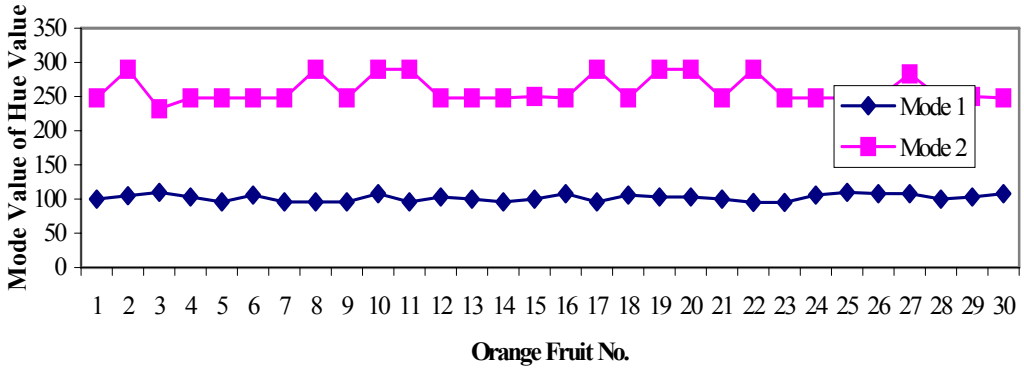


Figure 4 Mode values of hue color for Chokun orange: Raw.

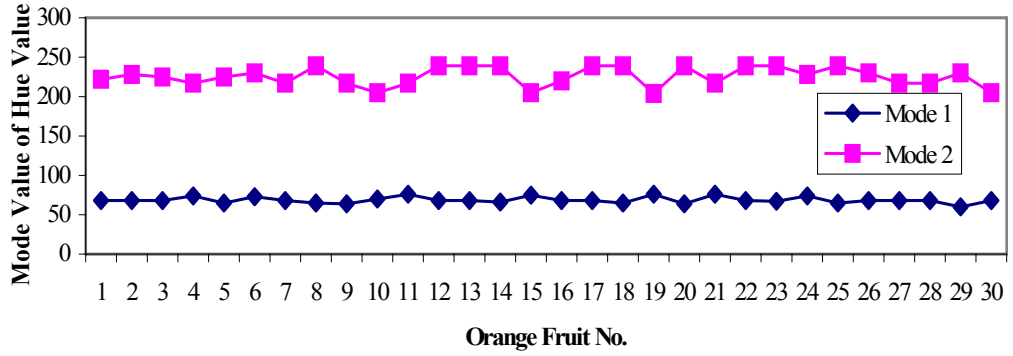


Figure 5 Mode values of hue color for Chokun orange: Ripe.

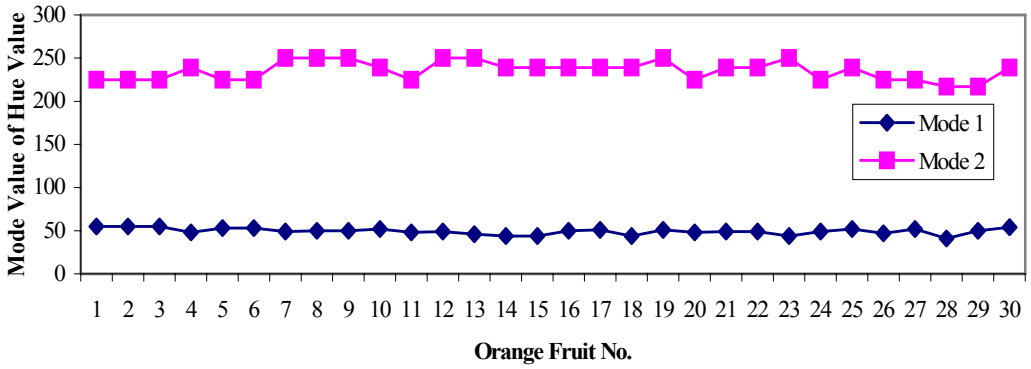


Figure 6 Mode values of hue color for Chokun orange: Overripe.

4. Chokun orange maturity sorting

After acquiring 50 Chokun orange images, an image was picked sequentially and used as a test set. First, the color image in JPEG format was converted into 24-bit RGB format using TJPEGImage Class provided in Borland C++ Builder. The 24-bit RGB color image was transformed to the ISH color model for obtaining the hue value, H, according to Eq. (1) and (2). The Chokun orange maturity was sorted by using the classifier obtained from step 3.

RESULTS AND DISCUSSION

The proposed method was implemented using Borland C++ Builder 6.0 on an Intel Pentium M 1.7 GHz Notebook with 512 MB RAM. All the 90 front-view Chokun orange images were processed according to the method explained in the previous section to obtain the hue color for building a classifier. Fifty front-view Chokun orange images were tested to evaluate the performance of the classifier. The results are summarized in **Table 1**.

Table 1 Results of Chokun orange maturity sorting from 50 orange images.

Grade	Amount	Correct	Incorrect
Raw	1	1	0
Ripe	36	35	1
Overripe	13	13	0
Total	50	49	1

From experimental results, the proposed method achieved 49 corrected sorting out of 50 samples accounting for 98 % success rate. The test on raw oranges is limited in number because the Chokun oranges sent to the factory in a real situation are mostly ripe and overripe.

CONCLUSIONS

An automated Chokun orange maturity sorting by color grading is developed. This system consists of a color CCD camera for image acquisition and a computer for image processing. The ISH color model is used and decision rules are derived from the hue color. Ninety Chokun oranges in three degrees (raw, ripe and overripe) are used in the training step and 50 Chokun oranges are evaluated in the testing step. The experimental results show that the technique is a considerable alternative and a more feasible method for grading large amounts of Chokun oranges compared with manual grading. To improve the standard of the grading, data from all sides of each orange have to be analyzed. To extend the research, we plan to work with other external physical properties of Chokun oranges such as size and shape.

REFERENCES

[1] S Nimesh, MJ Delwiche and RS Johnson. Image analysis methods for real-time color grading of stonefruit. *Comput. and Elec. in Agri.* 1993; **9(1)**, 71-84.

[2] S Nimesh, MJ Delwiche, RS Johnson and J Thompson. Peach maturity grading with color computer vision. *Trans. of ASAE.* 1992; **No. 92-3029**, 21-4.

[3] BK Miller and MJ Delwiche. A color vision system for peach grading. *Trans. of ASAE.* 1989; **32(4)**, 1484-90.

[4] Z Varghese, CT Morrow, PH Heinemann, HJ Sommer III, Y Tao and RM Crassweller. Automated insection of Golden Delicious apples using color component vision. *Trans. of ASAE.* 1991; **No. 91-7002**.

[5] Y Tao, PH Heinemann, Z Varghese, CT Morrow and HJ Sommer III. Machine vision for color inspection of potatoes and apples. *Trans. of ASAE.* 1995; **38(5)**, 1555-61.

[6] WC Lin, JW Hall and A Klieber. Video imaging for quantify cucumber fruit color. *Hort. Tech.* 1993; **3(4)**, 436-9.

[7] KH Choi, GH Lee, YJ Han and JM Bunn. Tomato maturity evaluation using color image analysis. *Trans. of ASAE.* 1995; **38(1)**, 171-6.

[8] P Yimyam, T Chalidabhongse, P Sirisomboon and S Boonmung. Physical properties analysis of mango using computer vision. *In*: Proceeding of ICCAS 2005, Gyeonggi-Do, South Korea. 2005.

[9] JB Njoroge, K Ninomiya, N Kondo and H Toita. Automated Fruit Grading System using Image Processing. *In*: Proceedings of SICE 2002, Osaka, Japan. 2002, p. 1346-51.

[10] G Kay and G de Jager. A Versatile colour System Capable of Fruit Sorting and Accurate object Classification. *In*: Proceedings of the 1992 IEEE South African Symposium on Communications and Signal Processing (COMSIG '92), 1992, p. 145-8.

[11] M Recce, J Taylor, A Plebe and G Tropiano. High Speed Vision-based Quality Grading of Oranges. *In*: Proceedings of the 1996 IEEE International Workshop on Neural Networks for Identification, Control, Robotics and Signal/Image Processing, 1996, p. 136-44.

[12] RC Gonzalez and RE Woods. *Digital Image Processing*, 2nd ed. Prentice Hall, New Jersey, 2002.

บทคัดย่อ

เยาวเรศ ศิริสถิตย์กุล นภสร ทุมเพ็ญ และ วีระยุทธ พวงทอง

การคัดแยกความสุกของส้มโชกุนแบบอัตโนมัติด้วยการจำแนกสี

งานวิจัยนี้เป็นการพัฒนาวิธีประมวลผลภาพลักษณ์ เพื่อใช้คัดแยกความสุกของส้มโชกุน ซึ่งมีวัตถุประสงค์คือ การประเมินความสุกโดยการจำแนกสี กระบวนการทำงานสามารถแบ่งได้เป็น 2 ขั้นตอน คือ การเรียนรู้ (training) และการทดสอบ (testing) ในขั้นตอนการเรียนรู้ ได้ใช้กล้องดิจิตอลสีถ่ายภาพส้มโชกุนจำนวน 90 ผล ที่มีระดับความสุกต่างกัน 3 ระดับ ซึ่งผ่านการคัดแยกจากเกษตรกรที่มีประสบการณ์ การถ่ายภาพเกิดขึ้นในโรงงานคัดแยกส้มโชกุนที่ใช้แสงจากหลอดฟลูออเรสเซนต์ จากนั้นแปลงภาพสี RGB ของส้มโชกุนเหล่านี้เป็นภาพ ISH และวิเคราะห์ค่าสี (hue) จากภาพ Hue แล้วนำไปสร้างเป็นกฎการตัดสินใจสำหรับใช้งานในโปรแกรมการคัดแยกความสุกของส้มโชกุนในขั้นตอนการทดสอบได้ทดลองจำแนกระดับความสุกของตัวอย่างส้ม 50 ผล โดยใช้โปรแกรมการคัดแยกความสุกของส้มโชกุนที่สร้างในขั้นตอนการเรียนรู้ ผลการทดลองแสดงให้เห็นว่า การคัดแยกความสุกของส้มโชกุนแบบอัตโนมัติด้วยการจำแนกสีสามารถเป็นทางเลือกที่นำมาใช้ในการคัดแยกความสุกของส้มโชกุนได้ โดยมีอัตราความถูกต้องประมาณ 98 %

สำนักวิชาสารสนเทศศาสตร์ มหาวิทยาลัยวลัยลักษณ์ อำเภอท่าศาลา จังหวัดนครศรีธรรมราช 80161