

Full Length Research Paper

Development of a lemon sorting system based on color and size

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Grading systems give us many kinds of information such as size, color, shape, defect, and internal quality. Among these color and size are the most important features for accurate classification and/or sorting of citrus such as oranges, lemons and tangerines. Basically, two inspection stages of the system can be identified: external fruit inspection and internal fruit inspection. The former task is accomplished through processing of color images, while internal inspection requires special sensors for moisture, sugar and acid contents. In this paper, an efficient algorithm for grading lemon fruits is developed and implemented in visual basic environment. The system consists of two CCD cameras, two capture cards, an appropriate lighting system, a personal computer and other mechanical parts. The algorithm initially extracts the fruit from the background. The samples of different grades of lemon are situated in front of the cameras and are calibrated off-line. Then information on the HSI color values and estimated volumes of fruits are extracted and saved in a database. By comparing the information during sorting phase with the available information inside the database, the final grade of the passing fruits are determined. This algorithm can be easily adapted for grading and/or inspection of other agricultural products such as cucumber and eggplant.

Key words: Lemon, sorting, volume, image processing, machine vision, HSI color.

INTRODUCTION

Color and size are the most important features for accurate classification and sorting of citrus. Because of the ever-growing need to supply high quality food products within a short time, automated grading of agricultural products is getting special priority among many farmer associations. The impetus for these trends can be attributed to increased awareness by consumers about their better health well-being and a response by producers on the need to provide quality guaranteed products with consistency. It is in this context that the field of automatic inspection and machine vision comes in to play the important role of quality control for agricultural products. Fruit size estimation is also helpful in planning packaging, transportation and marketing operations. Among the physical attributes of agricultural materials, volume, mass and projected areas are the most important

ones in sizing systems (Tabatabaeefar and Rajabipour, 2005; Wright et al., 1986; Safwat and Moustafa, 1971).

Computer vision has been used for quality inspection of fruits. Quality inspections of fruits have two different objectives: quality evaluation and defect finding. In recent years, computer machine vision and image processing techniques have been found increasingly useful in the fruit industry, especially for applications in quality inspection and shape sorting. Researches in this area indicate the feasibility of using machine vision systems to improve product quality while freeing people from the traditional hand sorting of agricultural materials. Raji and Alamutu (2005) reviewed the recent development and application of image analysis and computer machine vision in sorting of agricultural materials and products in the food industries.

Generally, quality grading includes outer parameters (size, color intensity, color homogeneity, bruises, shape, stem identification surface texture and mass), inner parameters (sweetness, acidity or inner diseases) and freshness. Although, both outer and inner quality information

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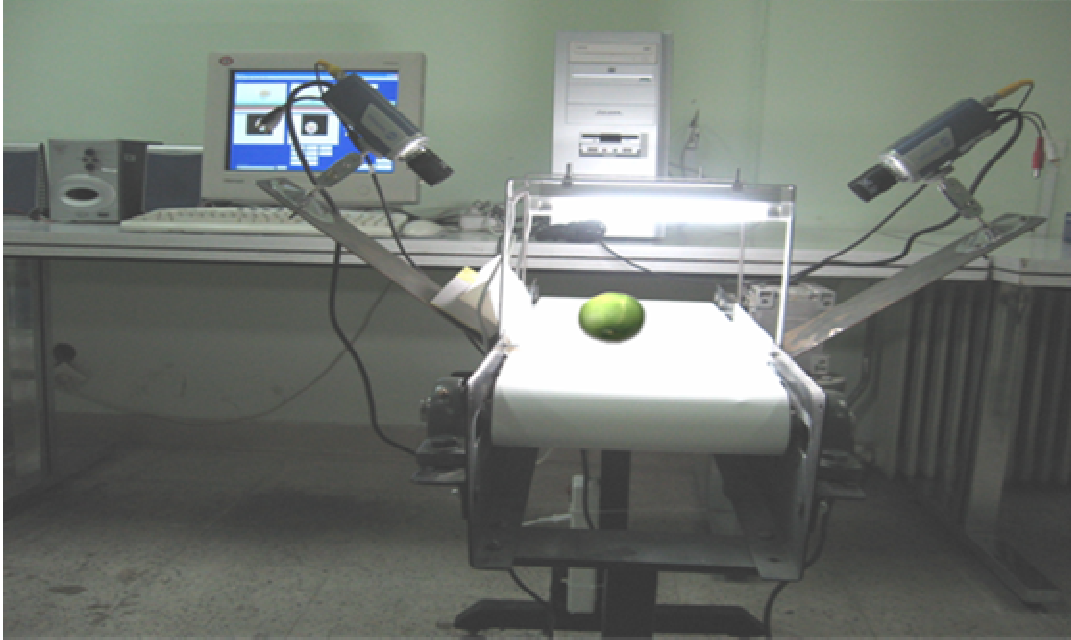


Figure 1. Developed machine vision system.

can be collected by an automatic grading system in a factory, but machine vision is more effective for measuring outer parameters (Lee et al., 1999; Majumdar and Jayas, 2000; Shahin and Symons, 2001; Paliwal et al., 2003; Shigeta et al., 2004; Shahin et al., 2004; Qiao et al., 2004; Lorestani et al., 2006). The algorithm can successfully estimate size, sort colour, classify shape, detect bruises or scar tissue and predict the mass of the pepper fruits. Njoroge et al. (2002) described the operations and performance of an automated quality verification system for agricultural products. Kondo et al. (2005) proposed a multi-product grading system for agricultural products.

Recently we developed an image processing technique for estimating citrus fruits physical attributes including diameters, volume, mass and surface area using image processing technique (Khojastehnazhand et al., 2009). There we developed a machine vision system to automatically determine the diameter, volume and surface area of tangerine. This image processing procedure can be readily applied to other axi-symmetric agricultural products such as eggs, pearl, pepper, carrot, limes and onions. The objective of this work is to extend the scope of the algorithm for a sorting system, designed specifically for citrus fruits such as lemon.

MATERIALS AND METHODS

In order to sort lemons, a general purpose machine vision system was developed. The proposed system (Figure 1) consists of two CCD cameras with 510 x 492 pixels (PROLINE-565 s), two capture cards (WinFast DV2000 with a resolution of $320H \times 240V$), an

appropriate lighting system and a personal computer (PC). Cameras had a CS lens mount, a focal length of 3.5 - 8 mm with a 510 by 492 pixel resolution and provided a resolution of 480 vertical TV lines. The cameras were mounted about 25 cm above the belt and powered by a 24 V power supply. To provide uniform lighting, four fluorescent tubes, placed above the conveyor, were used. The position of the lighting tubes was adjusted to provide uniform, well illuminated and free from shadows images of fruit. The light source and cameras were mounted on a frame and were attached to the measurement table. A white cardboard was used as background surface to facilitate and simplify the segmentation task. Signals from lemon samples were captured by the camera, transferred to the PC through the video capture card, digitized, and stored on the PC in RGB (red, green, blue) color space. A program was developed to capture and record the surface images of the lemon. Algorithms were implemented using Visual Basic 6.0 programming language. In order to remove the background from fruit images, firstly an image from the background is captured. By determination of R, G and B values for all pixels of background by Eq. (1), standard deviation of the images are calculated and stored in the database.

$$P(X, Y) = B \times 2^{16} + G \times 2^8 + R \quad (1)$$

Where; X and Y, ranging from 0 (black) to 255 (white), refer to the position of each pixel, and R, G and B values of each pixel in the image were obtained from the real color image. Once the image of the fruit is captured, the RGB value of any pixel in the image can be computed by Eq. (1). The RGB values in the fruit image are then compared with that of the stored information on the background image available in the database. If the difference between the two RGB values is less than 3σ , then it is regarded as the background, else it is fruit:

$$\text{IF } |P_B - P_F| \leq 3\sigma \text{ THEN Pixel} = \text{Background} \quad (2)$$

Where P_B is the RGB values of background image pixel, P_F is the RGB values of fruit image pixel and σ is the standard deviation of

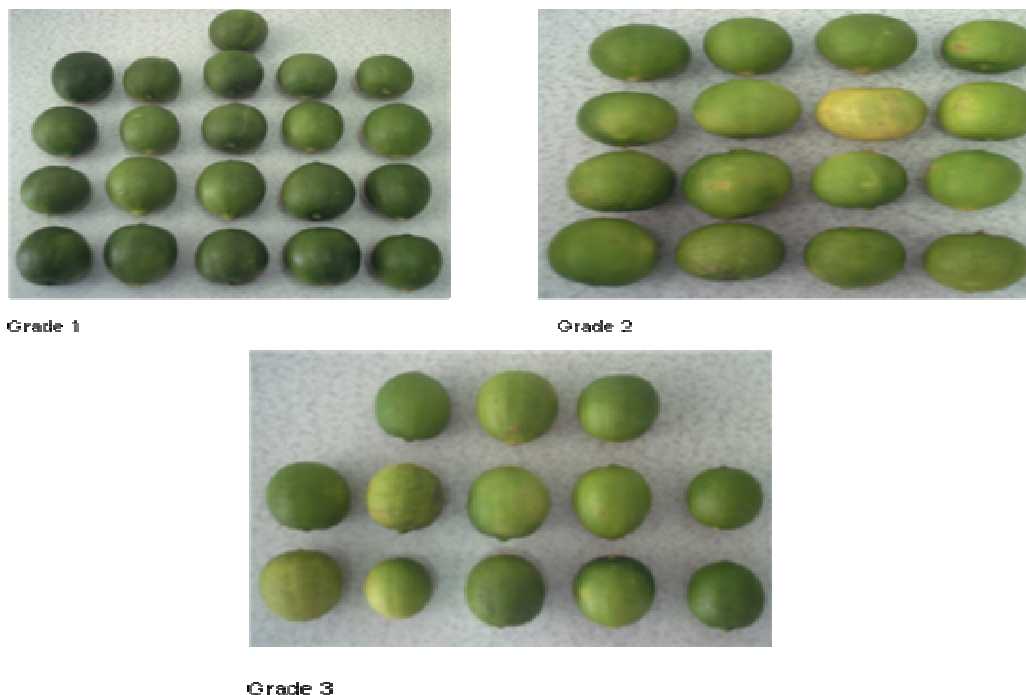


Figure 2. Selected lemons of various sizes and grades according to human export judgements

background image.

Color evaluation

RGB color space is the most popular color model. Some algorithms of fruit vision are based on this color model (Steinmetz et al., 1996; Leemans et al., 1998; Paulus et al., 1997). When color is presented with R, G and B, the amount of information is tripled. Thus more algorithms could be developed to comprehensively utilize the color information in an image. However, RGB system is sensitive to lighting or other conditions. Another color model is HSI (Hue, Saturation and Intensity). Here we prefer using HSI, as in this system Hue value is comparatively stable. The color of fruit is determined by calculating average Hue (H) value for the fruit. In order to evaluate the color of captured images of fruit, the acquired RGB color information was transformed to HSI color by:

$$H = \cos^{-1} \left\{ \frac{(2R - G - B) / 2}{\left[(R - G)^2 + (R - B)(G - B) \right]^{1/2}} \right\} \quad (3)$$

$$S = 1 - \frac{3}{(R + G + B)} [\min(R, G, B)] \quad (4)$$

$$I = \frac{1}{3}(R + G + B) \quad (5)$$

From a close examination of image histograms, we observed that the uniform green is restricted in a certain range (330 to 360) or (0 to 20), so accurate color classification is possible with only hue parameter. The RGB values are determined using the following VB code for all pixels of background:

```
Private Sub RGBcolor (ByVal Point As Long)
Blue = Point \ 256 ^ 2
Temp = Point Mod 256 ^ 2
Green = Temp \ 256
Red = Temp Mod 256
End Sub
```

Volume evaluation

To determine the volume of lemon fruits, image of fruit is captured. Using (2), the background is removed from the main fruit. By dividing the fruit image into a number of distinct sectors, the volume of lemon fruit can be estimated (Khojastehnazhand et al., 2009).

Calibration stage

A total of 50 randomly selected lemons of various sizes and colors were purchased from a local market for evaluation (Figure 2). Initially the fruits are graded by human expert into 3 classes; 22 into class One, 13 into class Two, and 15 into class Three. The relevant information for these fruits (Averaged Hue value and volume information) were extracted from the above mentioned algorithms as implemented by VB program (Figure 3). The actual volume of lemons was measured using the water displacement method (WDM). In this method, the object is completely submerged in water and the weight of the displaced water measured (Mohsenin, 1970). Even though this method is quite accurate, it is not ideal for objects that absorb water and for some products, this approach might be considered intrusive or destructive. Statistical measures including, maximum, minimum and average values were also calculated for three grades (Figure 3). Finally operator selected two threshold for volume and color with obtained data by calibration stage of machine vision system. These two thresholds were minimum volume and hue of grade one. Figure 4 shows the designed interface in

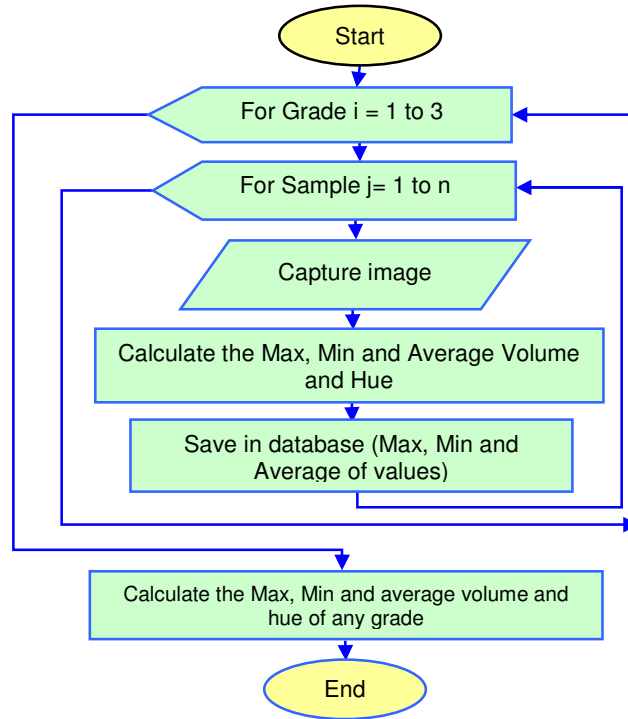


Figure 3. The algorithm of calibration stage.

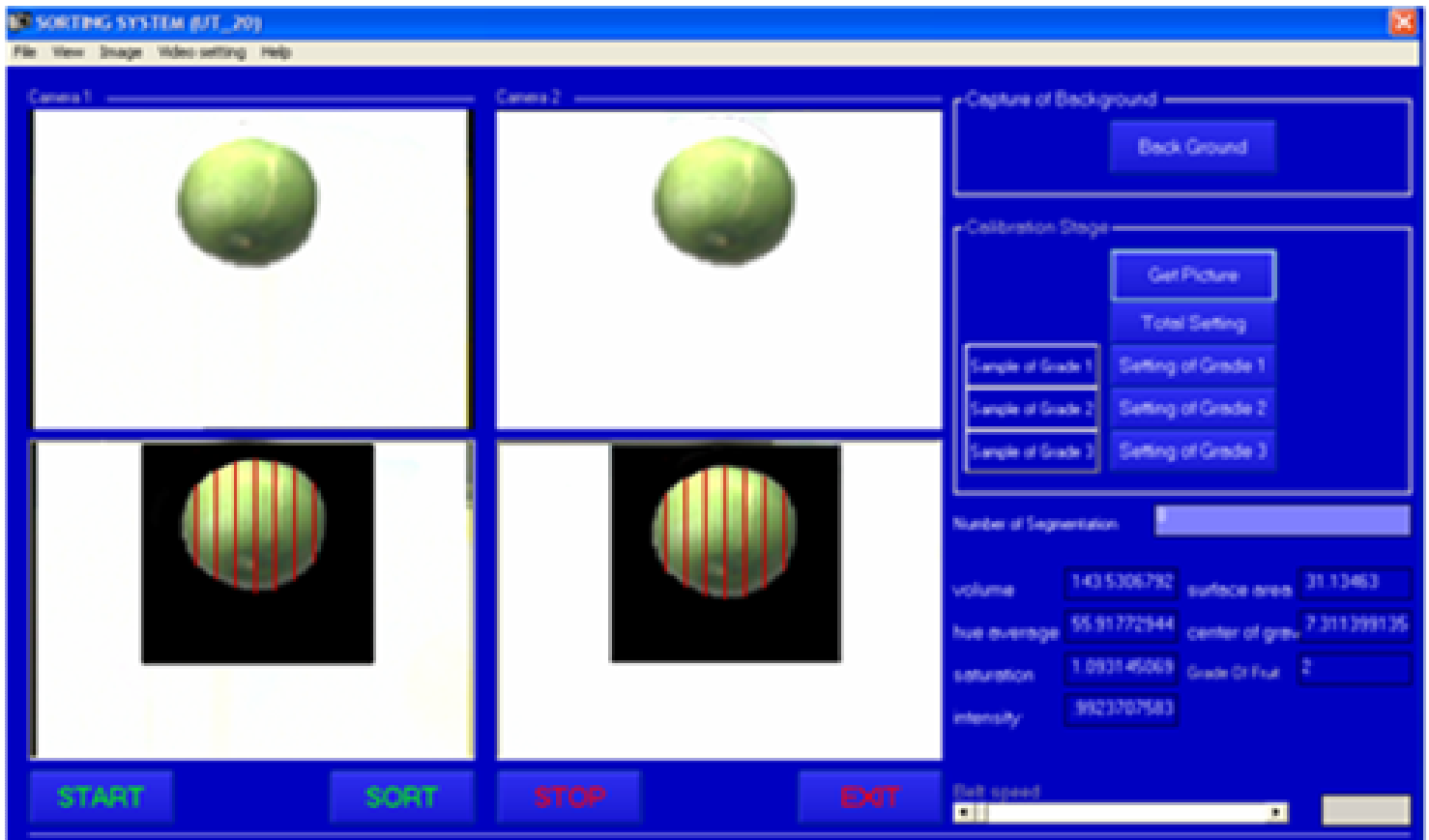


Figure 4. Designed interface in Visual Basic 6.0 programming language.

Table 1. Comparison between measured and calculated volume of lemon.

	Volume, cm ³		R ²	Paired t-test	Diameter, mm		
	WDM	IPM			a	b	c
	Max	26.6			28.9		42
Ave	20.7	20.8	0.9616	0.6131	37.3	32	31.6
Min	9.6	8.5			29	24.4	24

VB 6.0 programming language for system calibration and sorting the citrus product.

Sorting stage

During the sorting stage, the online images of fruit passing in front of cameras were captured and HSI color values and their estimated volumes were determined. By comparing the information during sorting phase with the available information in the database, the final grade of passing fruits were determined. The fruit was graded as class One if its volume and color (Hue) were bigger than volume and color thresholds determined in calibration stage. The fruit was graded as class Two if its volume was bigger than threshold volume and its color was less than the threshold color determined in calibration stage. Finally fruit was graded as class Three if its volume was less than the threshold volume. At the final stage of algorithm, fruit's center of gravity was calculated to be later used for automatic sorting through phenematic mechanism.

The number of pixels in the foreground (fruit) has to be scaled in order to convert (map) the total number of pixels into a real volume value. The constants C (scale factor of volume) of $C = 2.35 \times 10^{-4}$ were obtained after rationing the real and measured volume of a perfect sphere. The C is eventually used to convert units of measurement from pixels to cm³.

RESULTS AND DISCUSSION

The results of comparison between predicted (IPM) and actual (WDM) volumes of lemons with $R^2 = 0.9852$ are shown in Table 1. The diameters and volume of lemons were computed using the set up shown in Figure 1. Details are available in Khojastehnazhand et al. (2009). The results of volume calculation by proposed IPM and WDM show the fruit volume can be accurately be calculated by this algorithm (Table 1). The paired t-test results shows that the volume computed with IP method was not significantly different from the volume measured with WDM.

A summary of our findings is shown in Table 2. The correct classification rates (CCR) are calculated from the confusion matrix given in Table 2. The CCR percentages for grade one, grade two, and grade three are 95.45, 100 and 86.67, respectively. Calibration results show that the algorithm produces the CCR of greater than 86 % for all grades of lemon fruits. The total weighted average in system accuracy is 94.04%, that is to say only 6% of fruits are misclassified.

Table 2. Confusion matrix showing the number of correctly classified fruits with the developed machine vision system.

	Machine vision system			Human expert	CCR (%)
	Grade 1	Grade 2	Grade 3		
	Grade 1	21	1		
Grade 2	0	13	0	13	100
Grade 3	2	0	13	15	86.67

Conclusion

In this paper, we presented a novel approach for development of a sorting system for grading lemon based on color and size. The calibration of system is done by samples of different grades of fruit. The volume and color of fruit determined and saved in database during calibration stage. During sorting stage, the calculated color and volume compared with saved information in database. The final grade of fruit was determined and its center of gravity calculated to be later used for automatic sorting through phenematic mechanism. This algorithm can be easily adapted for grading/sorting different agricultural products such as cucumber and eggplant.

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