ON-LINE DETECTING SIZE AND COLOR OF FRUIT BY FUSING INFORMATION FROM IMAGES OF THREE COLOR CAMERA SYSTEMS

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Abstract: On the common systems, the fruits placed on rollers are rotating while moving, they are observed from above by one camera. In this case, the parts of the fruit near the points where the rotation axis crosses its surface (defined as rotational poles) are not observed. Most researchers did not consider how to manage several images representing the whole surface of the fruit, and each image was treated separately and that the fruit was classified according to the worse result of the set of representative images. Machine vision systems which based 3 color cameras are presented in this article regarding the online detection of size and color of fruits. Nine images covering the whole surface of an apple is got at three continuous positions by the system. Solutions of processing the sequential image's results continuously and saving them into database promptly were provided. In order to fusing information of the nine images, determination of size was properly solved by a multi-linear regression method based on nine apple images' longitudinal radius and lateral radius, and the correlation coefficient between sorting machine and manual is 0.919, 0.896 for the training set and test set. HSI (hue-saturation-intensity) of nine images was used for apple color discrimination and the hue field in 0o~80o was divided into 8 equal intervals. After counting the pixel in each interval, the total divided by 100 was treated as the apple color feature. Then 8 color features were got. PCA and ANN were used to analysis the 8 color features. There is a little overlapped in the three-dimensional space results of PCA. An ANN was used to build the relationship between 8 color characters and 4 apple classes with classification accuracy for the training/test set 88%/85.6%.

Keywords: Apple, sequential image, size, color, detection

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1. INTRODUCTION

The external appearance is one of the most important factors in pricing the apples. Nowadays, several manufacturers around the world produce sorting machines capable of pre-grading fruits by size, colour and weight. Numerous studies have been conducted in order to perform non-destructive measurements of the quality parameters of fresh fruits. Characterization of apple features included the presence of defects, the size, the shape and the colour. Descriptive variables are, e.g. the roundness, the diameter, the average green colour on the apple and the colour properties of defect spots (Tao Y., et al, 1994; Nakano K., 1997; Paulus I., et al, 1997; Leemans V, et al, 1998; Blasco, J., et al 2003). On the common systems, the fruits placed on rollers are rotating while moving. They are observed from above by one camera. In this case, the parts of the fruit near the points where the rotation axis crosses its surface (defined as rotational poles) are not observed. This can be overcome by placing mirrors on each side of the fruit lines oriented to reflect the pole images to the camera, but the quality of images reflect by mirrors are blurred. Another system was presented by Guedalia. He used three cameras observing the fruit rolling freely on ropes.

As it may be seen, most researchers (except V. Leemans, Tao and Guedalia) did not consider how to manage several images representing the whole surface of the fruit. It seems that each image was treated separately and that the fruit was classified according to the worse result of the set of representative images. The objective of this paper was: first, to present a method to combine the data extracted from the different images of a fruit moving on a machine in order to dispose information related to the whole surface of the fruit. Therefore, it would be possible to build a fruit database from which grading can be operated. Second, some methods for improving rapidity and precision of apple inspection were investigated.

2. MATERIALS AND METHODS

2.1 Image acquisition

The external trigger that is composed of an emitter and an acceptor was place at the grading line. The three frame-grabbers grab images when every roller passes through the trigger. As it mentioned above that there are three apples in the view field of each camera, therefore, nine images were grabbed from an apple.

2.2 Image preprocessing

The images in the field of view are not only the apples waiting for measurement but also including the rollers in grading line and other mechanical parts above line. Image preprocessing includes background segmentation, image de-noise, child image segmentation and sequential images processing.

The background is relatively complicated. To get rid of the background, multi-thresholds method was put forward. That is, the R value in RGB(red-green-blue) and S value in HIS (hue- intensity - saturation) were taken into account. The segmentation values are as follows

$$p(x,y)=\begin{Bmatrix} \text{background pixel}: & R<90 \,\|\, (S<0.20 \;\&\&R<200) \\ \text{apple pixel}: & \text{else} \end{Bmatrix} \quad (1)$$

There may still be some noises in the image after getting rid of the background, so this paper introduces medial filter to getting rid of the noise. Fig.1 shows the image after background segmentation and de-noise.

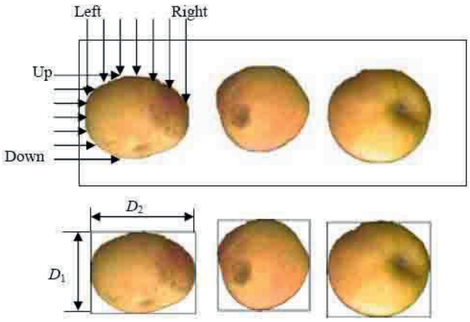

Fig.1: Single child apple images segmentation

There are three apples waiting for measurement in the field of view at most. In order to take out one's own information of the individual apple, single apple division has become inevitable operation. The minimum enclosing rectangle of each single apple was used to divide the view image to three child images as shown in fig.1.

2.3 Size grading

In the image preprocess, the minimum enclosing rectangles of each child single apple image are obtained. It is very easy to get the longitudinal radius (D_1) and lateral radius (D_2) as shown in fig.1. Therefore, 18 D_i (i=1,2, …, 18) are obtained from an apple since nine images were grabbed from am apple.

Any one of the 18 character parameters cannot represent the size of the apple as the apples are randomly oriented on the grading line.

We can imagine that there is some information of apple's size in the 18 characters. We sort the 18 characters in ascending first. Then, a multi-linear regression model was build between apple's size and the 18characters which got from nine apple images of an apple as following:

$$Size = a_1 D_1 + a_2 D_2 + \cdots + a_{18} D_{18} + C \tag{2}$$

where, $a_i (i = 1,2,\cdots 18)$, C are constants. D_i (i=1,2, …, 18) are characters in sort ascending.

2.4 Color grading

2.4.1 Color feature parameters extraction

Color is one of the most significant inspection criteria related to fruit quality, in that surface color of a fruit indicates maturity or defects. Color representation in HIS (hue-intensity-saturation) provides an efficient scheme for statistical color discrimination. These attributes were the closest approximation to human interpretation of color. So color RGB signals of apple were transformed to HIS for color discrimination. For digitized color image, the hue histogram represented the color components and the amount of area of that hue in the image. Therefore, color evaluation of apples was achieved by analyzing the hue histogram. After analysis the hue values of the nine images which obtained from an apple, the hue values of "Fuji" apple images are mainly between 0^o-100^o. The hue field in 0^o-80^o can be divided into 8 equal intervals. The number of pixels in each interval divided by 100 was treated as apple's color feature. Then 8 color features were got. The hue curve of the different category apples is presented in Fig.2. The maximum feature appeared in 0^o~20^o for Extra "Fuji" apples, 20^o~40^o for first degree, 40^o~60^o for substandard degree. There is no maximum feature for second degree.

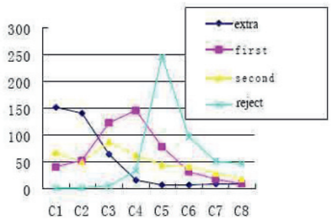

Fig.2: Hue curves of different 'class' Fuji apples

2.4.2 Color pattern recognitions

The 8 color parameters data obtained by the process mentioned above was subjected to PCA and ANN for pattern recognition.

PCA (principal component analysis) is a projection method that allows an easy visualization of all the information contained in a dataset (Buratti et al., 2004; Falasconi et al., 2005). In addition, PCA helps to find out in what respect a sample is different from others and which variables contribute most to this difference.

ANNs (artificial neural networks) are one of the promises for the future in computing. They offer an ability to perform tasks outside the scope of traditional processors. They can recognize patterns within vast datasets and then generalize those patterns into recommended courses of action. A major area where neural networks are being built into pattern recognition systems is the processors for sensors. Sensors can provide so much data that a few meaningful pieces of information can be lost. These neural network systems have been shown successfully in recognizing targets.

While determining the suitable network topology, the network processes the inputs and compares its resulting outputs against the desired outputs. Errors are then propagated back through the system, causing the system to adjust the weights that control the network. This process occurs over and over as the weights are continually tweaked. During the training of a network the same set of data is processed many times as the connection weights are ever refined.

2.5 Fruits

318 apples used in this study were sent directly to our laboratory from a farmer. The size of an apple was measured by manual calipers according to the China grade standards. The 318 “Fuji” apples were divided into 2 sets. An initial experiment was conducted with 200 fruits (“Training set”). The samples were inspected by the machine vision system. Reference measurement for color was then taken. An independent set of 118 samples (“Test set”) was fed into the robotic device to assess the efficiency of the on-line machine vision procedure and to test the precision of the on-line machine vision process. The apples in “Training set” and “Test set” were classified into four classes: the three categories Extra, I, II and the reject, as Table 1 shows.

Table 1 318 apples in training set and test set detection by manual

Size and color detection		Samples	
		Training set (200 apples)	Test set (118 apples)
Size measurement	Max (mm)	96.3	89.3
	Min(mm)	56.1	62.6
	Mean (mm)	74.8	75.5
	r	0.919	0.896
Color classification	Extra (fruits)	50	20
	Category I (fruits)	50	41
	Category II (fruits)	50	40
	Reject (fruits)	50	17
	p	88%	85.6%

** r: Correlation coefficient of size regression model; p:classification accuracy of ANN model*

3. RESULTS AND DISCUSSION

3.1 Apples size determination

200 apples with size between 56 and 96mm were randomly selected. The size (maximal diameter) of each apple was measured twice by the experts using a caliper. Both measurements were compared and the precision was calculated by averaging the differences. Some details of apple quality parameters used for the training and test sets are summarized in Table 1. Then, the 200 apples put to the grading line. 18 D_i (i=1,2, …, 18) characters in sort ascending were got for each apple, and they were used as independent value in the regression model. Regression models were obtained by stepwise algorithm. Finally the size model was determined as follows:

$$Size = 0.508 \times D_{14} + 0.330 \times D_{18} + 12.898 \quad (3)$$

The performance of the size model for training and test sets was shown in table 1, with correlation coefficient of training set/ test set 0.919/0.896.

As form (3) shows that it is not all characters got from the nine images were useful, only D_{14} and D_{18} have high relationship with Size. Apples are randomly oriented on the grading line, therefore, D_{14}, and D_{18} may come from any one of the nine images. There should be mentioned again that the 18 D_i (i=1, 2, …, 18) characters are in sort ascending.

3.2 Apples colour grading

The hue histogram of the nine images was obtained by statistical evaluation of the nine images. Then, the 8 apple color character parameters were calculated and chosen as pattern recognition parameters. Fig.3 exhibits the results of principal component analysis (PCA) for the four different color classes apples. PCA is a simple method to project data from several feature parameters to a three-dimensional space. The values of 85.26% of PCA1, 4.21% of PCA2 and 1.62% of PCA3(Fig.3) indicate contribution rate to pattern separation. It shows that the pattern separation is not sharp.

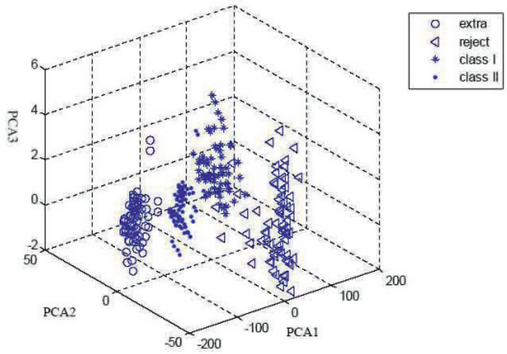

Fig.3: Results of the PCA of the 8 color features for the different apple grades.

In this study, the ANN with a standard back-propagation algorithm was applied. The 8 apple color character parameters were served as the input values for the neural network. The apple's four color grades were coded to serve as the output layer of the neural network: extra (1,0,0,0); class I (0,1,0,0); class II (0,0,1,0); and reject (0,0,0,1). There are 9 hidden nodes in the neural network. Other parameters of the BP-ANN were: Activation: Logistic; Learning Rate: 0.02; Momentum: 0.9. The artificial neural network was trained with the 200 training samples in training set 20,000 times. It was then used to classify the test set, which consisted of 118 'Fuji' apples with different color grades. The classification accuracy for the training set and the classification accuracy for the test set were 88% and 85.6% respectively as shown in table 1.

4. CONCLUSION

The grading of apples into quality classes is a complex task involving different stages. The main conclusions of this study are as follows:

(1) Nine images of an apple were grabbed by three CCD cameras during the motion of the fruit on the grading line.

(2) The apple is segmented from the black background by multi-thresholds *method* with R < 90 || (S < 0.20 & &R < 200) for background pixels, allowed fruits to be precisely distinguished from the background.

(3) 18 D_i (i=1,2, …, 18) characters in sort ascending were got from nine images of each apple and were used as size and shape character parameters. The *width* and *height* regression models were got by stepwise with correlation coefficient of learning set/validation set 0.949/0.936 for *width*, and 0.886/0.853 for *height*.

(4) HSI (hue-saturation-intensity) of nine images was used for apple color discrimination and the hue field in 0o~80o was divided into 8 equal intervals. After counting the pixel in each interval, the total divided by 100 was treated as the apple color feature. Then 8 color features were got. PCA and ANN were used to analysis the 8 color features. There is a little overlapped in the three-dimensional space results of PCA. An ANN was used to build the relationship between 8 color characters and 4 apple classes with classification accuracy for the learning/validation set 88%/85.6%.

This research provides some of our recent works on apple grading projects, and we hope to raise some interests among online sorting researchers about the fusing information of many images from a sorting apple. Enhancement of the grading process should come from every stage, and particularly, from the image acquisition stage.

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