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Study on Color Image Processing Based Intelligent Fruit Sorting System*

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***Abstract* - A machine vision system that can be used for automatic high-speed fruit sorting is proposed. Fruit area was first segmented out from image with an Ohta-color-space based thresholding algorithm; blob algorithm was utilized to remove noises in image; spline-interpolation based algorithm was adopted to detect fruit contour. In fruit sorting process, fruit's color ratio, which was calculated with HSI color space, was selected as classification feature. Fruit sorting was realized by classic Bayes classifier, whose parameters were obtained by a study module. This system was tested with Crystal Fuji apples, and an average sorting accuracy of 90% was achieved.**

Index Terms - fruit sorting; color image processing; Bayes classifier; machine vision

I. Introduction

Quality Inspection of fruit up until the 1990s was performed manually. Manual inspection is labor intensive, slow and can be inconsistent due to fatigue and due to the relatively large staff turnover caused by boredom [1]. Experimental work on machine grading of apples was done under laboratory conditions. In 1985 an automatic bruise detection system was proposed by Taylor [4] et al. Majority of primary systems were mostly based on grey scale or monochrome images. Color image processing based systems have more recently been used in grading, however, they have been mostly applied to assessing fruit quality rather than bruise detection.

This paper describes a color image processing based vision system for sorting of Fuji apples. The image-processing algorithm first extracts the apple area from image background and then calculates its color ratio, which is the key feature in quality grading of Fuji apples. A specific study module is added in software and used to initialize parameters of classic Bayes classifier, which is responsible for the classification of apples.

II. System Description

Fig1 shows the sketch of Intelligent fruit sorting system, which can carry out quality inspection of various circular-shape fruit: apple, tomato, pepper etc, and can complete fruit charging, transportation and sorting procedure automatically. This system consists of 3 sections: electric control system; vision inspection system; fruit transportation and sorting mechanism. Transportation of fruit is achieved through chain driven mode, pans used for carrying fruit are installed on chains equidistantly. This assembly line is driven by stepless servo-motor.

Fig 2 is the diagrammatic sketch of vision system. The imaging modular of vision inspection system is composed of three CCD cameras: two CCD cameras are installed top-left and top-right of inspected fruit, which hold 120 degree between each other, the other one is installed normally above the pans. There exist some overlapping imaging area of these three cameras, which can guarantee majority of fruit's surface to be inspected sharply. Because the pose of fruit is invariant on assembly line, there does exist some surface that are unseen during the inspection process, but experiment result shows this has little influence on fruit sorting accuracy.

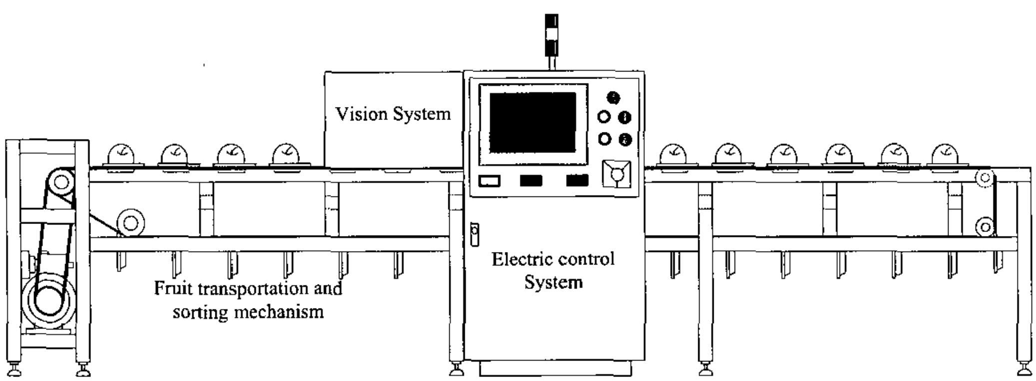

Fig.1 sketch of intelligent fruit sorting system

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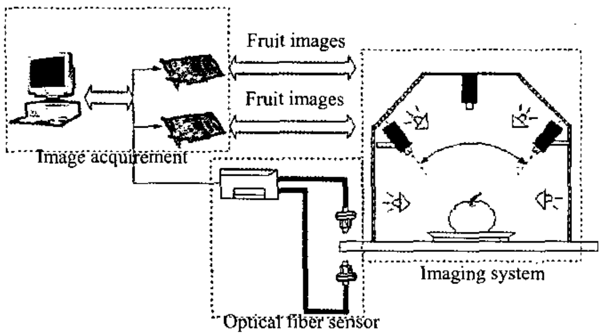

Fig.2 Diagrammatic sketch of vision system

Because the reasonable speed of fruit sorting is 4~5 fruits per second, the system is required to give judgment result in 200 milliseconds, and the time left for image acquirement is limited in 100 milliseconds. So we choose two Matrox Meteor-II frame grabbers for the fruit image acquisition task: two side-cameras are allocated to one frame grabber, the camera installed above the fruit is allocated to the other. Experiment shows that with the assistance of multi-threads software structure, the image acquirement system can finish grabbing three images of the same fruit in 100 milliseconds.

In order to guarantee image quality, optical fiber sensor is adopted to provide outside trigger signal for imaging system; multi-threads program structure is designed to improve grabbing speed; single field grab mode is applied to resolve the blurred image problem caused by motion.

III. Feature Extraction

3.1 Ohta color space based image segmentation

Segmentation of fruit image is crucial to correct sorting, and is the foundation of feature extraction. In order to achieve satisfying segmentation result, two problems have to be solved in the design of segmentation algorithm. At first, the segmentation algorithm must be fast enough to be completed within 50 milliseconds; Secondly, it must have high stability. Because the images of fruit are acquired on assembly line, its background is very complicated and can not be kept invariant all the time, so the algorithm is required to maintain certain precision under such circumstance.

In order to solve the problems given above, Ohta color space based image segmentation algorithm is presented in this paper. At first, we convert the image from RGB color space to Ohta color space, with the I_2' color feature, traditional threshold-based segmentation algorithm is utilized to segment apple area from color image; then with the priori knowledge of image, blob algorithm is used to remove noises in image.

3.1.1 Conversion from RGB to Ohta Color Space

On the foundation of experience, ohta analyzed more than 100 color features which are thus obtained during segmenting eight kinds of color pictures, and had found a set of orthogonal color features $\{I_1, I_2, I_3\}$ or $\{I_2', I_3'\}$, which are called Ohta color space(1979)[2]. Compared with other traditional color spaces, HSI, HSV etc, the conversion from RGB to Ohta color space is linear and computationally inexpensive, and its performance is satisfying. Ohta color space has two different kinds of expression as shown in equation (1):

$$\begin{cases} I_1 = (R+G+B)/3 \\ I_2 = (R-B)/2 \\ I_3 = (2G-R-B)/4 \end{cases}, \quad \begin{cases} I_2' = R-B \\ I_3' = (2G-R-B)/2 \end{cases} \tag{1}$$

Original image Result of threshold segmentation

Fig. 3 result of image segmentation

Experiment results show that the I_2' color feature can mask out the image background, a constant threshold is used to segment fruit area out from background. This method is easily done in real time and its performance is satisfying. The segmentation result is shown in Fig3.

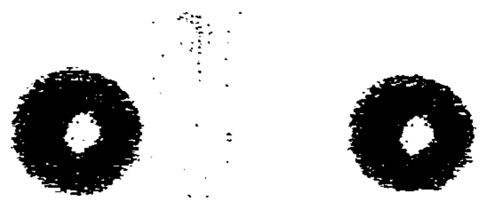

Fig .4 Result of blob algorithm

3.1.2 Blob algorithm based noises removal

Blob analysis is very important in image processing, which is used to find some blocks satisfying certain conditions in image. As the difference between the area of apple and area of image noise is quite large, we can remove noises according to the area of blob. The procedure of noises removal is introduced below: at first, an area threshold is stated, then the blobs whose area are smaller than certain threshold will be removed from image. The result of blob algorithm is shown in Fig 4

3.2 Spline-Interpolation based contour detection

A successful contour detection is crucial to the correct fruit shape feature extraction. From the result of image segmentation, we can see the contour of apple blob is not smooth, and traditional edge detector will lose its effect in such condition, so an interpolation-based contour detection method is applied in this paper. At first, we calculate the coordinates of apple blob's geometrical center, which is adopted as original point of polar coordinate system; then we search 24 points on the contour 15 degree each, calculate the

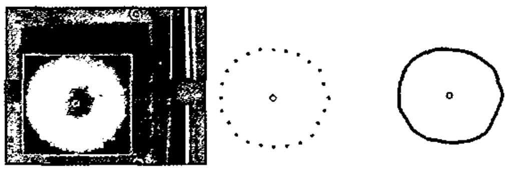

Fig. 5 Process and result of interpolation based contour detection

distance between the contour points and geometrical center and use them as the lengths of relating radius; at last, spline-interpolation algorithm is used to produce smooth contour of apple.

The contour detection result is shown in Fig5. We can see the contour is precise and smooth enough for apple's quality feature extraction.

3.3 color ratio judgment of apple:

To Fuji apple, the criteria for evaluating an apple's external appearance are: uniform red color distribution on the surface (color ratio), looking visually appetizing and having a good shape. The calculation of uniform red color area on apple's surface is indirectly used to determine the sugar content of apples, because high correlation coefficients have been obtained between the sugar content and the color ratio of apple.

3.3.1 HSI color space based calculation of apple's color ratio

In the calculation of color ratio, a different color space HSI is introduced. The HSI color space is broken down into hue, saturation and intensity. Hue refers to pure color, saturation refers to the degree or color contrast, and intensity refers to color brightness. Modeled on how human beings perceive color, this color space is considered more intuitive than RGB. The conversion from RGB to HSI can be achieved through equation (2):

$$\begin{cases} H=\cos^{-1}\left\{\dfrac{(R-G)+(R-B)}{2\sqrt{(R-G)^2+(R-B)(G-B)}}\right\}, \\ R\neq G \;\; or \; R\neq B \\ if \;\; B>G \;\; H=2\pi - H \\ S=1-\dfrac{3}{R+B+G}\left[\min(R,G,B)\right] \\ I=\dfrac{R+B+G}{3} \end{cases} \quad . \tag{2}$$

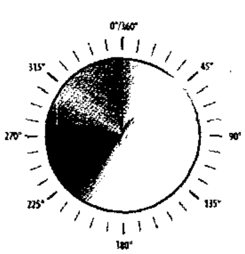

Fig. 6 Hue color feature distribution

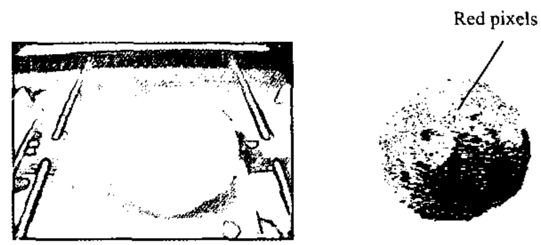

Fig. 7 Result of searching red pixels in the image

From the Fig6, we can see the uniform red is restricted in a certain range (330 to 360) or (0 to 20), so accurate color classification is possible with only hue parameter. Fig7 shows the result of searching red pixels in an image.

If the uniform red area in an apple has been detected precisely, the color ratio of apple can be calculated with equation (3):

$$C=\frac{R_L+R_R+R_T}{A_L+A_R+A_T}. \tag{3}$$

In the equation (3), C represents color ratio, R_L, R_R, R_T represent the area of red pixels in the left , right and top images of an apple, A_L A_R, A_T represent the area of apple in the left , right and top images.

3.3.2 Bayes classifier based apple classification

An intelligent study module is necessary for automatic fruit sorting. At first, system must learn standard pattern of different samples, then realize sorting according to knowledge acquired from learning process.

Because the probability distribution of apple pattern can be assumed a Gauss normal distribution, so traditional Bayes classifier is selected to achieve sorting function [13]. The mean and variance of samples are calculated through study module, then Bayes classifier is utilized to realize fruit sorting. The specific process has been listed below:

(1) learning : Compute the estimates of the mean value vector μ and variation σ ;

(2) compute the estimates of the priori probability densities $p(x|\omega_r)$ with equation (4)

$$p(x|\omega)=\frac{1}{\sqrt{2\pi\sigma}}\exp\left(-\frac{(x-\mu)^2}{2\sigma}\right). \tag{4}$$

(3)Compute the estimates of the a priori probabilities of classes with equation (5):

$$p(\omega_r)=\frac{K_r}{K}. \tag{5}$$

where K is the total number of objects in the training set; Kr is the number of objects from the class r in the training set

(4) Classification: Classify all patterns into the class r according to equation (6):

$$\omega_r=\max_{i=1,\ldots,s}\left[p(x|\omega_i)p(\omega_i)\right]. \tag{6}$$

IV. Experiment And Discussion

4.1 Materials and methods

The apples used in experiment were bought directly from market, The variety of apple used was the "crystal-fuji". The quality grades for the external appearance of apples are classified into three categories: excellent, A, where more than 70% of the surface is deep red; B, good, where 40-70% of the surface is red; C, poor, where less than 30% of the surface is red.

Fruit sorting procedure is given below:

At first, samples are sorted manually into three groups (A,B,C) according to grading criteria, and 10 typical samples are selected from each group .

Secondly, start the fruit sorting system and the study module begins to work. Samples of each group are put on the assembly line sequentially, study module calculated mean and variation of every ten samples and input them to Bayes classifier as parameters, then the study process finished.

At last, sorting module begins to work and apples are sorted automatically.

4.2 Classification result of apple

TABLE I CLASSIFICATION RESULT OF APPLES

Samples	Number of apples classified into each group			Accuracy
	A	B	C	
A	18	2	0	90%
B	1	17	2	85%
C	0	1	19	95%

The classification result is showed in tab 1. Experiment result shows that because the pose of apple is invariant during sorting process and some part of its surface are unchecked, which will cause the mistake of coloring calculation, so misjudging is unavoidable, but the ratio of misjudging is tolerable.

4.3 Discussion:

The sorting experiment and result shows that because intelligent fruit sorting system has study module, what the operators have to do before fruit sorting is just to provide system with typical samples according to criteria, complicated system adjustment is avoided; color image processing based algorithm can provide correct quality features for classification, and the sorting result is satisfying.

V. Conclusion

A typical color-image-processing based fruit sorting system is introduced in this paper. Two different color spaces (Ohta color space for image segmentation, HSI for color ratio calculation) are utilized in color image process to get distinct and smooth contour of fruit , so the correct quality feature (color ratio) extraction is guaranteed. With the parameters acquired from study module, classic Bayes classifier is adopted to realize fruit sorting. Experiment result shows the performance of this system is stable and satisfying.

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References

[1] *Masateru Nagata, Qixin Cao. Study on Grade Judgment of Fruit Vegetables Using Machine Vision. JARQ 32, pp 257-265,1998*

[2] *Yu-Ichi Ohta, Takeo Kanade. Color information for region segmentation [J]. Computer Graphics and Image Processing 13, 1980,pp 222～241.*

[3] *C.J. Studman . Computers and electronics in postharvest technology—a review. Computer and Electronics in Agriculture. 30 ,2001,pp 109～124*

[4] *Recce, M. ; Taylor, J. High speed vision-based quality grading of oranges. Neural Networks for Identification, Control, Robotics, and Signal/Image Processing, 1996. Proceedings., International Workshop on , 21-23 Aug ,1996. pp 136-144*

[5] *Kazuhiro Nakano. Application of neural networks to the color grading of apples . Computers and Electronics in Agriculture. 18 1997,pp 105-116*

[6] *E. Laemmer, A. Deruyver, M. Sowinska. Watershed and adaptive pyramid for determining the apple's maturity state . IEEE ICIP 2002 (1).pp 789-792.*

[7] *Taylor, R. W. and Rehkugler, G. E. Development of a system for automated detection of apple bruises. Proceedings of Manufacturing Engineers,ASAE,ChicagoIllinois,1985*

[8] *S.Limsiroratana, Y. Ikeda. On image analysis for harvesting tropical fruits . SICE 2002 Aug. 5-7, 2002. Osaka. pp 1336-1341*

[9] *Y. Tao, P.H. Heinemann, Z.Varghese, Ⅲ .Machine Vision For Color Inspection of Potatoes and Apples. Trans of ASAE,1995, 38(5), pp 1555~1561*

[10] *Growe T G etal. Real-time defect detection in fruit (II): An algorithm and performance of a prototype system. Transaction of the ASAE, 1996, 39 (6) :pp 2309~2317*

[11] *Tao Y. Spherical transform of fruit images for on line defect extraction of mass objects. Optical Engineering, 1996, 35 (2) : pp 344~350*

[12] *Heinemann P H, H J Sommer III. Machine vision based station for grading of "golden Dellicious" apples. Proceedings of the FPAC IV Conference, 1995. pp 239-248*

[13] *Milan Sonka，Vaclav Hlavac. Image Processing, Analysis, and Machine Vision(Second Edition)[M]. Beijing：人民邮电出版社. 2002年1月第1版*