Automatic shape grading of pearl using machine vision based measurement system

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Abstract

A method of auttomatic shape grading of pearl using machine vision is presented in this paper. Firstly, the preprocessed color image is segmented according to its' grey degree histogram. Then the morphological closing operation is adopted to eliminate the noise points. An 8-directional boundary-tracing algorithm is applied to obtain the sequences of the boundary. And then the Euclidean distance between the pearls under checking and the ones in the standard template library, which is utilized to distinguish the pearls' shape. Finally the experimental result demonstrates the validity and practicability of this method.

Keywords: Quality grading; pearl; shape; machine vision; Fourier descriptor

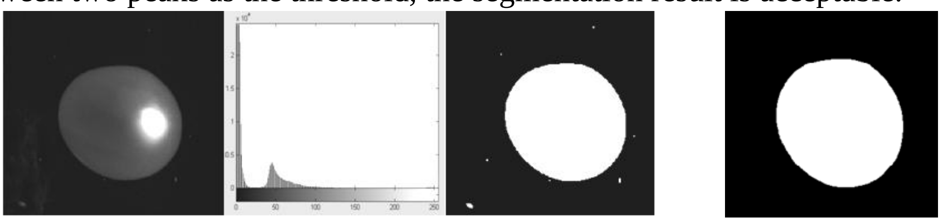
1. Introduction

At present, pearls mostly rely on manual classification in China. It is not only a large quantity of labor, low productivity, but also difficult to control grading standards, which lead to the lower classification accuracy [1]. The research of computer vision for automatic grading pearl is still in its infancy, the current commonly used method is to calculate the ratio of the long axis to short axis of pearl, although this method is fast, but less precise [2]. This paper presents a method which use Fourier descriptors to describe the shape then grading the pearl according the descriptors.

2. Pearl image pre-processing

STEP 1. Image segmentation

The purpose of image segmentation is to distinguish image of pearl from background. To segment the color image, extracting pearls profile, first color image is converted to grayscale image through mapping the RGB color space to the NTSC color space. Then, the histogram of the image can be calculated as shown in Fig. 1. Since the image histogram are bipolar model which have two peaks obviously [3], so simply select the corresponding gray value of the trough between two peaks as the threshold, the segmentation result is acceptable.



(a) Pearl image (b) Histogram (c) Segmented image (d) After noise cancellation

Fig. 1. Image segmentation.

STEP 2. Noise Cancellation

Morphology close operation is used to remove noise. The step is first take morphological expansion operation and then corrosion operation [4]. Through a large number of tests, we find that take close operation with a circle with radius of 10 pixels can realize noise removal, and did not affect the shape of pearls. Figure 1(d) shows the effect of the noise cancellation.

STEP 3.Contour Extraction

In order to identify the shape of pearls, pearl contours should be extracted, and use parametric methods to describe. In this paper, 8-neighbor search algorithm is used to extract the coordinates of contour.

A3	A2	A1
A4	A	A0
A5	A6	A7

Fig. 2. Pixel *A* and its 8-neighbors.

Figure 2 shows pixel A and its 8-neighbors, take A0 as the first point and the order is A0, A1 ⋯A7. The extraction algorithm is as follows:

(1) Scan every pixels from the image upper left corner to bottom right corner, if the pixel's gray value f (x, y) = 1, take the pixel as the contour's point. Recorded as S0;

(2) Start from A5 with anti-clockwise order to examine 8 adjacent pixels of the point;

(3) If find one pixel's gray value f(x,y) = 1 and the pixel have not been recorded, take the pixel as the contour's point and recorded as Sn (n for the contour point sequence);

(4) If the coordinates of Sn are same as S0, then finish the searching, otherwise, take the pixel Sn as the next starting point to continue the search and then go step 3;

In this way, the contour points are S0, S1 ... ... Sn-1 which represents the outline of pearl.

3. Pearl shape recognition

3.1 Fourier descriptors

The extracted pixels S(p)=[x(p),y(p)],p=0,1,⋯,n-1, the plural form can be expressed as:

Ошибка! Источник ссылки не найден. $z(p)=x(p)+iy(p) \quad p=0,1,2,\cdots n-1$

(1)

The normalization of the Fourier descriptors is used to describe the shape. Rotate the contour with φ degrees, zooming r times, move the location with (△x,△y), as shown in Fig 3. The Fourier descriptors Z '(k) is as follows:

$$\begin{cases} Z'(k) = re^{j\varphi}Z(k) + (\Delta x + i\Delta y) \quad k = 0 \\ Z'(k) = re^{j\varphi}e^{j\frac{2\pi}{L}ka}Z(k) \quad k = 1,2,3\ldots\ldots,p \end{cases} \tag{2}$$

Where $x'(p) + iy'(p) = x(p+a) + iy(p+a)$.

From Eq. (2), the shape rotation, starting point translation just simply change the phase, zooming r times, the Fourier transform corresponding r times amplification, translation object, only to change the DC component Z'(0). Therefore the normalized Fourier descriptors can be defined as:

$$D(k)=\frac{\|Z'(k)\|}{\|Z'(1)\|}=\frac{r\left\|e^{j\varphi}e^{j\frac{2\pi}{L}ka}Z(k)\right\|}{r\left\|e^{j\varphi}e^{j\frac{2\pi}{L}a}Z(1)\right\|}=\frac{\|Z(k)\|}{\|Z(1)\|}\quad k=1,2,\ldots\ldots,p \tag{3}$$

where, ‖ . ‖ is modulus operator。D (k) eliminates the affect of the rotation, translation, scaling, and change of starting point to Fourier descriptors. It can be applied to identifying shape of pearl.

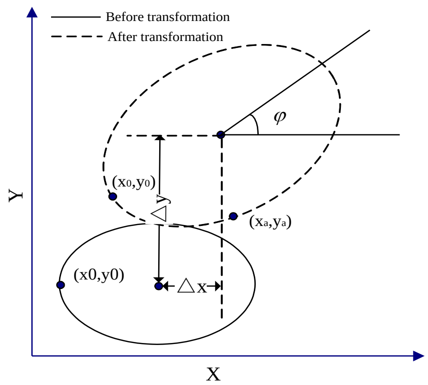


Fig 3. The boundary after rotation, zooming, translation

3.2 Recognize of the pearl shape

Due to the shape of the majority of pearls' energy on the low-frequency part [7], as long as the selected 12 coefficients normalized Fourier descriptors can be used for pre-characterization of pearl shapes, the restoration of the shape have a very small difference compare to the original shape. The only difference is the high-frequency part in the graphics after the restoration lost and contours appear smooth, but do not affect the determination the shape of pearls.

In order to distinguish different shapes of pearls, first set up a suitable template library according to grading requirement, then use the Fourier descriptors for template matching. According to grading requirements, the target will be divided into eight categories, i.e.{Perfect round, Round, Close to round, Short oval, Long oval, Two sides flat, Four sides flat, Irregular} and given a serial number from 1 to 8. Corresponding to the shape of the establishment of templates and forms eigenvector description:

$$B_i=[D_{bi}(1),D_{bi}(2),\cdots,D_{bi}(12)] \tag{4}$$

as $i=1,2,\cdots,7$ (exclude Irregular) to indicate the sequence of shape.

Euclidean distance is used to calculate the eigenvector of the different shape:

$$\mathrm{dis}(A,B_i)=\sqrt{\sum_{k=1}^{12}\|D_a(k)-D_{bi}(k)\|^2} \tag{5}$$

The smaller the $\mathrm{dis}(A,B_i)$ is, the higher the degree of similarity between A and Bi, Bj represent the shape of pearls which is identified, at this time are:

$$\text{dis}(A, B_j) = \min(\text{dis}(A, B_1), \text{dis}(A, B_2), \cdots, \text{dis}(A, B_7)),\ j \in [1, 2, \cdots, 7] \qquad (6)$$

Due to irregular shape classification is a big classification, concrete can contain a variety of shapes, and previous formula can not give specific information on Fourier descriptors of irregular shape, so assume the irregular threshold K (determined by experiment). In the grading time if $\text{dis}(A, B_j) > K, j = 1, 2, \ldots, 7$ the election is that the pearls are irregular.

4. Experimental investigations

4.1 Machine vision based measurement system

Experiment equipment is composed of pearl transmit part、visual detect part and electrical equipment part, as shown in Fig. 4. When pearl reach the image pickup place, photoelectric sensor activate camera to take pearls' image, and transmit images to computer. Because do not involve separations as color, defects etc., so the light source can use normal circular fluorescent lamp. CCD camera use IEEE1394 interface's DH-HV3000FC model, output RGB color of color image space.

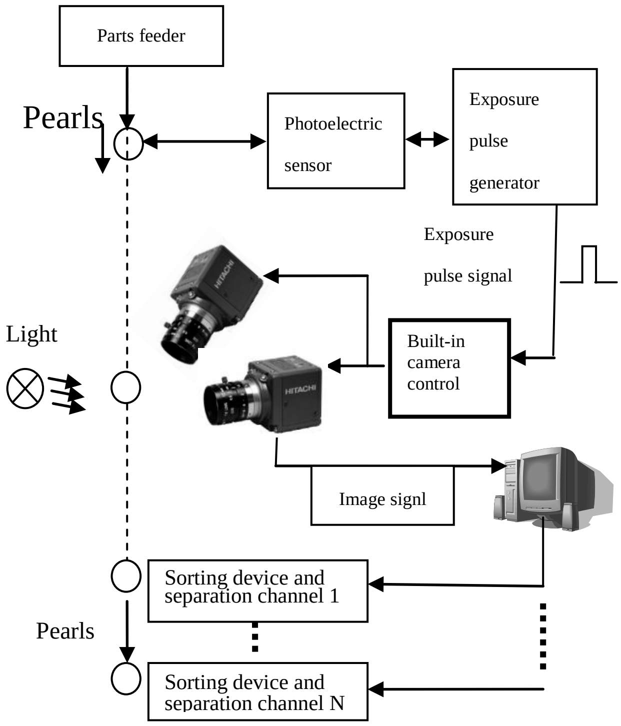


Fig. 4. Sketch of measurement system.

As the pearls fall when the point of view can not be determined by a single camera to capture images just the outline of pearls in a plane projection, which identify the shape of pearl will have a huge impact. To solve this problem, experiments set up two 90-degree angle to place the camera. This can significantly reduce the perspective as a result of Pearl unknown whereabouts of the impact.

4.2 Experiment and analysis

In order to verify the accuracy of algorithm, use a company's pearls which have been graded by professionals to test. The first experiment is single shape recognition, each category take 100, a total of 800 pearls. The recognize accuracy results are

100%,99%,98%,96%,97%,97%,95%,96% respectively, i.e. the average recognition rate is 97.25%. The second is mixed experiment, in which mixed pearls of various shapes is carried out 5 times to repeat the experiment. The experimental results show that the shape of the pearls for automatic identification and grading of the total effective rate reached 96.4%, grading speeds of up to 3 pearls/s, the speed and accuracy have reached the practical requirement.

5. Conclusion

This paper research a method based on computer vision for recognizing the pearls' shape, through preprocessed the picture, pick up pearl's boundary curve's Fourier Descriptors, then the Euclidean distance between the pearls under checking and the ones in the standard template library, to realize recognize the shape of the pearls according to the distance, and examples validation the method.

Further analyze can find, the main reason influence the accuracy of the decision is the image of the pearls is not enough comprehensive. In order to decide more accuracy pearls' shape, can use many cameras take image, through compare the process results of different cameras to get higher decision accuracy.

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