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Design of Steel Ball Surface Quality Detection System Based on Machine Vision

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***Abstract*—In this paper, in the environment of Labview and NI Vision Assistant, the defect image is processed and the defects features from the steel ball surface defect image are abstracted. And at last, according to the effective features, the defects of steel ball are classified, automatical detection of the ball defects on the surface is achieved. Compared with the previous detection methods, the experiments indicate that the system can achieve the defects feature more effectively, and the proposed method in the system is computationally efficient, has lower flaw missing rate and false alarm rate , and meets the need of on - line flaw inspection.**

Keywords-steel ball;surface quality detection ; machine vision; labVIEW

I. INTRODUCTION

In the modern industrial automation, with the demands of high-precision, high-speed, high-quality continues to raise, the role of bearing increases prominently. Steel ball takes great impact on the performance of bearing, like speed, noise, vibration, and lifetime and so on. The geometric accuracy and surface quality of the bearings plays a decisive role in reducing bearing's vibration noise. And it is one of the main factors affecting the bearing dynamic performance[1].So improving the ball's geometric accuracy and surface quality is the main way to reduce the principal means of bearing vibration noise.

At present, the domestic steel ball manufacturers mostly adopt artificial visual approach to verify the surface quality inspection of the ball[2]. This method is labor-intensive and ineffective. And the test results are vulnerable to inspection personnel for technical quality, experience, ability of the naked eye to distinguish, and fatigue factors, so that the normal product quality can not be guaranteed. As the steel ball bearing industry continuously improves the requirements of surface quality, automatic detection device of a steel ball is cried out for proper and efficient conduct of detection of steel ball surface defect. The application of machine vision in the detection of steel ball surface defect would be an effective way to realize automatic detection of steel ball surface quality.

II. SYSTEM COMPOSITION AND WORKING PRINCIPLE

The surface quality detection system of steel ball based on machine vision is mainly targeted at the classification of spot,burn, scratch and abrasions in the steel ball processing,due to equipment accuracy and quality of raw materials and other reasons. The overall structure of the system can be divided into the following sections: lighting unit, steel ball surface deployer, image acquisition and processing unit, defects recognition unit[3]. The whole system block diagram is shown in Fig.1.

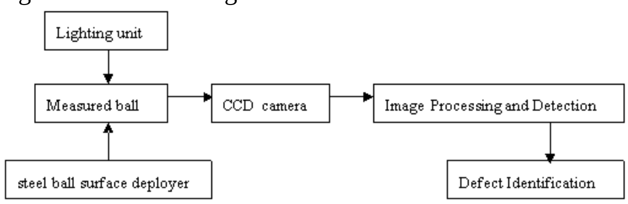


Figure 1. steel ball surface defect detection system block diagram

At first, place the steel ball on the steel ball surface deployer, use a camera to take the image of the steel ball surface continuously. And then digitize the collected analog image signal , store it in the hard disk storage devices, display in the application main interface in real time. Image processing unit once call the image stored in the hard disk storage devices, it will undertake image processing, defect feature extraction and automatic identification of defect types, and complete the identification of surface defects on steel ball at last.

To exclude the interference of all sorts of odd light including natural light and the surrounding environment, image acquisition is carried out in an enclosed light box. Homemade red high brightness LED light source is used as a system illumination[4,5]. Frosted glass is used to block the LED light sources. Light box walls are painted white, the bottom of the box is painted black, so that light can be approximated as uniform scattered light and the ball contrasts with the background obviously. Steel ball and the loading platform will be placed in a light box. In the box ,there is a stent system used to adjust the distance between the camera and loading platform. There is a cylindrical hole on the loading platform which can rotate around the axis, so that the camera can achieve the full image of the steel ball. The image processing and defect identification use LabVIEW as the software development platform, and use NI Vision Assistant and IMAQ Vision at the same time.

III. IMAGE PROCESSING ALGORITHM DESIGN

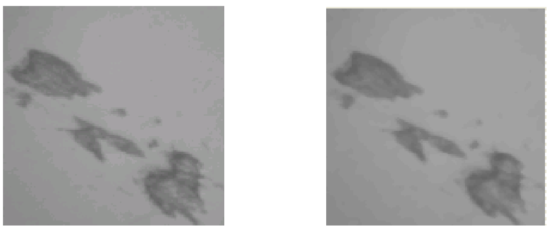
A. *Median Filter*

The median filter is a taxis to make the pixels of neighborhood by gray level domain, and then select the median group as the output pixel value [6]. For the odd elements, the median is the middle value after sorting. For the even-numbered elements, the median is the average of the two middle gray scale after sorting. The median of O-field intensity is not subject to the effects of individual noise glitch, so the median filter removes impulse noise very well. Median filter in filtering noise (especially impulse noise) can be well protected the details of the signal information (for example, edge, acute angle, etc.), it is simple and fast.

Suppose there is a one-dimensional sequence $f_1 f_2 \cdots f_n$. The window length is m (m is odd). Undertake median filter in this sequence, there will be m number $f_{i-v} \cdots f_{i-1} f_i f_{i+1} \cdots f_{i+v}$ drawn from the input sequence. f_i is the central value of the window, $v = \frac{m-1}{2}$. And then arrange the value of these m points according to their values, take the middle number as the output filter. With the mathematical formula is expressed as:

$$Y_i = Med\{f_{i-v} \cdots f_i \cdots f_{i+v}\} \; i \in Z, v = \frac{m-1}{2} \qquad (1)$$

The effect of median filter is shown in Fig.2.



(a)Original image (b) Processed images

Figure 2. The effect of median filter

B. *Iterative Image Thresholding*

You can automatically calculate more appropriate segmentation threshold through iterative methods. Its calculation method is like this:

- Choose the threshold T, usually choose the average gray value of the image as the initial threshold value.
- The average gray value of the image is divided into two groups R1 and R2 through the initial threshold value T.
- Calculate the two sets of average gray value μ 1 and μ 2.
- Re-select the threshold T, the new T is defined as: T = (μ 1 + μ 2) / 2.

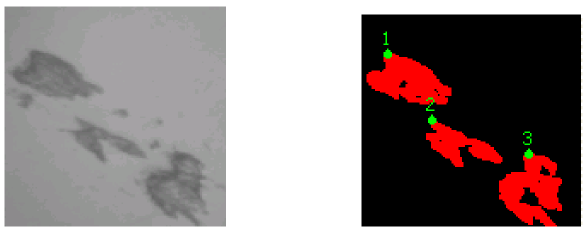
Do the second step to the fourth step circularly until the average gray value of two μ 1 and μ 2 are no longer changed, then we got the required threshold. Iterative thresholding can obtain good results, the iterative threshold can distinguish between the main regions of foreground and background images. The effect of iterative image thresholding is shown in Fig.3.

(a)Original image (b) Processed images

Figure 3. The effect of iterative image thresholding

C. *Region Labeling*

To extract features of the binary image of steel ball surface defect, we must first determine the image of each defect area whether it is independent of the target object or not, as well as the total number of defects in the image [7]. This requires that different flaws target in the image should be configured different tags and each pixel of the target area is assigned a single identification label. After binarization, test each pixel from left to right, top to bottom in turn. If we find a particular pixel value is 0, followed by detection of the pixel values of upper-right point, right- above point, top-left point and upper-left point. And then identify the objects. Change the pixel value of the object to label. The effect of region labeling is shown in Fig.4.



(a)Original image (b) Processed images

Figure 4. The effect of region labeling

D. *Image Measurement*

1) *Area Measurement*

Mark each pixel in the image, change the pixel value of the object to label, find the sum of a variety of labels,and then we obtain the area of different regions. Implementation steps are as follows:

- Obtain the pixel value circularly, pixel value is the label L;
- According to the different labels, added them to the corresponding array;
- Loop end, the size of the array is the value of the area.

2) *Round-degree*

With the value of area and perimeter,Calculate the characteristic quantities of the shape complexity of an object (or regions). The closer to round shape, the value of the round-degree is greater. The shape is more complex, the round-degree is smaller. The value of round-degree is between 0 and 1.

$$e = \frac{4\pi * Area}{(Circumference)^2} \qquad (2)$$

For the defects in Figure 4, calculate the value of round-degree and area of each region as shown in Table 1.

TABLE I. THE MEASUREMENT RESULTS OF STEEL BALL SURFACE DEFECT

Region	1		2		3	
Feature	*Round-degree*	*Area*	*Round-degree*	*Area*	*Round-degree*	*Area*
	0.60	901	0.43	546	0.58	970

IV. ANALYSIS AND RECOGNITION OF STEEL BALL SURFACE DEFECT

Calculate the characteristics of the various defects by image pre-processing, and then carry on feature recognition. In the process of recognition, the advantage of Round-degree in the features is obvious .First of all, scratch and abrasions will be designated to separate from other defects. And then separate scratch from abrasions through the Round-degree (threshold value T2).In the end, separate spot from burn through the area[7,8]. Categories binary tree is shown in Fig.5. T1, T2, and S are the corresponding defect classification discriminant threshold respectively. According to "Standard Photo Atlas of Steel Ball Surface Quality" [9], through the image analysis and computational experiments, we know that T1 =0.5, T2 =0.2, S=300.

According to the categories binary tree, the system is programmed in the environment of LabVIEW. Its procedures are shown in Fig.6.

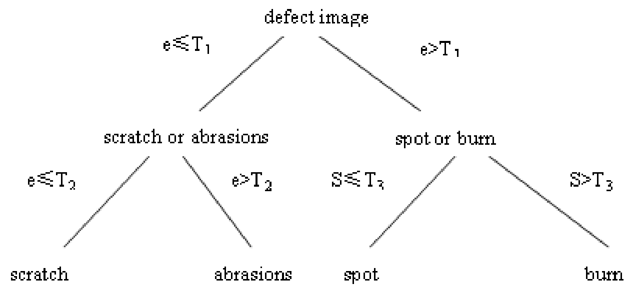


Figure 5. Categories binary tree

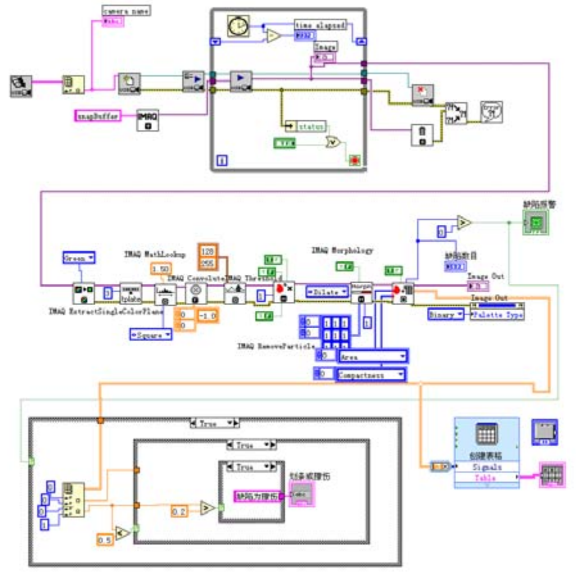


Figure 6. Procedures of the system

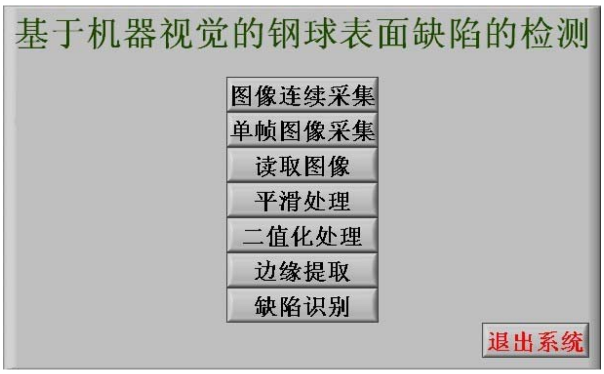
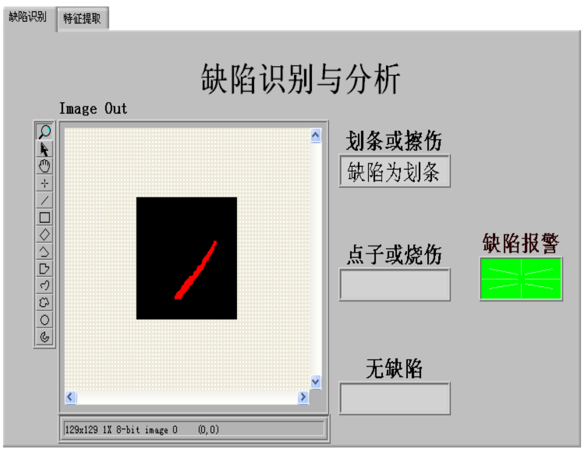
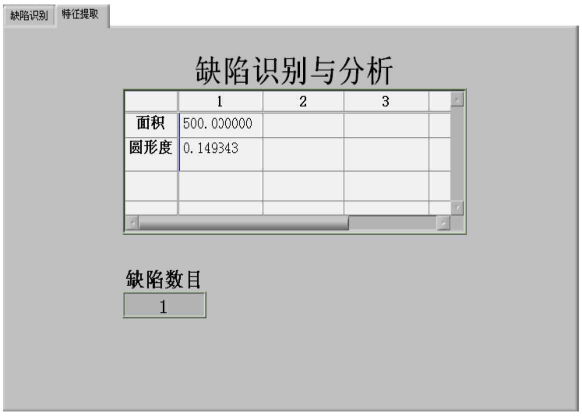


Figure 7. Main interface of the system



(a)Defect identification



(b)Feature extraction

Figure 8. Interface of defect analysis and recognition

The defect in the pre-processing defect image is identified. The system interface of the surface quality detection system of steel ball based on machine vision and the defect analysis and recognition results are shown in Fig.7 and Fig.8 respectively.

V. CONCLUTION

This paper is mainly targeted at developing a surface quality detection system of steel ball based on machine vision. Aiming at imaging charateristics of the steel ball with the strong reflection surface, the illuminate system and lighting are designed, in order to solve the problem that the light can not uniform irradiation and get clear images of balls' surface in this paper. The related image processing algorithms are studied. And on this basis, software design of the system is developed through the use of LabVIEW as the platform. At last, the identification of a steel ball surface defect is achieved, and the accuracy and practicality has reached the expected requirements. In the environment of LabVIEW, image-processing procedures are developed. The operation panels are intuitive and easy to operate. Using this practical technology, the detection of other types of surface defects can be also realized.

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