Design of Defect Detection System for Valve
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Abstract. To meet the demand of high precision and high speed of modern industrial inspection, this paper realizes defect detecting in the inner hole of valve. This paper builds a detection system using CCD camera and hard tube endoscope. Through the operation of the test bench can complete to collect image information. Collecting image distortion due to the bending of the bore itself and distortion of the camera lens, so it is necessary to eliminate distortion, image cutting, filtering and other operations before image matching, then, stitching image with Scale Invariant Feature Transformation algorithm (SIFT). The weighted average method is used to deal with the overlapped area of the image in the image stitching, continuously, a completed hole image of valve sleeve is obtained. Finally, use algorithm of template match between template and detection image to complete defect detection.

Introduction
Valve of the car steering is a core component of the automotive steering systems. Valve sleeve and valve plug with the quality of the car's steering performance has a great impact. Therefore, it is necessary to detect the defect on the inner hole of the valve sleeve, it image is shown in Figure 1. At present, the defect detection always being done manually, which wastes a lot of time and energy and the detection accuracy cannot be guaranteed. Machine vision detection technology is a new technology which use the camera to replace the human eye to judge and detect product quality [1], so there a way of machine vision, based on two-dimensional optical scanning image splicing method to get images and then stitching them.

Figure 1. The image of valve.

As for stitching image ways, more research is based on the image features method. Extraction image feature algorithm is mainly based on image color information [2-3], texture features and scale information. The feature extraction method which based on color information is intuitive and simple, but calculating time would be much more, and the result is easy to be affected by the difference of light and image color, which may lead to the failure of extraction. Texture-based feature extraction algorithm cannot get high-level image content, easily affected by image resolution and light changes. Based on scale invariant feature point as a local feature, it has invariance to the rotation, translation and resolution of the image, and object deformation without any change in illumination and viewing angle [4]. Considering the mentioned shortcomings, this paper comes up with a method that using SIFT algorithm to stitching valve inner-hole images.
This paper builds a detection system, which can get inner hole image, then, stitching them with SIFT and weighted average algorithm to get integral image. Finally, use method of template match between template and detection image to obtain defect area.

System Principle
To complete the research of stitching image, this paper builds a detection system which applies a CCD camera. As Figure 2 shows that the main components of the system are: a table, a driven guide mechanism by the stepping motor, a stepping motor rotary table, two stepper motor drives, a stepper motor controller, an RS232 communication line, a tube endoscope, a CCD camera, a xenon lamp cold light source, an image acquisition card, a computer and so on.

Put valve on the turntable driven by a step motor, then, computer gives command to motor driver by RS232 communicate wire, linear guide mechanism would take endoscope and camera vertical movement. Through endoscope movement and valve rotation, the camera can capture all round images of valve, and then, computer gets information by the image acquisition card. Next, computer uses SIFT get image feature points. According to feature points to match and fusion, which get a completed valve inner-hole image.

Image Preprocessing
There some reason maybe can cause image include noise signal, such as uneven light, mechanical jitter and others. Image would be blurred and the color distribution is not uniform due to the noise signal, which makes the feature points change. Therefore, the paper will deal the noise that from the image during the acquisition process with some method, like image filtering, image smoothing and so on, which can improve image quality. Except image noise, there are other factors that will affect the quality of camera captured image, so it is necessary to preprocess the image.

(1) Image enhancement
The main function of image enhancement is to strengthen the useful information, which can show image detail more clearly. This paper uses histogram equalization to enhance image. The method is adjusting the contrast of the histogram of an image and making the image clearer and enhances the local contrast in the image.

(2) Image noise reduction
Image filtering is a commonly used method of noise reduction, which can improve the quality of images and enhance the image characteristics of images [5]. In order to improve the image information of the valve, so that the collected images as close as possible to the original image, this paper uses the median filter method to deal with the image.

(3) Distortion correction
As the endoscope view angle is 85°, if the collected image is for the plane, the smaller distortion can be directly processed, but for the holes structure will be large distortion. The middle pixel on
the inner holes image is not distorted, but the greater distortion is gradually expanded from the row of middle to both sides. It is difficult to stitching image directly from original image, so deal them with distortion correction algorithm to get high quality image.

According for view angle and structure character of endoscope, we can know that the inner hole perspective principle. In the Figure 3, R is the radius of valve, and \( \theta \) is the viewing angle of the endoscope.

![Figure 3. Inner-hole image perspective principle.](image)

Fig.3 shows that relationship of geometry:

\[
FG = OG \times \tan \beta = R \cos \frac{\theta}{2} \times \tan \beta
\]  

(1)

\[
BC = OC \times \tan \beta = R \tan \beta
\]  

(2)

So the distortion is:

\[
\Delta = BC - FG = R \tan \beta - R \cos \frac{\theta}{2} \tan \beta
\]  

(3)

Use mentioned method to preprocess images, the result as shown in Figure 4.

![Figure 4. Preprocessed image.](image)

**Stitching Image**

After preprocessing images of inner hole, we should stitch them with SIFT to get the integral image. The algorithm proposed by David Lowe [6-7], the feature point of it can remains invariant when image changes, zooms, rotation translation. Use it we can get SIFT feature vector description as shown in the Figure 5.

![Figure 5. SIFT feature vector description operator.](image)

In the image matching, the Euclidean distance of two similar feature vectors can be taken as the measure of the feature points. SIFT algorithm to deal with the matching images U and V after feature extraction, the resulting set of feature points are:

\[
F_U = \{f(U)_1, f(U)_2, \cdots, f(U)_{n_U}\} \quad F_V = \{f(V)_1, f(V)_2, \cdots, f(V)_{n_V}\}
\]  

(4)
Suppose that the spatial dimension of the feature vector detected by SIFT is K, Euclidean distance is:

$$d(F_U, F_V) = \sqrt{\sum_{i=1}^{K} (f(U)_i - f(V)_i)^2}$$

When we match two images, the nearest European distance from the two feature points is \(d_1\), the nearest European distance is \(d_2\), and the ratio of Euclidean distance \(R = d_1 / d_2\). Be sure a standard value is \(\varepsilon\), if \(R\) is less than \(\varepsilon\), the match succeeds, otherwise fails.

![Figure 6. Matched two images.](image)

Two images in Figure 6 show that most of the feature points can be matched together, but there are also obvious errors. Since these errors are a few, so the impact of the subsequent image stitching is relatively small.

Image fusion is an important part of the image stitching process, which determines the quality of the stitching results. In this test, since the image is obtained under the external conditions of the same light intensity, the brightness difference between the images is relatively small, so, use weighted average method to merge image, the integral inner-hole image shown in Figure 7.

![Figure 7. The integral inner-hole image.](image)

**Differential Defect Detection**

The difference algorithm subtracts the image to be detected from the template image, and the result will reflect difference between two images. Since the image has a series of operations in the acquisition process, the threshold is set to reduce the possibility of misjudgment. Therefore, setting a standard value \(T\), contrast it with subtract result. If less than \(T\), the value is unqualified, if the difference is greater than \(T\), the valve is qualified.

![Figure 8. Detect defect. (a) The image of preparing to detect defect, (b) Differential results.](image)

To filter the pixel interference, subtracted image should process with threshold, we select threshold is 80, processed image showed in Figure 8. After the number of pixels in a defect region of the image statistics, the number of pixels in the defect region is 525, which greater than the pre-set 300 pixels, so this valve is unqualified.

**Summary**

The defect detection system described in this paper is helpful to detect valve of car.
(1) This paper builds a defect detection system of valve, which provide a hardware for realizing detect defection.

(2) In this paper, the images collected by the camera are preprocessed, and then the SIFT algorithm and the fusion algorithm are used to obtain the complete hole image, finally, use difference algorithm to get defect region and determine whether the valve sleeve is qualified by calculating the number of pixels in the defect area. It is verified that this test bed can be used to detect flap defects.

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References


