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Computer vision algorithm for measurement and inspection of O-rings

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ABSTRACT

O-rings are one of the most common seals used in industry. Precision measurement and inspection of O-rings play a vital role in seal quality control. Human inspection is a traditional way to remove defective O-rings, which is instable and time consuming. The aim of this paper is to utilize the detection algorithms based on computer vision technology to control the quality of O-rings, which includes the accurate measurement algorithm for the internal/sectional diameter and the classification algorithm for the surface defects. A machine vision system is implemented analyze the captured images of O-rings and perform the measurement and inspection processes. The proposed system is evaluated by inspecting a series of O-rings. Experimental results show that the proposed vision system is capable for measuring and inspecting O-rings seal with good accuracy and efficiency.

1. Introduction

Sealing quality is important criteria for the evaluation of equipment quality. Sealing quality will directly affect the accuracy and stability of device. O-ring is currently the most widely used and simple structured sealing element. So ensuring quality of O-rings is particularly important.

Seals are mass-produced, but also require a relatively high quality. Whether the quality of O-rings meets the requirements or not is mainly judged from two aspects. First, the requirement on O-ring size demand that the error of internal dimension and cross-sectional diameter (thickness) must be within the permitted tolerance. Second, the O-ring surface quality requires that O-rings must not have any defects such as material shortage, bumps, dents, and breakage.

The detection of O-rings relies on human inspect currently. Many experienced inspectors detect O-rings in adequate lighting conditions, which is low-accuracy, high in labor-intensity and also time consuming. What's more, it's also instable because the test results are prone to subjective factors. Thus, it is hard to guarantee a stable quality.

Machine vision is an excellent tool for inspecting a variety of items such as textiles, electrical components, and machine tools. With the rapid development of image processing and pattern recognition, machine vision technology have attracted more and more attentions and is widely used in industry area [1], for its simplicity, noncontact and robustness. However, surface defects inspection is both one of the most common and most difficult problems in the area of machine vision. In literature, many detection technologies have been adopted in industry, such as gear detection [2], bearing inspection [3], and saw detection [4]. Moreover, defects on seal surface often have similar color with their background, which makes it difficult to distinguish the defect from their background. The study of precisely detection for low contrast material is still long way to go. Various techniques used for these aspect have been reviewed by many studies. Martinez et al. [5] designed a machine vision system for surface quality inspection of transparent parts, like headlamp lens. Roby et al. [6] compared four different defect detection algorithms based on Fourier filtering, auto-median, image convolution, and single-step thresholding approaches. Li et al. [7] investigated an appropriate real-time defect detection and location algorithm on surfaces of sequence circular objects. However, the issue of seal surface detect detection has not been previously discussed in these literature yet.

It's very difficult to measure the size accurately and to detect the defect efficiently when contrast of acquired O-rings images is not obvious. Therefore, automatic detection system for O-rings still have much room for improvement. This paper proposes an on-line machine vision system for O-rings quality inspection. A simulation rotating platform and a lighting solution were designed to enhance the contrast of image and make the environment controllable. A series of image processing methods were used to improve the localization accuracy of edge detection. In particular, we compare different defect classification algorithms and select CKFD algorithm to analyze images. The proposed system can achieve size

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measurement and defect inspection processes for the O-rings with satisfactory efficiency and accuracy.

The paper is arranged as follows. Section 2 describes the overall layout of the system. In Section 3 we describe edge detection methods for size measurement. The defect detection method is introduced in Section 4. Section 5 includes experiments and discussion. In Section 6 conclusions are drawn.

2. The proposed system

The schematic diagram of the experimental set up used for O seal measurement and inspection is shown in Fig. 1. The hardware consists of a light source, an industrial camera, optical lenses, a computer, an ultra-white glass platform, a light bracket. A simulation platform was set up to simulate the movement of the production line in industrial environment. The ultra-white glass platform, connected to the rotating platform together, can achieve high-precision movement in desired manner under the computer control. The model of rotating platform is HRA200, which has a resolution of 0.01° and a repeat positioning accuracy of 0.005°.

In order to meet requirements of the national testing standard, the measurement accuracy should be higher than 0.08 mm when detecting the O-rings with diameter less than 80 mm. The model of CCD camera is MV-EM510C, which has a resolution of 2456 × 2058 and the field of view of 100 mm × 100 mm.

The clear surface features and edge profile are needed to measure the size and detect surface defects of O-rings. In this paper, we combine the forward lighting and back lighting [8] as the lighting solution. Two lighting schematics are shown in Fig. 2.

The forward lighting highlighted the surface defects while eliminating the shadow. Back lighting highlighted the edges, and at the same time can eliminate partial reflection of the forward lighting in the ultra-white glass platform. The specific installation form is shown in Fig. 1.

According to the requirement of O-rings inspection, a suitable software was modular designed. The specific process of O-rings quality inspection is shown in Fig. 3. It consists of two separate modules: the size measurement module and defect detection module. Two modules work together to determine whether O-rings are qualified.

As soon as the platform starts to run in a designed manner, software starts to capture images simultaneously. Collected images were analyzed to obtain the current indicators to be detected. It's not necessary to go through the size measurement module if O-rings sample is flawed. So the software was designed to set a flag to indicate the O-rings defect status. When unqualified seals were detected, the computer marked it out and issued a warning. Otherwise, the system will output the size parameters. All the algorithm detail will be explained in following sections. So the software is capable of processing the size measurement and defect detection simultaneously.

3. The size measurement algorithm

This step measures the inner/outer diameter and the thickness of O-rings. In this process, image noise, positioning accuracy of the edge and the measurement algorithms will have an impact on the accuracy. In the scenario of O-ring seal, we can use the following steps to improve detection accuracy.

3.1. Edge detection with pixel accuracy

Physical contour is one of the most important properties of an object. In order to extract the contour of O-rings, we must detect its edges [9]. The accuracy of edge detection will directly affect the accuracy of dimensional measurements. People have done a lot of research about this, so a lot of methods were developed to detect edges. One can use simple edge detectors like Roberts, Sobel, Prewitt, LoG, or more sophisticated Canny edge detector [10]. All these methods perform edge detection with a pixel accuracy.

For ring detection, we don't need to extract the seal surface texture, since the edge detection is only used to measure the diameter of the inside and outside. And the extracted texture may affect the measurement accuracy. So we can also use the robust morphological edge detectors [11,12], because the morphological methods can eliminate seal surface texture easily. Therefore, an improved anti-noise type morphology edge detection algorithm was used to improve the positioning accuracy by introducing multi-structure elements. In Formula (1), A denotes the original image, S_1, S_2, S_3 respectively denote three different structural elements.

$$D_9 = [(A \Theta S_1) \oplus S_2] \oplus S_3 - [(A \oplus S_1) \Theta S_2] \Theta S_3 \tag{1}$$

Fig. 4 shows a comparison of the results by using various algorithms to detect O-rings edge. It can be found that the Roberts, Sobel, Prewitt and LoG edge operator cannot eliminate the unnecessary edges very well. The Canny detector can eliminate some unnecessary edges, but there are still some redundant edges. However, the morphology edge detection algorithm can effectively eliminate the edges of the texture and the reflection-caused edges. So we use morphological edge detection algorithms to extract edges in this machine vision system.

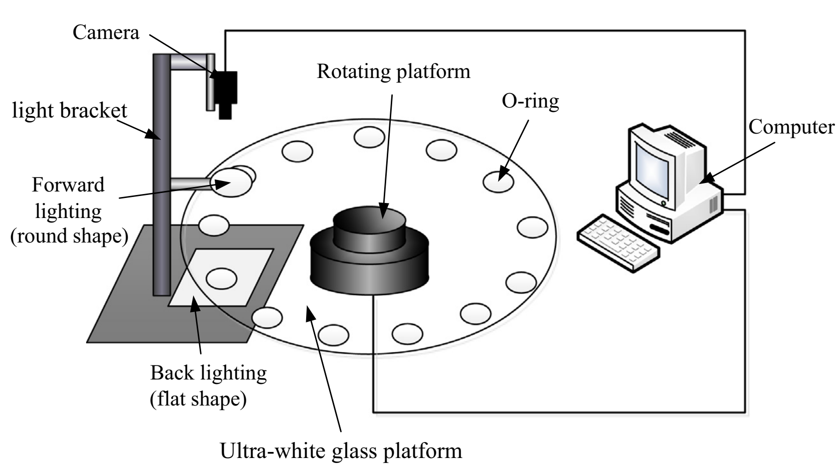

Fig. 1. Schematic of the proposed vision system.