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Vehicle Steering Gear Sleeve Defect Detection Method Based on Machine Vision

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Abstract: - This project takes the steering gear sleeve as the research object, and uses computer vision technology to detect it. By using this method, the Canny operator is adaptive filtered and integrated with the watershed method, and many features of the image are extracted. SVM classifier was established for three representative defects, such as lack of material, burr and coating. It is used to identify the steering gear sleeve. A test platform is set up to automatically classify and remove defective parts of automobile steering gear sleeve based on UR5 robot. The accuracy and stability of detection are improved by an improved edge segmentation algorithm. The experimental results show that the system can diagnose the fault of the axle sleeve of the automobile steering gear and cooperate with the operating arm to make it possible to automatically detect and remove the fault products.

Keywords:Steering Gear Sleeve; Defect Detection; Machine Vision; Deep Learning.

I. INTRODUCTION

At present, due to the progress of various processes, the domestic car industry has been rapid development, among which, the demand for steering wheel cover has been high. Various types of steering knuckle bushings vary in size and structure, and their manufacturing processes include injection molding and stamping. In the production of all kinds of vehicle steering gear sleeve, due to a variety of reasons, surface damage will inevitably occur. Taking automobile steering gear ring injection molding as an example, its molding quality is closely related to cavity temperature, mold structure and pressure value, etc. If the setting is not proper or the machine is not running properly, it is easy to lead to unqualified injection molding products [1]. However, due to the use of stamping technology to manufacture the steering gear ring, due to the surface of the abrasive dirt, the inner layer off and dust in the process of processing, it is easy to cause damage to the parts. Moreover, the steering gear sleeve is used for the vehicle assembly, and its quality problems will shorten the service life of the product, and in serious cases will pose a threat to the life and property of the personnel, so the quality test of the steering gear sleeve of the vehicle is an indispensable part of the manufacturing process. At present, the inspection method of the vehicle steering gear sleeve surface defects of various companies still relies on manual operation, relying on skilled technicians according to their own experience, this method has the following shortcomings: (1) The test speed is slow. When a large number of finished products are processed, the conventional manual inspection method, to arrange a lot of inspection employees on each production line, which greatly increases the consumption of manpower, and the detection time is relatively stable, difficult to greatly improve. (2) Signal detection is unstable. Because it is a manual test, so the same parts, everyone has their own views, more rely on the experience of workers. If the continuous test time is too long, there will be visual fatigue and low mood and other phenomena, at the same time, in this state, the product test will be disturbed by artificial emotions, can not be objectively tested, which will cause the stability of the test to decline. (3) The detection accuracy is not high. Due to the constraints of human physiological conditions, it is difficult to find subtle color and shape changes in continuous visual observation, especially in a specific environment such as strong reflection, resulting in fatigue detection and reduced measurement accuracy.

Driven by the rapid development of artificial intelligence and the concept of Industry 4.0, the country has vigorously developed intelligent equipment and intelligent products, accelerating the intelligent process of production technology, making it gradually move from the original simple mechanical processing to more complex intelligent manufacturing, but it is relatively backward in the intelligent testing of the piece tube. Some companies are also actively exploring how to better use machine vision to replace traditional manual inspection methods [2]. The use of mechanical vision technology can be used for non-contact detection and detection of the tested object, with high efficiency, safety and reliability, stable performance, long-term continuous operation characteristics, as well as in high temperature, high pressure, toxic and harmful working conditions. In the long run, replacing manpower by machine vision is an inevitable trend of human development. At present, although

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the theoretical research of computer vision system continues to deepen, the software system and the hardware system continue to improve, but there are still many shortcomings. For example, in some complex working environments, the detection system is highly susceptible to dust, vibration, noise and other factors, thereby reducing the detection accuracy and efficiency, and in serious cases, it will cause device damage [3]. Therefore, how to improve the efficiency and stability of the computer image acquisition system, improve the computational efficiency and real-time performance of the algorithm, is the current research hotspot in the field of computer vision. Through interviews with some collaborative enterprises, although their production scale is large, their test mode is still carried out manually, and the classification and positioning of defects are dependent on manual conduct, which consumes time, and the speed of testing is slow, and it is difficult to match with the automated intelligent production line. Some companies that use computer vision must achieve higher application requirements under more stringent application conditions, otherwise it will reduce the recognition accuracy and work stability of the system. In order to accelerate the intelligent transformation of Chinese enterprises and improve product quality, it is necessary to develop an automatic surface defect detection system suitable for various types of automotive steering gear rings.

At present, from the perspective of spatial scale, it can be divided into three-dimensional vision and two-dimensional vision, and two-dimensional vision is the most commonly used measurement means in the production process [4]. At present, a lot of research has been done on the surface quality of various industrial products such as metals, textiles and chips, and it has been well applied in some fields. Researchers at home and abroad have used advanced optical equipment to carry out high-precision imaging of the parts under test, and used the self-developed ULMA detection system to detect scratches, dark spots and bubbles on the surface. Some researchers have developed vehicle-based test systems for on-line monitoring and grading of track surface quality. Some studies have proposed automatic wood fiber texture recognition method based on one-dimensional Hough transformation [5]. By keeping the low-frequency information of the target area unchanged, the target can be recognized effectively. Some scholars studied the mechanical vision detection method suitable for the surface damage of cold rolled plate, and used BP neural network to establish a fault classifier, which improved the fault diagnosis accuracy to more than 90%. This method replaces the traditional manual inspection method and improves the speed of fault diagnosis. In recent years, researchers at home and abroad have proposed a method to measure the surface of high-speed rolling bearings based on the slider mechanism of crankshaft. According to the diffusion characteristics of light, some researchers propose a laser irradiation mode that can improve the shape characteristics of the machined parts, and then image according to the reflection theory to realize the imaging of large-size curved parts [6]. This project intends to study a new idea for surface quality measurement of flexible printed boards. It intends to use differential imaging theory to build an optical modeling theory and study the mechanism of each optical path parameter on its focusing accuracy. In this way, a high precision focusing error detection system for surface machining can be constructed. According to the bionics principle and optimization process of "Firefly", some scholars have studied the method of dividing the surface damage area of IC chips, and adopted the multi-threshold optimization optimization strategy to speed up the test time, so as to achieve the rapid non-destructive detection of the surface quality of IC chips. Researchers at home and abroad have developed a mechanical vision system for rapid and accurate measurement of track diseases, which solves the problem of exposure in image acquisition by spectral analysis of LED light source spectrum, and uses synchronous trigger technology to steady-state imaging of track. By means of image enhancement and image reconstruction, some scholars have effectively suppressed the surface texture of injected products, and imported the extracted defect information into the artificial neural network, so that the recognition accuracy of the appearance quality of injected products can reach more than 95%. Some researchers have used linear laser to develop the orbit surface topography measurement device, which integrates the position sensor and motion control functions together, so as to achieve the purpose of real-time control and detection of the orbit surface [7]. There have been studies on the fusion of 3D visual detection and convolutional neural network to improve the recognition accuracy. Some scholars plan to use the corresponding relationship between point and image, combined with point cloud segmentation and image segmentation to obtain the 3D feature parameters of the target. In view of the current problems such as difficult identification of surface damage of lithium-ion power batteries and small number of samples, this project uses the new idea of point cloud damage identification, obtains high-quality 3D contour information of lithium-ion power batteries through repeated scanning, and realizes high-quality identification up to 97.17% with MiniImageNet as the source. The automatic identification of surface damage of Li-ion power battery is realized. There have been studies on vehicle registration based on point cloud and vision measurement system with damage model. Firstly, an error threshold is set according to the collected point cloud information, and then it is matched and positioned, thus improving the detection speed and accuracy [8]. Researchers have proposed a linear laser detection method that can achieve a detection accuracy of 15 microns, which is suitable for the three-dimensional reconstruction of most small targets and surface damage. A structured light code 3D scanning platform which can obtain high precision point cloud of steering gear bushing under test has been established. The coarse and precise connection of point clouds is studied by using 2D image and 3D point cloud neighborhood information to obtain multi-view cloud of the steering gear sleeve under test. In this paper, the irregular point cloud coding is transformed into fixed length sequence point cloud coding to realize the accurate identification of bogie casing type and attitude. The bridge identification method based on point cloud has been studied, which combines depth and gradient to realize the accurate identification of the defective area. For various types of steering casing, the mechanical vision method is used to check the 10 main problems existing in its manufacturing to ensure the processing quality of the product [9]. This project intends to give full play to the advantages of 2D and 3D vision to solve the problem of effective detection of various defects. Fully mining the depth information in the image to complete the extraction of convex points, pits and other defects; The multi-angle attitude measurement method is used to improve the adaptability to lighting conditions.

II. SYSTEM STRUCTURE AND PROCESSING FLOW

This paper presents a fault diagnosis method for automotive steering gear ring. The intermediate communication layer is the serial communication between the computer and the UR operator, camera and other devices, and the decision layer is the fault identification algorithm executed on the computer. Figure 1 shows the hardware of the system (image cited in J. Sens. Netw. 2021, 10(1), 7).

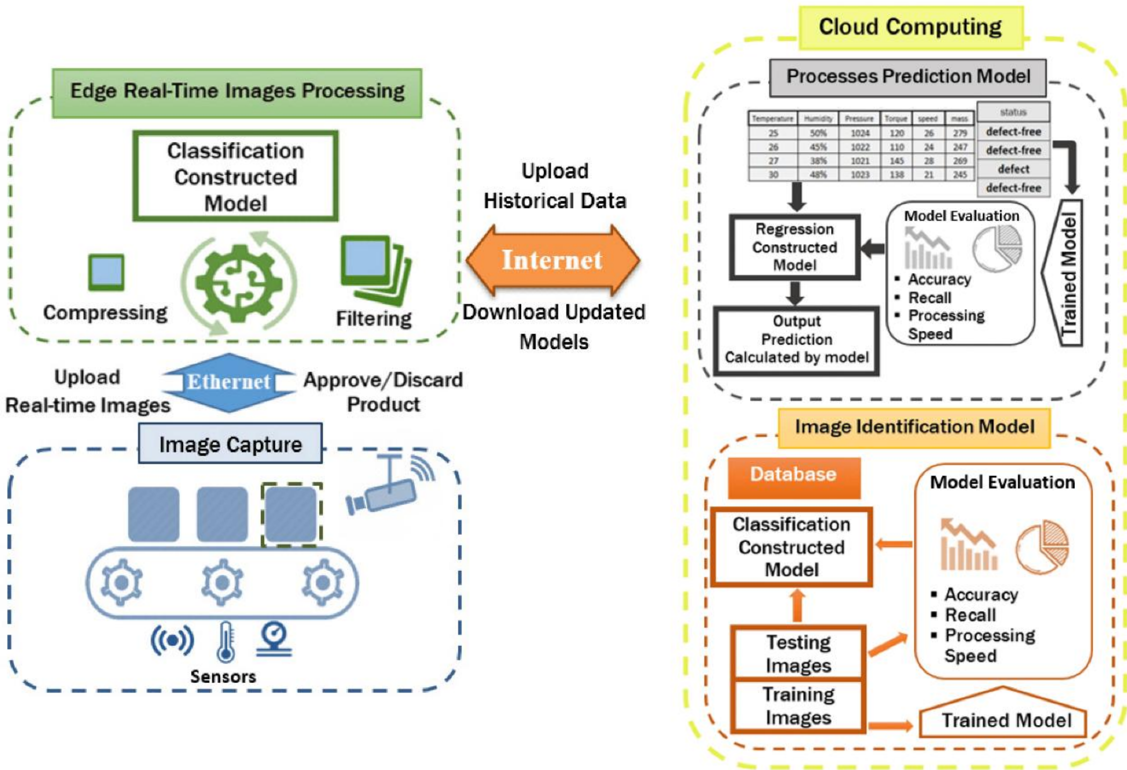

Fig.1 Hardware of auto parts inspection system based on machine vision

The test system is mainly used in industrial assembly line, which has higher requirements for its accuracy and real-time performance. In general, the software can be divided into two stages, one is the process of error identification, and the other is the process of judgment. The IPC and UR operators are powered on and the entire system is in working condition. After the UR manipulator moves the threaded part to the specified fixed point, the industrial camera is started and the image analysis is carried out. Finally, the UR operator is graded by serial communication, the finished product is placed in the qualified area and the unqualified area, and the unqualified product is classified. In this paper, a method of surface defect identification based on laser scanning technology is proposed [10]. The existing point cloud detection technology adopts either conventional algorithm or deep neural network for detection, but the massive point cloud data makes the learning and detection of deep neural network take too long, and it is difficult to apply to the actual application. When applying feature identification technology to defect identification, we must first understand the characteristics of the measured object, which can usually be applied to the identification of the damage category on the flat surface or a specific object. However, the shape of the tested parts is irregular, more complex and easier to change, and some fault features cannot be accurately described, and can not reflect the typical structural characteristics, so it is difficult to achieve by feature identification. Simply put, template matching is to scan the detected image after rotation, translation, scaling and other operations. Finally extract and analyze these two different parts, and determine the state according to the defect of this part to determine its correctness. Two 3D point cloud images were obtained by scanning the inspected part and the template part with laser scanner [11]. The template matching technique is used to analyze the two point cloud data obtained, so as to complete the surface detection of the measured part. The specific work flow is shown in Figure 2 (the picture is quoted in the Misalignment inspection of multilayer PCBs with an automated X-ray machine vision system).

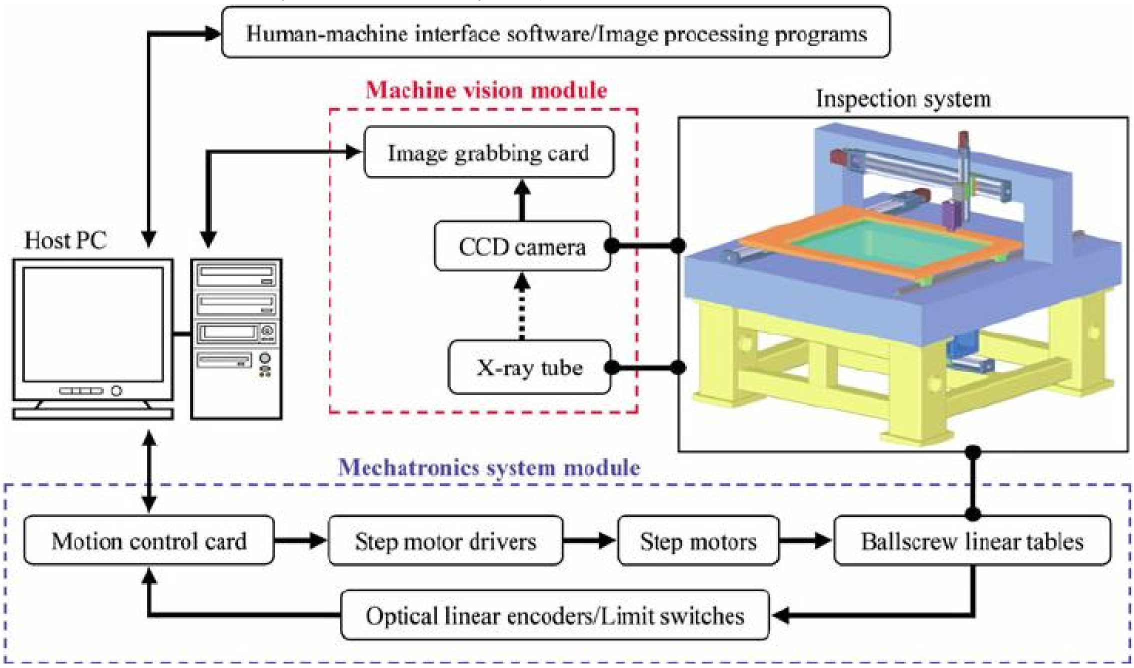

Fig.2 Workflow of inspection system based on machine vision

The initial image of the vehicle steering gear sleeve is shown in Figure 3. The boundary extraction results obtained with different operators are shown in Figure 4. Both the classical Robert operator and the Sobel operator are used in the obtained images, which contain many false boundaries and can not identify defects well [12]. Using the conventional Canni operator, although it can get the general outline of the object, it still has defects in details, and it is likely to treat some special noise as the edge. A new Kanny operator is used for boundary detection, and the results show that the algorithm is feasible.

Fig.3 Original image of automobile steering gear sleeve

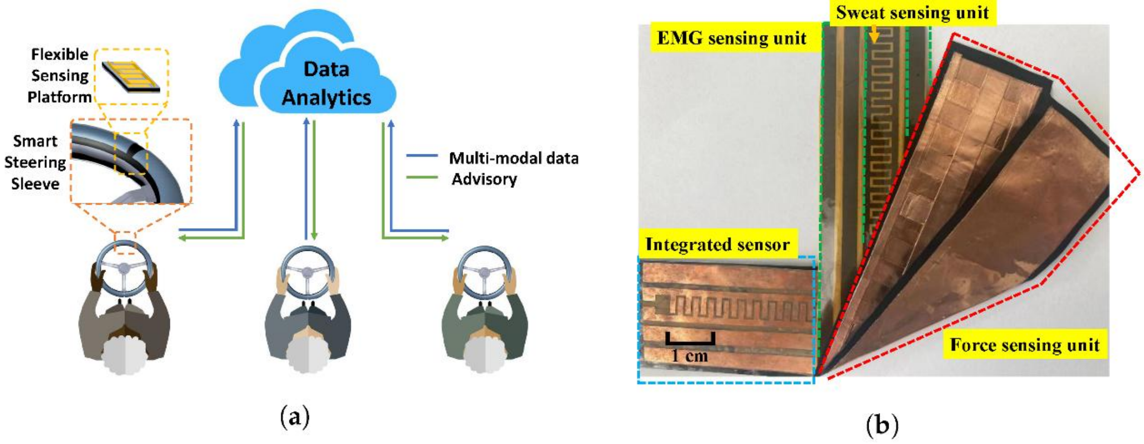

Fig.4 Edge extraction results

Four different image characteristics are obtained by using the watershed method: perimeter, area, roundness and gray variation based on extracting the exterior shape of the car steering gear. The circumference is the sum of the spacing between the points on the extracted boundary, while the area is the number of pixels in the final obtained feature region [13]. The above three image characteristics can be used to determine the material missing and plastic bag problems in automobile steering knuckles. This paper presents a method of calculating the inner surface roughness of automobile steering gear tire based on wavelet transform.

A. Steering gear sleeve defect detection method

Aiming at the steering gear sleeve of a certain car, mechanical vision technology is used to diagnose its fault. The workflow for this approach is shown in Figure 5 (image cited in Machine vision intelligence for product defect inspection based on deep learning and Hough) transform).

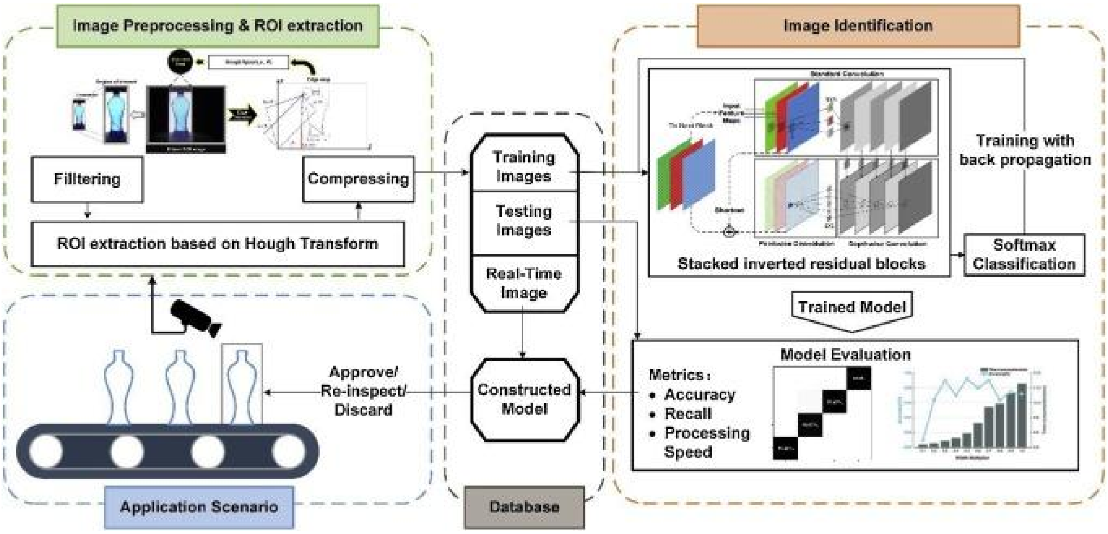

Fig.5 Operation flow of auto parts inspection based on machine vision

B. Image Preprocessing

In order to diagnose the fault of the turbocharged steering gear sleeve of a certain type of car, it must be pre-treated. In the image recording, imaging and transmission, there will be pepper and salt noise, Gaussian noise and bounced noise, so the geometric structure analysis method and numerical analysis method in mathematics are used to detect, that is, the use of components to control another component, and then according to the connection between the components to process the image, so as to improve the quality of the image. Aiming at the detection background of bogie casing, the linear least square method is used to measure its effect on the image [14]. After the minimum mean value is obtained, the fitting variation background can be determined, so the fitting calculation formula is as follows:

$$\lambda(u) = \varepsilon_1 u + \varepsilon_2 u + \varepsilon_3 u + \varepsilon_4 u \quad (1)$$

In the formula, $\varepsilon_1, \varepsilon_2, \varepsilon_3, \varepsilon_4$ is the influence factor of background information in each direction, and u is the mutation value of the factor. Calculate the mean variance according to this formula (1):

$$\gamma^2 = \sum_{i=1}^{n} [U_i - \lambda(u)]^2 \quad (2)$$

The result of the calculation is 4 positive background information factors, because there are errors in the position is not accurate, so there is also a calculation error, so when the information interference in other directions is performed, the middle value is weighted. The corrected background estimates are:

$$B = b_1 \gamma^2 + b_2 R \quad (3)$$

C. Determine and segment the defect projection area

In the process of image preprocessing, it must first identify the projection range in the image. The image of the rudder barrel is positioned on the whole image, so that it is isolated from the background and the area of interest is obtained [15]. Then the steering gear sleeve in this range is judged and divided according to the result of judgment. When the selected image is evenly arranged on the axis, and the orientation of each part is the same, then the gray level projection method can be used to analyze the gray level in the image and get the target area. According to the results of formula (3), the calculation formula of gray projection on the axis is as follows:

$$g(v) = \frac{1}{B} \cdot \sum_{i=1}^{B} j(u, v) \quad (4)$$

The imaging boundary of the steering gear sleeve on the v axis is determined to obtain the projection curve sample as shown in Figure 6 (the picture is referenced in Drawing High-Definition and Reversible Hydrogel Paintings with Grayscale Exposure) [16].

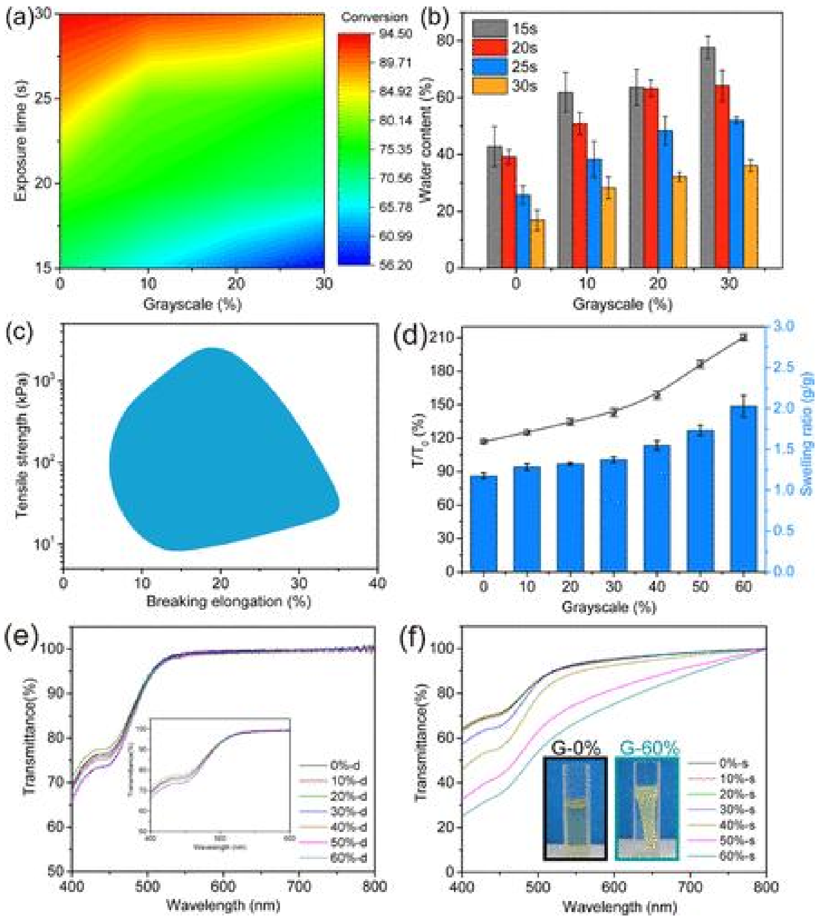

Fig.6 Gray projection sample curve

The four types of samples are arranged in order, which are: no damage sample, scratch sample, scratch sample and scraped sample projection curve. No matter what type of car engine the turbocharged steering wheel cover has a similar projected shape, the above background is not detected object. Because of the reflection from below, it causes the curvature to fluctuate [17]. Aiming at the problems such as unclear image edges and inability to accurately distinguish fault types in steering gear casing images, this project proposes a method based on wavelet conversion and segmentation. Realize accurate segmentation of steering gear casing images (Figure 7 is referenced from Semantic segmentation of bridge components and road infrastructure from mobile LiDAR data).

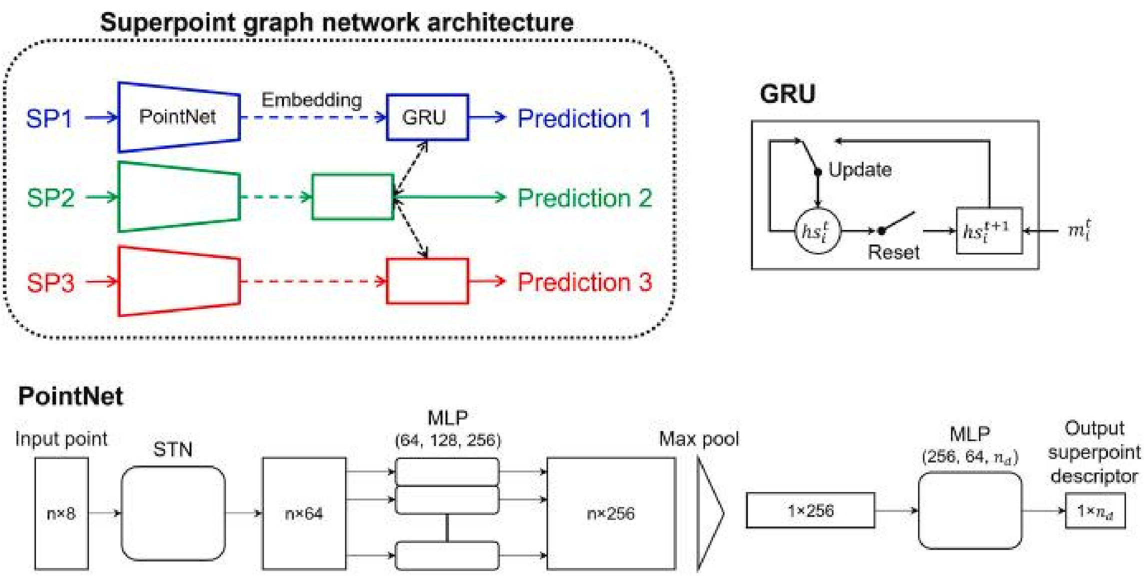

Fig.7 Schematic diagram of segmentation image

There are image set M and element set N, and N is usually used to perform operations on M. The morphological processing calculation process is as follows [18]:

$$\begin{cases} H_2 - H_1 = W_1 \\ D_1 - D_2 = W_2 \\ H_1 - D_1 = W_3 \end{cases} \tag{5}$$

In addition, color feature extraction is also carried out for the imaging of the steering gear sleeve. Under machine vision, the color distribution of the steering gear sleeve is divergent under the condition of light source, illumination and object reflection [19]. Assuming the hue is F, saturation is W, and brightness is C, calculate the color distribution:

$$\chi = (N + \frac{f}{F}) + \sum_{i=1}^{n} \sqrt{\left(\frac{W_{\max} - W_{\min}}{W_{\max} + W_{\min}} \right)} + \ln \left(1 - \frac{|C - 0.5|}{0.5} \right) \tag{6}$$

$$\begin{cases} i = \sum_{i=1}^{n} u_i g(u_i) \\ j = \sum_{i=1}^{n} [u_i - i] g(u_i) \end{cases} \tag{7}$$

An image feature extraction method is proposed [20]. The first limitation is "separability", that is, to have a certain representativeness, to be able to reflect the various characteristics of things, but also to be able to show the characteristics of things. Secondly, the characteristics of the graph should have a strong anti-noise ability to ensure that different lighting, light source, shape and other factors have the least impact on the graph. Maximize consistency [21]. The information for each feature is similar in the demarcated scope, and each feature is independent of each other. This project intends to study the algorithm of proportional feature extraction.

$$\delta = \sqrt{\eta_n \cdot (\chi^2 \cdot i + \chi^2 j)} \tag{8}$$

η_n represents the value of form n, and χ and i, j are the result statistics obtained by formula (6) and (7) to extract data features.

III. Support vector machine classifier design

Support vector machine (SVM) is a common method, which is based on SVM. It can diagnose and classify parts. Compared with traditional BP neural network, K-nearest neighbor and multi-layer perceptron, SVM has better generalization performance [22]. Radial basis function, as a special kernel function, has advantages that other methods cannot compare with. Because the core function requires very few parameters, so it can greatly reduce the whole design process, and its constraints are usually not much, so the author chose the most commonly used radial basis function as the core. Its function is expressed as follows:

$$K(x_1, x_c) = \exp(\frac{\| x_1, x_c \|^2}{2\sigma^2}) \tag{9}$$

x_1 is any point in the kernel space; x_c is the center of kernel function; σ is the kernel width parameter. Taking 60 threaded holes of 15 threaded parts as training samples, 4 features, including circumference, area, roundness and gray variance, are extracted from the samples and combined with the SVM classifier. The problematic workpieces are divided into three types: lack of material, burr and colloidal-wrapped based on SVM classification method [23]. According to its test results, it can be divided into qualified test and unqualified test.

IV. Test results

According to the structure and procedure of the system, the corresponding test platform is established. The computer was the MXE-5401, with the i7-4700EQ as the CPU, and three different monitors. The MV-CA030-10G is an Internet-connected industrial camera with a 1920x1440 maximum frame rate of 25 frames per second and a 35 mm lens. In order to ensure that the lens can get uniform ring light, the infrared ring light source is designed. The test bed is shown in Figure 8 (image cited in Sensors 2017, 17(6), 1403).

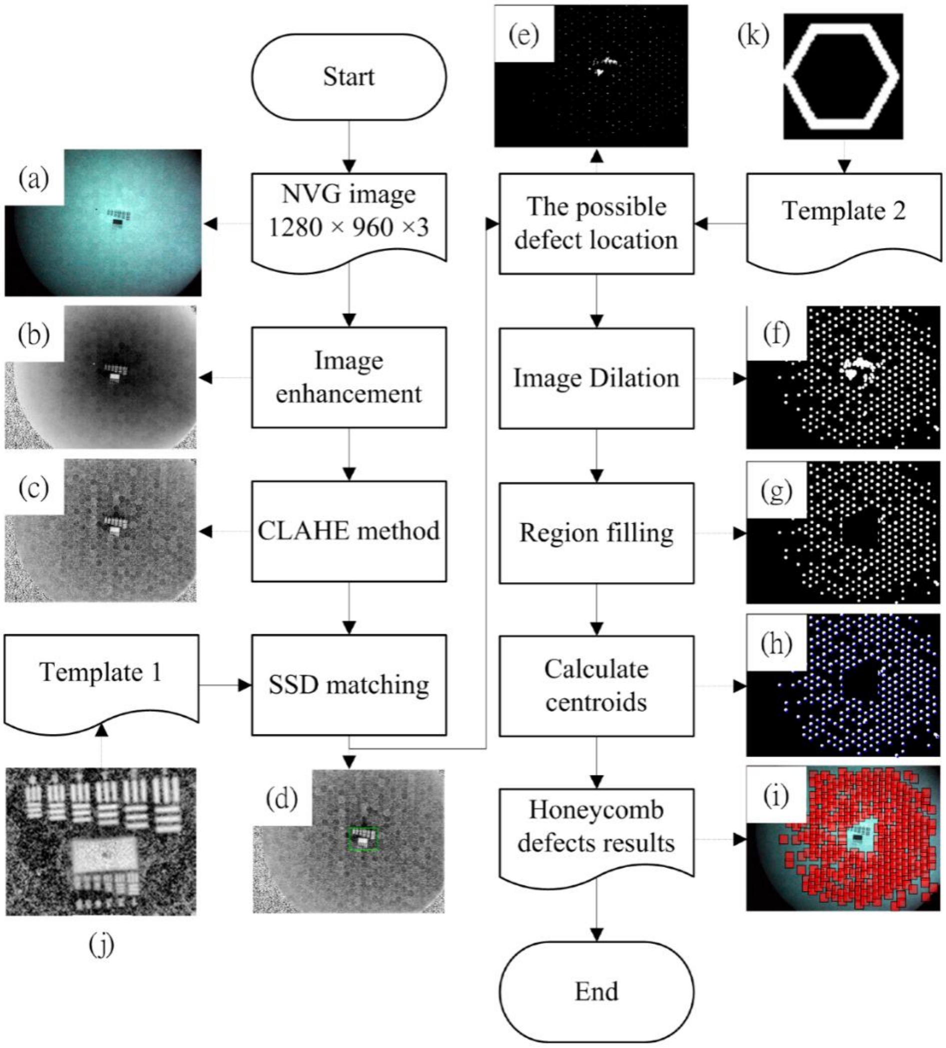

Fig.8 Test platform

In this paper, improved Canny operator and classical Canny operator are used to test 50 threaded parts and 200 threaded hole specimens. In the test, the non-conforming products and the problematic threaded holes are classified respectively, and the results are shown in Table 1.

Table 1. Test results

type	Option	Sample size	Number of false drops	Detection rate
No defect	Traditional Cannier operator	125	3	97.60%
	Improved Canney operator	125	0	100.00%
starving	Traditional Cannier operator	75	5	93.33%
	Improved Canney operator	75	1	98.67%
burr	Traditional Cannier operator	25	3	88.00%
	Improved Canney operator	25	1	96.00%
encapsulating	Traditional Cannier operator	25	4	84.00%
	Improved Canney operator	25	3	88.00%

As can be seen from Table 1, the improved Cannier operator has obvious advantages over the traditional Cannier operator, and has better effect on product defect identification. The detection rate of qualified products can reach 100% and that of unqualified products can reach 95%. In the actual industrial production process, the proportion of unqualified products is low, so the accuracy of system detection will be further improved. The detection system and test effect are shown in Figure 9.

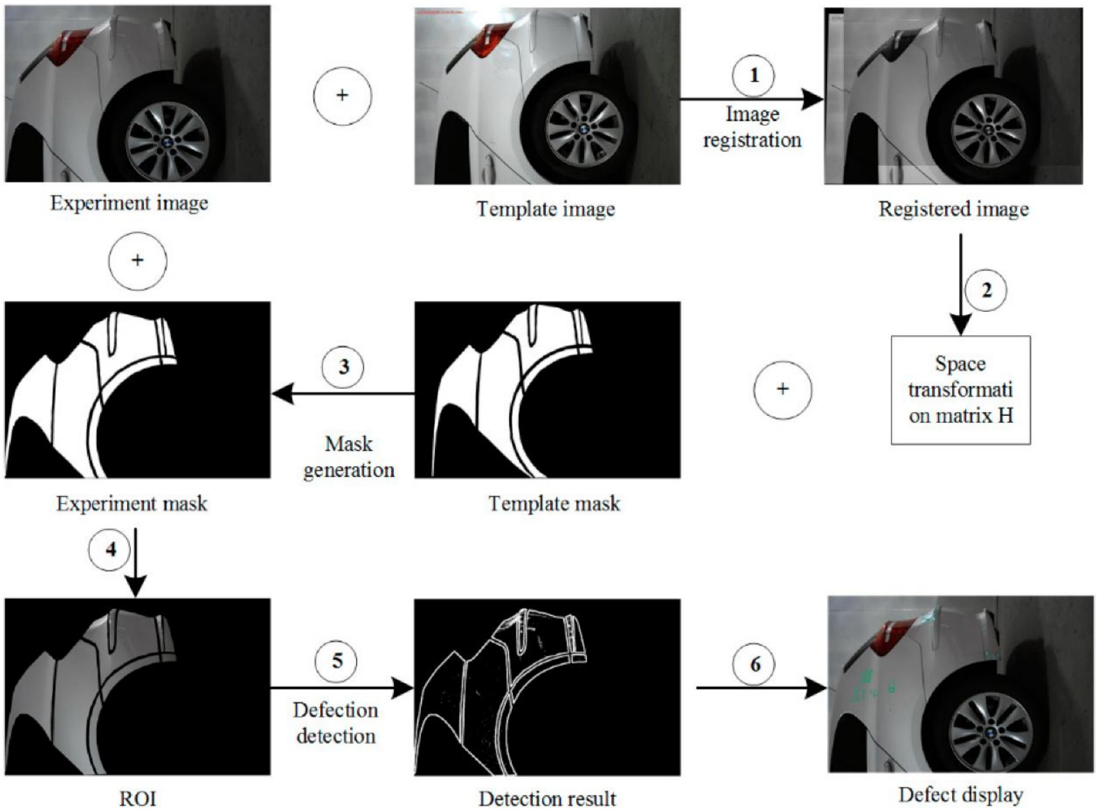

Fig.9 Detection system and test effect

V. CLOSING REMARKS

Computer vision technology is used to test the outer cover of automobile steering gear. The whole detection process adopts the method based on mean filtering, adopts a detection method based on SVM, pretreats the detected data, and then uses SVM to distinguish the detection results. The experimental results show that the algorithm can effectively improve the measurement results of the steering gear sleeve, and it is a new technology with great application prospects.

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