ENGINE CONNECTING ROD OFFLINE DEFECT DETECTION BASED ON HALCON

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As the power transmission link between piston and crankshaft, the quality of connecting rod is critical in the engine production. The typical failure mode of the connecting rod is fatigue failure. The reason for this is the surface defect of the connecting rod. Aiming at the present situation of heavy workload, low efficiency and large error in manual inspection of engine connecting rod surface defects, a method of detection of engine connecting rod surface defects combining machine vision and HALCON software is proposed. According to characteristics of engine connecting rod defects, an offline defect detection system is designed. The detection system mainly includes CCD camera, lens, light source, light source controller and adjustable detection platform. The image of the connecting rod is obtained by an area array CCD camera. The image is preprocessed, gray level adjusted, and histogram modified. Then, the image is filtered and de-noised, edge extraction, and defect location. Finally, the defect area feature is extracted to detect the connecting rod. The experimental results show that the method proposed in this paper can quickly and accurately realize the automatic detection and recognition of the surface defects of automobile connecting rods, and the system has the characteristics of non-contact and good detection effect.

Key Words: Engine Connecting Rod, Machine Vision, Offline Defect Detection, HALCON, Image Processing

1. Introduction

The automobile manufacturing industry is a typical large-scale competitive product industry. The lower the cost of a single product, the larger the production scale. The price of its products is in a more advantageous position in the price competition of similar products. There are advantages and disadvantages. Although the scale is enormous and the production speed is high, efficient assembly line production will reduce the production cost. However, the factory also has to bear the considerable risk of accidental scrapping of large quantities of workpieces due to the control quality. Therefore, it can not be avoided that the engine connecting rod surface will produce defects in the manufacturing process.

The main reasons for the surface defects of the connecting rod are as follows: surface defects of raw materials, improper operation of workers during forging, surface defects of the connecting rod during heat treatment, and cold correction of

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the connecting rod [1]. The traditional product surface quality inspection mainly uses the manual inspection method. It not only increases the huge management cost and labor cost for the factory, but also increases the workload of manual workers. The worker's attention can only be focused for 20-30 minutes, which makes the staff prone to product omission and misunderstanding in the state of visual fatigue. Therefore, it is challenging to ensure the accuracy of the test results by traditional detection methods. The rapid development of machine vision technology can deal with this difficult problem of manual detection. It has the characteristics of non-contact detection, measurement, and high accuracy. At the same time, it has a broad spectral response range, and the operation time of machine planning is stable, which can save a lot of labor and management resources, and significantly improve work efficiency [2].

Currently, the dimension detection and defect identification of the connecting rod based on machine vision has become one of the research hotspots.

The quality of connecting rod assembly process mainly depended on operator visual inspection, and there was no effective error prevention. To solve this problem, Zhang et al. [3] developed an intelligent vision system based on YOLO3 to monitor the whole connecting rod assembly processand programmed it with Python. Finally, it realized the low-cost monitoring of the connecting rod assembly process, and the accuracy rate reached over 99.5%. Ding et al.[4] realized image acquisition, denoising, edge gray maximization, and feature extraction of automobile connecting rod using HALCON software. A filtering method combining the two rules was proposed. The renderings were evaluated by Imagetest software, and the recognition rate was compared. Adding new rules got ideal results, which verified that this method was more suitable for processing the connecting rod images. Pan et al. [5] designed an auto connecting rod detection system based on machine vision to solve the problems of mismatched serial numbers of connecting rods and manual detection, high misjudgment rate, and low detection efficiency. It can collect connecting rod images in real time and train the classifier with a neural network algorithm to recognize connecting rod characters, thus realizing the automatic detection of connecting rod products.

Liu et al. [6] proposed a machine vision-based detection method for automobile connecting rod cracking grooves, aiming at the current situation of a heavy workload, low efficiency, and significant error in manual detection of auto connecting rod cracking grooves. The background noise was filtered by filtering technology to improve the quality of the detected image, and then the edge detection method with an adaptive threshold was used to extract sufficient edge information, and the target features were detected and identified by roundness and flatnessto realize the detection of automobile connecting rod cracking groove. According to the characteristics of automobile engine connecting rod, Wang [7] used a CCD camera, image acquisition card, PLC, and so on to form the automobile engine connecting rod detection system. When the PLC received the detection instruction, it used the camera to expose it. After the target image was collected, the engine connecting rod was detected through image analysis and processing.Aiming at the problem of high dimensional accuracy of engine connecting rod, the traditional detection method neededvarious detection tools. Zhang et al. [8] designed and manufactured a set of engine connecting rod testing devices to quickly test the size of engine connecting rod and realize the function of data analysis.

Yang et al. [9] proposed a multi-parameter detection system of engine connecting rod quality based on machine vision and studied the image preprocessing based on multi-threshold analysis and filtering to remove the shadow in the engine connecting rod image. Based on the sub-pixel analysis and Hough transform, the characteristic geometric targets of engine connecting rod images, such as straight lines and circles, are detected. The typicalgeometric parameters of the engine connecting rod are fitted by the least square method, and the quality parameters are analyzed to realize the multi-parameter detection of automobile engine connecting rod quality. Lin et al. [10] proposed a method based on machine vision to solve the geometric dimension detection problem of auto connecting rod cracking tanks. The designed detection system mainly includes a camera, lens, coaxial light source, industrial computer, and programmable logic controller. Through preprocessing, template matching, and depth processing of the collected connecting rod images, the complete outline of the cracking tank is obtained, and the real-time detection of the connecting rod cracking tank parameters is realized. Flota-Bañuelos et al. [11] proposed a new method of the speed control system of linkage mechanism. To measure the coupler point position, a computational vision system is adopted. The precise parts of the critical points at various crank speeds are sent to the system controller, and a proportional integral differential control system is designed in the microprocessor. The system'sperformance has been verified by experiments in a prototype of a planar mechanism.

At the same time, machine learning, image processing, and other technologies are also widely used in detecting various parts. Xu et al. [12] proposed a comprehensive dimension detection method based on the tolerance design principle and image processing to detect the dimension of brake padsquickly. The camera was used to collect the brake pad image, and the minimum circumscribed rectangle optimization algorithm is used to determine its scaling factor. Then, the actual contour map and the standard template map are added to get the detection result. To ensure the measurement accuracy of the calibrator of the headlamp detector, Pan et al. [13] proposed a verification method combining image processing technology with a high-precision electric turntable. Using the proportional relationship between actual displacement and pixel displacement and the linear relationship between image gray and object illumination, the high-precision automatic calibration of the calibrator of the headlamp detector is realized.

Sun et al. [14] proposed a new vision sensor based on combined laser structured light to realize online detection of welding groove parameters. Through the improvement and suitable combination of different image processing algorithms, the subsequent image processing speed is effectively improved. The least square method is used to fit the discrete points of the laser center line, and the image coordinate values of characteristic points of the welding groove were accurately identified.

Jiang et al. [15] proposed a processing method of B-spline most minor square fitting based on a gray histogram to improve detecting hot spots of photovoltaic arrays. The experimental results showed that the proposed waywas effectively processed infrared images of photovoltaic arrays with a lot of noise. Based on a convolution neural network, Zhang et al. [16] designed a system for the rapid detection of pavement cracks. High-precision convolutional neural network recognition algorithm was used to improve the efficiency of image recognition. By comparing the recognition accuracy of the model with the confusion matrix, the spatial domain filtering, threshold binarization, and morphological filtering processing methods were compared. Finally, the pavement cracks were extractedrapidly.

In this paper, the connecting rod is taken as the research object. Based on the machine vision detection technology, an offline detection system for connecting rod defects is established. The high pixel CCD camera is used to collect the image of the connecting rod, and the HALCON software is used for processing. Firstly, the image of the connecting rod is preprocessed, gray-scale adjusted, and histogram modified. The image is de-noised by filtering, edge extraction, and defect location. Finally, by extracting the feature of the defect area, the defect location and feature extraction of connecting rod surface is realized.

2. Overall design of the offline defect detection system for the connecting rod

Offline defect detection system for connecting rod consists of two parts which are the hardware system and the software system. The hardware system comprises an acquisition device, CCD camera, lens, light source, and processor. The software of the offline defect detection process includes five parts, which are image acquisition, image preprocessing, image threshold selection, image defect recognition, and defect location.

To achieve the desired effect and meet the recognition of the surface defects of the engine connecting rod, the designed system can realize the following functions.

In the process of image acquisition and image analysis, the system has an offline debugging function. Users can be allowed to process and detect images offline so that the defects of the connecting rod to be detected can still be analyzed without a network, and the automatic detection function can be completed.

The detection algorithm realizes interactive design. For the critical parameters of HALCON program operators, such as the selection of threshold segmentation conditions, the debugging of binary range, and the adjustment range of morphological opening and closing operations, interactive design is realized. Users can fine-tune the parameters in the algorithm during use to meet the needs of particular areas to be detected.

Use the visualization window to show the transformation process of the pictureclearly. The mark will be displayed on the original image, and the final result, parameter form, and feature style of image processing will be displayed and saved in the form of data.

The developed program supports the surface defect detection tasks of different parts. Not only can the surface defects of the engine connecting rod be identified, but also the surface defects of the engine piston, crankshaft, and other related auto components can be identified and extracted by appropriately modifying the algorithm, thus expanding the application range of the algorithm.

3. Hardware system design

The quality of machine vision image acquisition and hardware construction directly determines the accuracy of the full defect detection. The quality of image acquisition has an excellent influence on image post-processing. The image noise (external interference) is collected by using the camera. It takes a lot of time to remove the noise in image processing. Therefore, to reduce the noise interference in image processing and make the detection simple and convenient, the selection and design of the hardware part are significant.

In this paper, according to the production requirements of connecting rod visual inspection image acquisition and the factors that interfere with image acquisition, an image acquisition device for connecting rod surface defect detection based on machine vision is designed. The image acquisition device is composed of background stage bottom plate, left and right bracket slide rails and blocks, support slide rails, support slide blocks, camera slide rails, camera slide blocks, strip light source, CCD industrial camera, and lens. Based on this hardware device, it is easy to get the image. The background stage of the acquisition device is white because the white background and the surface of the connecting rod have different light absorption. In the threshold segmentation of the collected image, the gray value of the connecting rod is different from the gray value of the background bottom plate, the contrast of the image is obvious, and the edge extraction is relatively easy. The bracket is made of rigid material with moderate size and can bear considerable weight. It is suitable for the detection of most connecting rods. At the same time, it can ensure the stability of image acquisition. Fig.1 is the three-dimensional model of connecting rod offline defect detection. Fig.2 is the physical model of connecting rod offline defect detection.

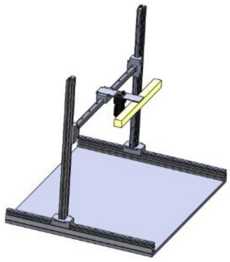
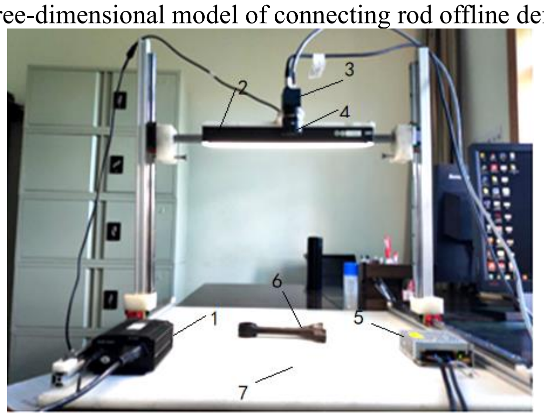


Fig. 1 The three-dimensional model of connecting rod offline defect detection



1—Light source controller 2—The LED light source3—CCD camera 4—The lens 5—Switching power supply6—Connecting rod to be tested 7—Adjustable detection platform

Fig.2 The physical model of connecting rod offline defect detection

4. Software system design

This system is designed based on the built-in language of HALCON software [17]. HALCON software is machine vision software with the complete algorithm developed by German MVtec [18]. It has more than 1000 independent functions, as well as the underlying data management core [19]. In HALCON software, almost all the operators about image filtering, mathematical calculation transformation, color transformation, geometric transformation, and so on. For example, in the processing of related morphology, it has a strong ability for identification and classification and the correction ability of calculation and analysis. Therefore, HALCON's complete analysis and calculation ability can be used in particularly all the work related to image processing. The application scope is almost unlimited, covering medicine, remote sensing detection, monitoring, and all kinds of automatic detection in the industry [20].

The software system has a complete detection process. First, the collected image is read in HALCON. Then the read image is preprocessed, such as image de-noising, and then the initial processing of the image threshold determination, segmentation, and image defect detection, positioning. The system mainly includes the following functions which are image acquisition, image preprocessing, threshold segmentation, image edge extraction, surface defect recognition, and surface defect location of the connecting rod. The overall flow chart of the image process for the connecting rod is shown in Fig.3.

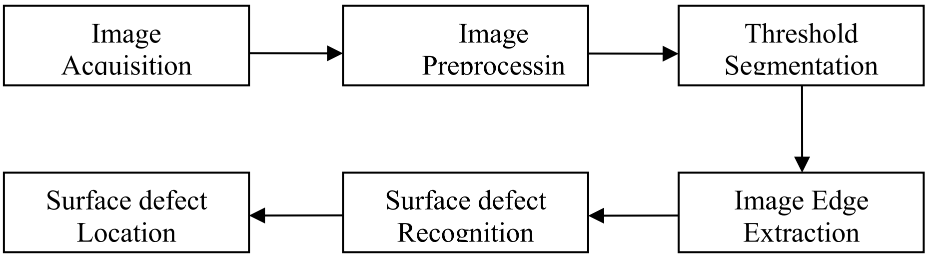


Fig.3 Overall flow chart of image process for the connecting rod

4.1 Image acquisition and reading

4.1.1 Image acquisition

In a complete machine vision system, the acquisition of images as a step before image processing, which is related to all the subsequent image operations, the importance can be seen. After the image is collected, the signal of the image can be converted into a digital format that the computer can process [21]. To continue in the computer for other subsequent operations, such as image preprocessing, image segmentation, and so on.

Daheng Galaxy Viewer software is used to collect the target connecting rod, and the collected image is saved in the computer to facilitate the subsequent operation.

4.1.2 Image reading

Image reading refers to the subsequent operation of reading the collected image information path in the processing software. An operator is used in the HALCON software for image reading of the defect detection system.

```
dev_open_file_dialog ('read_image', 'default', 'default', Selection)
read_image (Img2761, Selection)
```

Read the collected image information. "Img2761" represents the image name read, and "Selection" means the image's read path.

Based on the above operation, the original image of the connecting rod is obtained, as shown in Fig. 4.

Fig. 4 Original diagram of connecting rod

4.2 Image preprocessing

The primary purpose of image preprocessing is to reduce and eliminate interference, so that the quality of the image can be improved, and the processing of the picture is more convenient.

4.2.1 Image filtering

The image noise is generally divided into two situations. One is caused by electrical signals because the image is obtained by the acquisition of electronic devices, which often affect the imaging results in collecting images. The other is that light and its medium can also cause noise to the image, because the formation of the image cannot be separated directly from the light, so the noise caused by light will also be displayed in the image.

Image de-noising, also called image smoothing, is mainly used to reduce or eliminate image distortion caused by environmental influence or equipment itself. So it is easier to extract the critical information of the image. A machine vision system sensor will interfere with the image noise when processing and calculating the image information. Even the noise will affect the whole process of image processing, such as acquisition, reading, analysis, and output results. Because the noise will interfere with each link, the output result of image analysis and processing will appear deviation or even error. Therefore, the image is de-noised is necessary.

Because the obtained image noise is mostly salt and pepper noise, the median filter, which can remove salt and pepper noise, is selected in this software system to reduce the interference of image noise. Median filtering is a nonlinear smoothing technique based on permutation statistics theory which can effectively restrain image noise [8]. Median filtering is very effective for independent noise. It has an excellent clearance effect on the high-frequency components of Fourier space, and the sharp beat of the gray value at the edge of the region is just this high. The frequency component makes the image have a good smoothing effect. The pixel value after filtering is replaced by the neighborhood median of adjacent pixels, and the sensitivity to outliers is not good. Even without reducing the image's contrast, the interference of outliers can be weakened, and the removal effect of salt and pepper noise is excellent. Therefore, median filtering is selected to complete the de-noising of the software system [22, 23]. This example uses a circular two-dimensional template with a radius of 1 to sort the pixels in the template board according to the size of the pixel value, to generate a monotone rising or falling two-dimensional data sequence. The mathematical expression of the binary median filter is shown in formula (1).

$$g(x, y) = M_{ed}\{f(x, y)\} \tag{1}$$

where, $f(x, y)$ is a two-dimensional image data series. $g(x, y)$ is the median filtered value of the window data.

A median filter operator in HALCON software is:
median_image (Img2761, Image Median, 'circle', 1, 'mirrored')
"Img2761" means input image.
"Image Median" means output image.
"circle" and "1" means a circular radius of one using median filtering.

The filter output images of connecting rod with salt and pepper noise is shown in Fig.5.

Fig.5 Salt and pepper noise distribution of connecting rod

To analyze the effect of connecting rod images processed with different filtering radii, the filtering radii are set to 1, 3, 5, and 7, respectively. Filter the connecting rod images respectively, and the results are shown in Fig.6.

(a) Filter radius =1

(b) Filter radius =3

(c) Filter radius =5 (d) Filter radius =7

Fig.6 Connecting rod images processed with different filtering radii.

4.2.2 Gray-scale transformation

In image enhancement processing, image gray-scale transformation is a straightforward and effective spatial domain image processing method. The gray-scale transformation will change the gray value of the original image according to some conditions and pixel by pixel according to a particular transformation relationship. Due to various reasons, such as the influence of image noise, the dynamic range of the collected image is small, or the contrast is insufficient. Thus the visual effect is not particular good. Gray-scale transformation can enhance the contrast of the image well and increase the dynamic range of the image and make the image clearer. It is one of the essential means of image enhancement. Gray-scale transformation generally does not change the coordinate information of pixel points but only changes the gray value of pixel points. In image processing, spatial domain refers to the space composed of pixels, and spatial domain enhancement method refers to the enhancement method that directly acts on pixels. The spatial domain processing mode is shown in formula (2).

$$g(x,y) = T[f(x,y)] \tag{2}$$

where, $f(x,y)$ is the image before enhancement. $g(x,y)$ is the enhanced image. T is an operation on f, which is defined in the field of (x,y).

To effectively reduce the amount of image processing, this paper uses the weighting method to transform the gray level of the image, as shown in formula (3). In this paper, the gray level of the image is converted.

$$Gray = 0.299R + 0.587G + 0.114B \tag{3}$$

where, $Gray$ is a converted single color channel, R is a red channel, G is a green channel, and B is a blue channel.

The rgb1_to_gray operator is used to convert the original image into a gray-scale image. The rgb1_to_gray operator is shown below.

rgb1_to_gray (RGB Image, Gray Image)

"RGB Image" represents the input image.

"Gray Image" represents the name of the gray output image.

The gray-scale of the connecting rod is shown in Fig.7.

Fig.7 Gray-scale diagram of connecting rod

4.2.3 Gray histogram

The histogram is an important mathematical model of statistical data change law in statistics. The concept of the histogram is introduced into digital image processing from statistics. A gray histogram is used to represent the gray distribution. It is closely related to the contrast of the image. Gray histogram is an efficient tool in digital image processing. In addition to the use of basic gray to enhance the image, another common method of image enhancement is the gray histogram modification technique. Gray histogram refers to the statistical relationship between each gray level and its frequency in the digital images.

The gray histogram of an image is the probability density function of the image brightness distribution, which is used to reflect the relationship between each gray level in a digital image and its appearance frequency. It is the most basic statistical law of all pixel sets in an image. The histogram of the digital image with a gray-scale range of [0, L-1] is a discrete function, as shown in formula (4).

$$h(r_k) = n_k \tag{4}$$

where, r_k is the k^{th} gray level. n_k is the number of pixels with the gray level of r_k in the image. The histogram calculation formula can divide each value by the total number of pixels in the image (represented by n) to obtain a normalized histogram, as shown in formula (5).

$$P(r_k) = \frac{n_k}{n} \tag{5}$$

where, k=0, 1, … , L-1. P (r_k) is the probability value of gray value r_k, and it is also the frequency of r_k. L is the gray-scale series. Therefore, the sum of all values of the normalized histogram should be equal to 1, as shown in formula (6).

$$\sum_{k=0}^{L-1} p(r_k) = 1 \tag{6}$$

Gray histogram has the following properties.

The histogram is the statistical result of the occurrence frequency of each pixel's gray level in an image. It only reflects the transformation of different gray levels in the image. The number of occurrences of the value does not reflect the position of a particular gray-scale. That is to say, it only contains the probability of the occurrence of a particular gray pixel of the image while ignoring its location information.

Any image has a unique histogram corresponding to it. But different images may have the same histogram. That is, there is a many-to-one mapping relationship between images and histograms.

Because the histogram is obtained by counting the pixels with the same gray value, the sum of the histograms of each sub-area of an image is equal to the histogram of the whole image.

Therefore, the histogram is the basis of various spatial domain image processing technologies, and histogram operation can be effectively used for image enhancement. Besides providing helpful image statistics, the inherent histogram information is also beneficial in other image processing applications.

The gray-scale of the connecting rod and its gray histogram is shown in Fig.8.

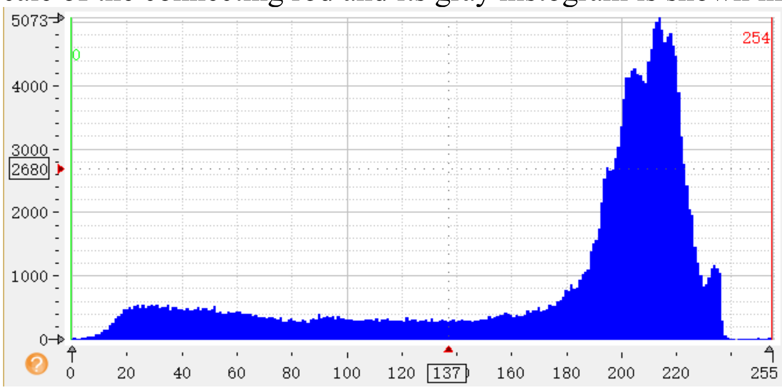


Fig.8 Gray histogram of connecting rod

Because the background color of the image acquisition device is white, most of it is the bright color area in the image, and the contrast with the connecting rod is significant. The concentrated area of bright color can be easily separated from the connecting rod image in the later stage. Fig.9 shows the connecting rod region corresponding to the peak position in the gray histogram.

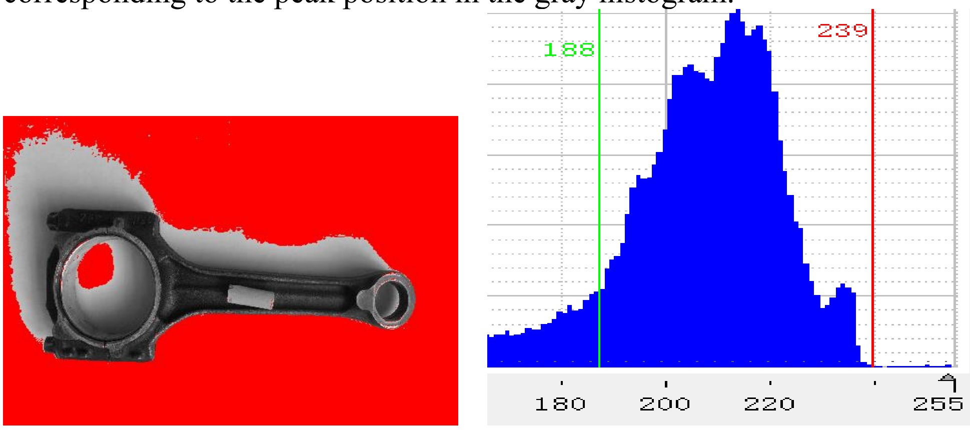


Fig.9 The area corresponding to the peak in the gray histogram of the connecting rod.

4.3 Threshold segmentation

Image segmentation is an essential problem in image processing [24]. Image segmentation is one of the primary methods of image processing technology. Image segmentation is to divide the image into many parts, which correspond to the surface of the object. The principle of image segmentation is to classify the pixels of the image according to specific rules.

The gray threshold segmentation method and the spatial domain region growth segmentation are the main methods of image segmentation. Because of the gray threshold segmentation method of measurement space, it only uses the gray features of the image to segment the image. Other useful information, such as color and texture characteristics in the image is not used, so the segmentation results are easily disturbed by image noise. Segmentation operation is more complex, and the speed of analysis operation is relatively slow.

Threshold segmentation is a method to segment the image according to the gray amplitude of the image pixel. The gray value of the image is divided into different levels, and then the gray threshold is set by itself to determine the region of interest. For a gray image, there are many threshold segmentation methods, such as the peak method, the iterative method, and so on, but their principle of segmentation is the same [25].

Let the original image be $I\ (x, y)$, find the characteristic value T in $I\ (x, y)$ according to specific criteria, and divide the image into two parts. The split image is shown in formula (7).

$$I'(x,y) = \begin{cases} b_0, I(x,y) < T \\ b_1, I(x,y) \geq T \end{cases} \tag{7}$$

If b_0=0 and b_1=255 are taken, it is what we usually call image binarization. For gray-scale images, pixels whose gray value is larger than the threshold are white, and pixels whose gray value is smaller than black. After thresholding, the gray image becomes a black-and-white binary image, so thresholding is a common method to convert the gray image into a binary image.

4.3.1 Threshold selection

The gray histogram can quickly determine the threshold, drag the upper and lower limits of the threshold in the histogram, and display the selected area of the threshold range in the graphics window in real-time to determine the gray value range of the defect. The gray value range in this figure is from 109 to 172. Fig.10 gives the gray histogram, which determines the threshold range.

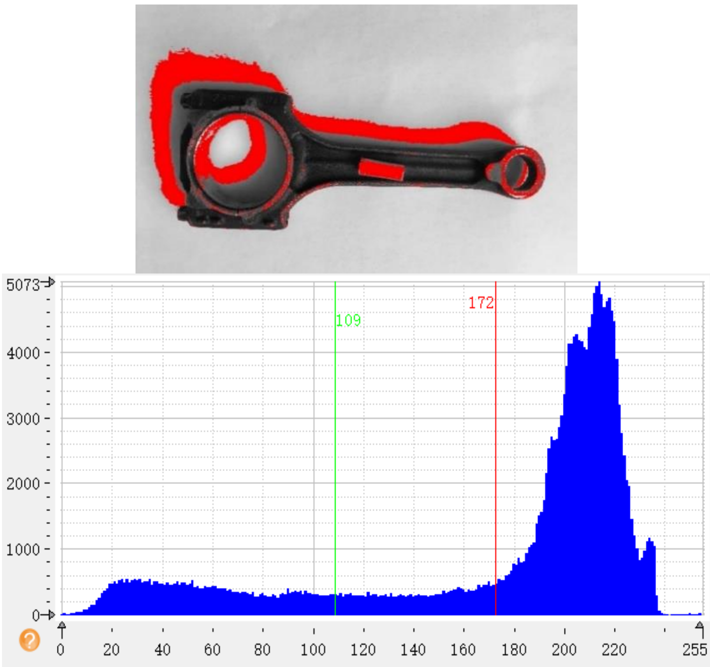


Fig.10 Threshold range of gray histogram of the connecting rod

The threshold segmentation of the image is divided into two ways [26]. One is global threshold segmentation, and the other is local threshold segmentation. The system uses global threshold segmentation to segment the image. In the HALCON, the global threshold segmentation operator is used to segment the image.

mean_image (Gray Image, Image Mean, 10,10)

fast_threshold(Image Mean, Regions2, 117, 177,20)

"Image Mean"is the input image in the operator.

"Regions2" is the output image.

"117,177"means that the given grey value range is 117~177.

"20"means that the selected area is more significant than 20 percent.

It can select areas whose area is more significant than a given numerical value and within the specified gray value range. This operator needs to be combined with filtering. The principle of the system is that the mean value of the pixel value in the original image is used to replace the initial pixel value to achieve the filtering function. It plays an essential role in fuzzy images [27].

4.3.2 Image Edge Extraction

The edge detection algorithms of image extraction can be divided into two categories: one is the algorithm based on direct search, the other is the algorithm based on zero crossing, besides, the Canny edge detection algorithm, statistical discrimination method, and so on.

Direct search method. The essence is to detect the boundary by finding the maximum and minimum value of the first derivative in the image, usually locating the boundary in the direction of the maximum gradient. It is an edge detection algorithm based on the first derivative.

Zero crossing method. The essence is to find the boundary by finding the zero crossing of the second derivative of the image, which is usually the zero crossing of Laplace or the zero crossing of nonlinear difference representation. It is an edge detection algorithm based on the second derivative. The edge detection operators based on the first derivative are gradient operators, including the Roberts operator, Sobel operator, Prewitt operator, etc. The edge detection operators based on the second derivative are mainly Gaussian Laplacian edge detection operators.

To make the image processing more specific, remove the area close to the target information and improve the speed of image processing. The area of interest in the image (Region of Interest, ROI) is usually selected[28, 29].

```
dev_set_color ('red')
dev_set_line_width (3)
dev_set_draw ('margin')
```

Fig.11 gives the boundary of the region of connecting rod.

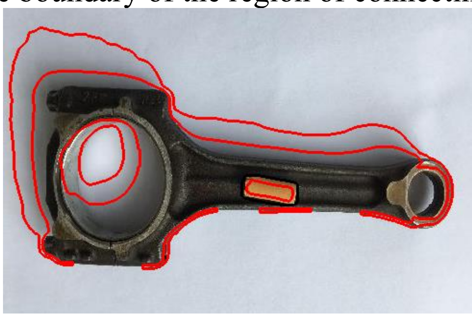


Fig.11 Boundary display of connecting rod

'red' indicates the display boundary color. It can be set according to actual conditions or preferences.

"3" indicates that the larger the line width value of the boundary, which is shown in Fig.12. The value of the output image is one, and the line width is five.

"margin" means the output image name.

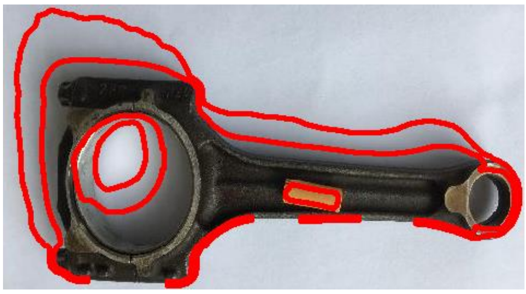


Fig.12 Output images with different line widths of connecting rod

4.4 Surface Defect Recognition of Connecting Rod

Image recognition is a task that machine vision systems must accomplish. The process of image recognition can be regarded as a marking process. The recognition program operator is used to distinguish the segmented parts of the image and then mark the identified features.

Before identifying connecting rod defects, it is necessary to carry out the connected domain marking operation on the image [30, 31]. The connected domain marking is one of the most primary methods of threshold segmentation image analysis, which is the basis of all threshold segmentation image analysis. By marking the target pixels in the threshold segmentation image, each region is connected to form an identified region. The parameters of these modules can be further obtained, such as the area of the region, the external moment of the region, centroid, etc.

After the connected domain is marked, the measurement area is selected in the threshold segmentation diagram of the connecting rod, as shown in Fig.13.

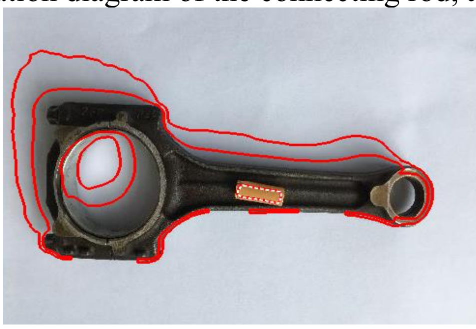


Fig.13 Selected measurement areas

Select_shape operator is used as follows:

select_shape (ConnectedRegions1, Selected Regions, 'area', 'and', 600, 1000).

"ConnectedRegions1"represents the input area.

"Selected Regions" represents the output area.

"area" represents the area of the input area.

"and" is the logical relationship between features. Here, "and" represents all features.

"600, 1000": represents the area in the range of 600~1000.

In surface defect detection, a particular characteristic value is often used as the basis of segmentation. The select_shape operator is very efficient, and only a few lines of programs are needed to extract these areas. The area features can screen out larger foreground objects and remove noise and small areas. select_shape operator is used to screening the area, so it is not necessary to calculate the specific area of each area separately.

In this paper, select_shape operator is used for feature screening. The input color image has a yellow defect area. To extract the yellow defective area from the image, we can first use threshold processing to extract the yellow area from the region of interest. Then select_shape operator is used to screening according to the area, and the remaining non-defective areas are removed. Then, the select_shape operator is used again, and the area width is used as the judgment condition to extract the yellow area. The final extraction result is shown in Figure 14.

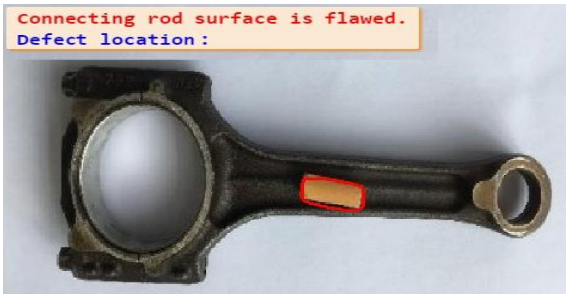


Fig.14 Region extraction

4.5 Surface defect location of connecting rod

To extract the features of a region, the region area and the coordinate information of the center point are most commonly used. In locating connecting rod surface defects, the area or center point is used to select and find features. The area center operator in HALCON is used to realize this function, which returns the following two results simultaneously. Area refers to the number of gray-scale pixels contained in a single area (there may be more than one input area). Center refers to the coordinates of the geometric center point, that is, the average row coordinates and column coordinates of the center point of a single area. For Fig.14, the bright yellow zone is the extracted area, which will be used as the input of the area_center operator. Fig. 15 results from finding the coordinates of the area and shape center. The area of the corresponding area is marked with 730. The average values of row coordinates and column coordinates of the central point of the region are (75.225, 217.248).

area_center operator is used to obtaining the area and center of the area.

area_center(Regions : : : Area, Row, Column)

This operator is used to measure the area and the center position of the region. The area is determined by the number of pixels in the area, and the center is determined by the average of the row and column coordinates of the area. If there are multiple input areas, there are also numerous sub-index numbers of output variables, and they correspond one to one. If the area is empty, all parameter values are 0. "Regions" represents the input parameter, which represents the measured region. "Area" represents the output parameter, which represents the area of the measured area."Row" represents the row index of the center of the measured area."Column" represents the column index of the center of the measured area.

Then, calculate the area and center of the input defect area and display the area size and coordinates in Fig.15, which is defined as the number of pixels in a region. The center is calculated as the average line or column coordinates of all pixels.

Fig.15 Defective coordinates

The above is the process of extracting the defects of the connecting rod surface in this software system. The software system separates the original defects of the connecting rod surface, and the effect is good.

5. Conclusion

Firstly, according to the manufacturing requirements of the engine connecting rod, the hardware device of the engine connecting rod surface defect detection system is designed and selected. Then, a set of connecting rod surface defect detection devices based on machine vision is built, which can quickly and non-destructively detect the connecting rod surface defects. As the bottom support and up-and-down adjustment of the device are completed by the slide rail, it is convenient to adjust with high freedom and moderate size so that it can detect various types of connecting rod defects. This detection system uses a CCD camera and lens to collect connecting rod images, uses HALCON software to process and analyze the acquired images, and completes some program design of connecting rod image defect extraction software. This software system has a complete detection process, and the whole process has a segmented design process and independent functions from beginning to end. The system includes the following five parts: image acquisition and reading, preprocessing, image segmentation, defect identification, and defect location determination. Specifically, the operation is to first read the collected image in HALCON, then preprocess the read image, such as image smoothing, select the threshold value of the preliminarily processed image by using the gray histogram, segment it after the threshold value is determined, and finally identify and locate the defects of the image. In image preprocessing, the threshold range is determined by combining the gray histogram of the image, and the image is segmented by the area and the given threshold range. After subsequent processing, the defects on the connecting rod surface are separated from the background, and the effect is ideal. The system has the characteristics of non-contact and non-interference in the production process. Experiments show that the design improves the detection efficiency and has good practical popularization value and application prospects.

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