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The application of digital image processing technology in glass bottle crack detection system[1]

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Abstract. In order to solve the current mass production of glass bottles and the stringent requirements of quality problems, this paper adopts digital image processing technology is applied to the detection of glass bottle crack, in order to establish a complete glass bottle crack detection system. The image preprocessing, image segmentation and feature extraction are used to monitor the crack in the glass bottle. Through the implementation of related algorithms and the construction of the frame, a rapid detection system of glass bottle cracks has been obtained. The experimental results show that the digital image processing has strong practicability in detecting the crack of glass bottle. This system greatly improves the detection speed and accuracy, and can bring great convenience for manufacturers.

Key words. Digital image processing, glass bottle crack detection, feature extraction, two-value image.

1. Introduction

The detection methods of glass bottle cracks are mainly as follows: artificial detection, sensor based inspection, and non-contact inspection based on machine vision. Artificial inspection costs a lot of human resources, and the human eyes cause fatigue and other nonresistance factors, so the accuracy of the detection cannot be well guaranteed. The precision of sensor based detection is higher. However, the instrument cost is too high and the flexibility is not high. In the two aspects, the machine vision inspection method has great advantages.

Chen Hanqing mentioned that in the today's society dominated by computer technology, digital image processing has received great attention (Chen et al. 2013) [1]. Digital image processing first appeared in 1950s. Because of the rapid processing of images by computers, computer technology has been applied to graphics and image information processing. The initial application of image processing is to improve the

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quality of images, and to improve the visual effects for human objects. Zhang Hong found that with the further development of image processing technology, extensive attention in many applications has been received and milestone progress has been achieved, such as aerospace, biomedical engineering, and even artificial intelligence (Zhang et al. 2015) [2].

Through the screening and image segmentation and other operations of the head images of the part taken by the CCD camera, the core part and crack were extracted, which successfully improved the detection efficiency of threaded parts head crack (Yang et al. 2013) [3]. Because of the successful application of crack detection in many fields, digital image processing technology is also used in the detection of glass bottle mouth. Ding Ting obtained the best threshold according to the iterative method, extracted the features and imported rectangular displacement sensor (Ding et al. 2007) [4]. The crack point was searched by double circle method, and the crack was determined by field scanning method. Practice has proved that the application of digital image processing in crack treatment of glass bottle mouth is very successful. Due to the quality of the picture affected by many factors, Chen Tong made more attempts on the basis of the original (Chen et al. 2013) [5]. In order to improve the efficiency of the system, Li Juncheng made accurate judgment on the glass bottle crack through a series of operations, such as the pretreatment of glass bottle image, the image segmentation and the rough positioning of the center of the bottle mouth (Li et al. 2015) [6]. In the detection of glass fiber reinforced plastic composites, Glud captured white light images from the specimen, used transmission light to detect cracks in the image, then processed the cracks and calculated their cracks within the duration of the test (Jia et al. 2016) [7]. With the development of computer technology, great progress has been made in crack detection based on digital image processing.

2. State of the art

With the development of computer software and hardware, the theory and method of digital image processing have been improved day by day. Therefore, its application fields are gradually expanding, from the original aviation, aerospace and other specialized fields to other industries closely related to human daily life. Many glass bottle crack detection systems based on digital image processing have been established and perfected step by step. Chen Yuanyan used CA-MPE-1000 black and white image acquisition card to obtain the 8-bit grey image of the detected glass bottle (Chen et al. 2001) [8]. In order to reduce the research scope, the bottle neck region with the crack might be fixed relative to the whole image. He used field averaging to preprocess the glass bottle to eliminate most of the random noises. Since the black and white images cannot obtain the grey threshold directly, we choose the method of setting the threshold. This method is not suitable to realize the binary images of the position object and the background point, which is the percentage of the total pixel. Therefore, the grey scale histogram is selected to better judge the threshold in this topic. Only the domain average method cannot eliminate the small error, so a median filtering method is added to make the image better recognition.

On the basis of previous studies, Luke chose to add a median filter to suppress the noise of the image, and the median filter method could better protect the image edge information. Grey histogram was adopted to set the threshold (Lu et al. 2015) [9]. This method could find the most suitable threshold so that the binary image was more suitable for feature extraction. The roundness index was used to determine whether the image was a crack image. The method was fast and accurate, and it could well meet the needs of actual production. But for the region of interest, if the interference spot or background brightness was too large, it would lead to the wrong result of the algorithm. In order to solve this problem, Yan Taishan adopted the new intelligent model of neural network, which provided a new framework for industrial inspection system (Yan 2005) [10]. The crack detection system of glass bottle was realized by BP neural network structure, which improved the flexibility of environment change, the fault tolerance, the learning and adaptive ability of the system. Through the training of a large number of samples, it could well meet the situation of large interference with good judgment.

3. Methodology

The subject is in accordance with the flow chart, as shown in Fig. 1, for the glass bottle crack detection.

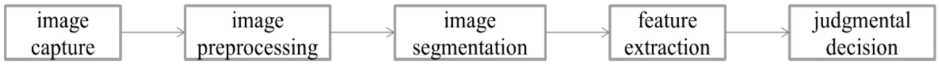

Fig. 1. Operation process of glass crack detection system

3.1. Image acquisition

Yu Fashan proposed that, because the camera could capture the moving image in real time, it converted the optical signal into a two-dimensional electrical signal (Yu et al. 2013) [11]. The digital image could be obtained by converting the image acquisition card with A/D conversion function, which could meet the needs of actual production. Therefore, the camera image is usually taken to obtain the glass bottle image.

3.2. Image preprocessing

In actual production, the quality of the image does not reach the ideal state because of the illumination condition and the image transformation. Therefore, the quality of the image is reduced to a certain extent. Li Li concluded that before the analysis of the image, the quality of the image should be improved (Li et al. 2016) [12]. In order to reduce the image noise, the image needs to be processed smoothly. In this paper, we choose the smoothing method and median filtering method to process the image, which can filter the noise effectively and protect the edges of the image better. The basic idea of the domain averaging method is to replace the

greyscale of each pixel with the average of several pixels. It is assumed that there is image $F(x, y)$ with $N \times N$ pixels, and another image $g(x, y)$ is obtained after smoothing. The $g(x, y)$ is determined by the formula

$$g(x, y) = \frac{1}{M} \sum_{(m,n)\in x} f(x, y) \tag{1}$$

where $x, y = 0, 1, 2...$ is a collection of coordinates at the midpoint of the field, but it does not include (x, y) points. And M is the total number of coordinate points in the collection. The formula (1) indicates that the grey value of the pixel is determined by the average value of the predetermined field.

Figure 2, left part shows an example of the original image and right part depicts the same image after processing by domain filtering.

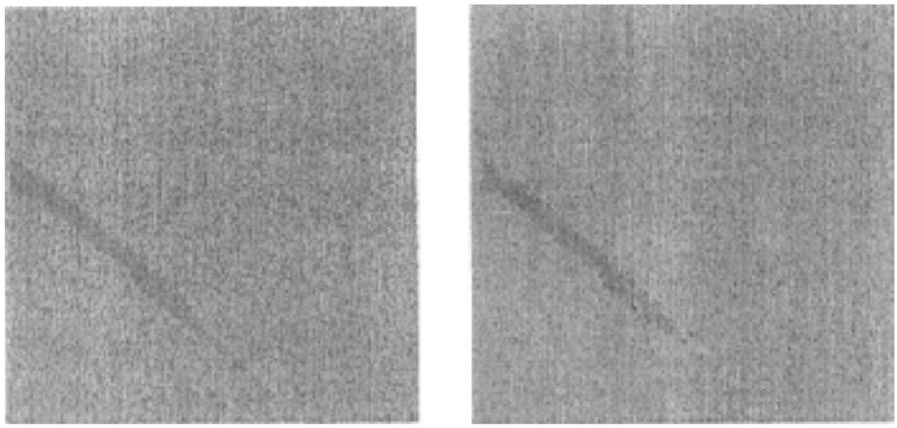

Fig. 2. Original image (left) and image after processing by domain filtering (right)

By comparing the image processed by the original image and the domain filter, we can see that the algorithm can eliminate the noise and make the edge smooth, but the image becomes more blurred. Because the image noise of glass bottle is not strong enough, the image sharpness and edge strength are highly demanded in the following work. To improve this, we have added the use of median filtering.

Median filter is a kind of nonlinear spatial filter, which has good effect on eliminating the interference of isolated points. The basic principle of median filtering method is to use a median of each sample point in the field instead of digital image or in a sequence of values.

The field of a particular length or shape of a point is called a window. At this point, two-dimensional windows in some forms are used. Let $\{x_{i,j}, (i, j) \in I^2\}$ represent the grey values of each point of the digital image. In the filter window A, two-dimensional median filter can be defined as

$$y_{i,j} = \mathrm{Med}\{x_{i,j},\ (i, j) \in I^2\} = \mathrm{Med}\{x_{(i+r),(j+s)},\ (r, s) \in A,\ (i, j) \in I^2\}, \tag{2}$$

where A is a two-dimensional median filter window.

Median filter is used in image processing. By setting a filter window, it traverses the points on the image. Replace the value of the center point of the window with the median value of the original values in each window.

Single use of the domain average method and median filtering method cannot meet the desired requirements. In order to obtain better image, it is found by comparing Fig. 3, left and right parts that the combination of one domain averaging method and four median filtering can filter the original noise in the image to a great extent. Moreover, the edge information of the crack image is well saturated, so that the edge is strengthened. Through the image preprocessing of the crack image, the subsequent feature extraction can be carried out more smoothly.

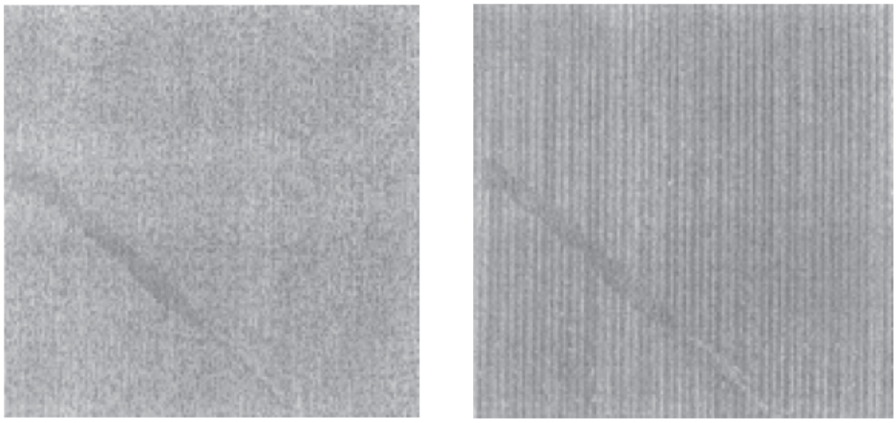

Fig. 3. Original image (left) and image after median filtering (right)

3.3. Image segmentation

In order to make computers better for image recognition and processing, the most important thing is to segment a large amount of information. The purpose of image segmentation is to divide the image space into some meaningful areas. The computation speed is greatly improved by studying only the regions of interest. Feng Xue believed that image segmentation included discontinuous detection, threshold processing, region processing, morphological processing, watershed method and so on (Feng et al. 2014) [13]. Each method has its advantages and disadvantages. In order to improve speed, we choose threshold processing.

Since the range of grey values of the objects and backgrounds to be processed is different, the grey values of each pixel in the image are compared with the threshold by using the threshold setting method. The pixel grey value which is greater than the threshold is set to 255, and the pixel grey value which is less than the predicted pixel is set to be 0. A new grey scale image can be obtained. This method is simple in calculation and can obtain good results. It can close and connect the needed area without overlapping erroneous judgment. The choice of threshold is very important, which affects the quality of image segmentation. This subject uses grey image binarization principle to segment the processed image, and separates the

crack image from the background, so as to prepare for the feature extraction.

The image after the binarization process is depicted in Fig. 4.

Fig. 4. Image after binarization processing

3.4. Feature extraction

Feature extraction is an important part of digital image processing and computer vision, and it is the key step of feature matching. Grey scale information of image is used to detect the corner and edge points of grey scale and gradient transform. In this paper, we need to extract the crack in the image to make the later judgment.

Jia Ping found that in his study, since the feature points of the crack were different from the background, the crack in the image was determined by giving some parameters of the characteristic points of the glass crack (Jia et al. 2013) [14]. According to the characteristics of the grey value of the glass crack image, the geometric features of the segmented image are analyzed and measured. In these characteristics, there are some quantities that can be represented by numbers, such as area, perimeter, etc., which can be used as the basis for judging the existence of cracks. The features are extracted by feature extraction and used for image recognition and understanding.

In an image that has been segmented, the area of the target can be simply defined as the number of pixels contained in the target boundary. By scanning the entire target area, the grey value is calculated to be one pixel total.

$$A = \sum_{x=1}^{N} \sum_{y=1}^{M} f(x, y)\,, \tag{3}$$

At the same time, the perimeter of the crack can be obtained by finding the sum of the pixels of the outer boundary of the image.

After obtaining the area and perimeter of the crack, we can calculate the roundness of the crack. Since the shape of the crack is generally slender, the characteristic

parameter roundness can be used as an index to determine whether there is crack or not.

Cai Qing mentioned that roundness was defined as (Cai et al. 2017) [15]

$$C = \frac{p^2}{4\pi A}, \tag{4}$$

where A represents the area of the object and p represents the perimeter of the object:

$$\text{Area} \in \begin{cases} \text{circle, when} & C = 1, \\ \text{thin, when} & C > 1. \end{cases} \tag{5}$$

If the calculated target circularity conforms to the standard range, it can be judged as crack. According to the result, whether there are cracks in glass bottles is determined. They are displayed and stored in the appropriate files to facilitate subsequent production needs.

3.5. Software design

Because VS has the advantages of simple interface and good programming language, Visual Studio 2010 is used as the development platform to realize the function of each module in this paper. The process of image processing includes the image acquisition and display, image processing, analysis and image storage. In order to meet the needs of actual production, the basic functions of the system are image preprocessing, image segmentation, feature extraction and crack detection. Through the comparison results of the original image and the processed image, a decision is made. Specific modules and implementations are shown below, in Fig. 5.

4. Result analysis and discussion

Several experiments have shown (see Table 1) that the roundness of the edge of the crack spot is maintained at about 0.35, and the length of the crack is maintained at about 0.80, so that the principle of fast determination of the boundary crack can be obtained. If such an area of light appears in an image, the roundness of its edge is between 0.30 and 0.50, and the fine length is between 0.70 and 0.85, there is a spot in the image that is reflected by the crack, which indicates that there is a crack region in this image. Through the conclusion, we can test the crack of glass bottle more quickly in actual production.

Table 1: Ten samples of glass bottles: crack detection, roundness and fine length

number	1	2	3	4	5	6	7	8	9	10
roundness (cm)	0.33	0.30	0.34	0.32	0.40	0.38	0.33	0.36	0.33	0.31
slightness (cm)	0.81	0.78	0.75	0.81	0.74	0.71	0.80	0.78	0.82	0.83

In addition to the above conclusions, it has been proved by many practices that the combination of domain filtering method and median filtering method can make

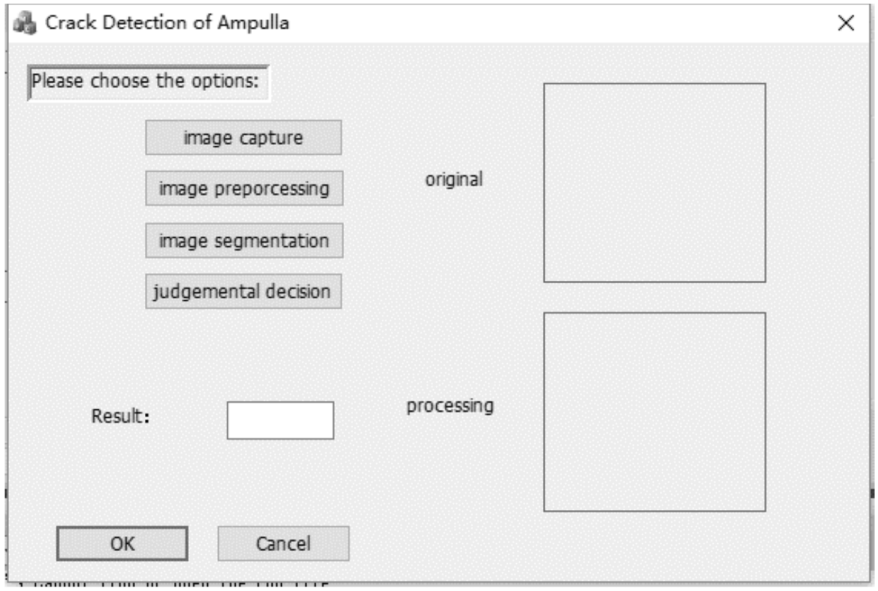

Fig. 5. Interface of glass bottle crack detection system

image processing more delicate, which is more suitable for subsequent feature extraction. Judging whether there is a crack in the glass bottle by roundness, it has a high accuracy rate. For the detection of 300 samples, the detection system only misjudges 1 bottle without cracks, the error detection rate is 0.3 %, and the omission rate is zero. At the same time, the speed of the detection system is very high. By setting timers in the program, the detection of each glass bottle needs only about 40 ms, while the average rate is 100 ms. The speed is more than doubled, and it can well meet the needs of the actual production test of the glass bottle. A typical result can be seen if Fig. 6.

5. Conclusion

This paper aimed to establish a glass bottle crack detection system based on digital image processing to help manufacturers improve the quality of products. The noise of the picture was suppressed and the edge of the image was smoothed by means of averaging and median filtering. Then we drew grey histogram to set the threshold, and made binarization processing of the image. Finally, the crack on the binary image was detected and judged to obtain the result that whether the glass bottle had cracks. Through the research of this subject, some conclusions were drawn. In the process of image preprocessing, considering the factors of computation speed and processing accuracy, the image quality could be better by one domain filtering and three median filtering. At the same time, due to the particularity of the crack image, the corresponding threshold could be set to determine whether there was a crack in the image.

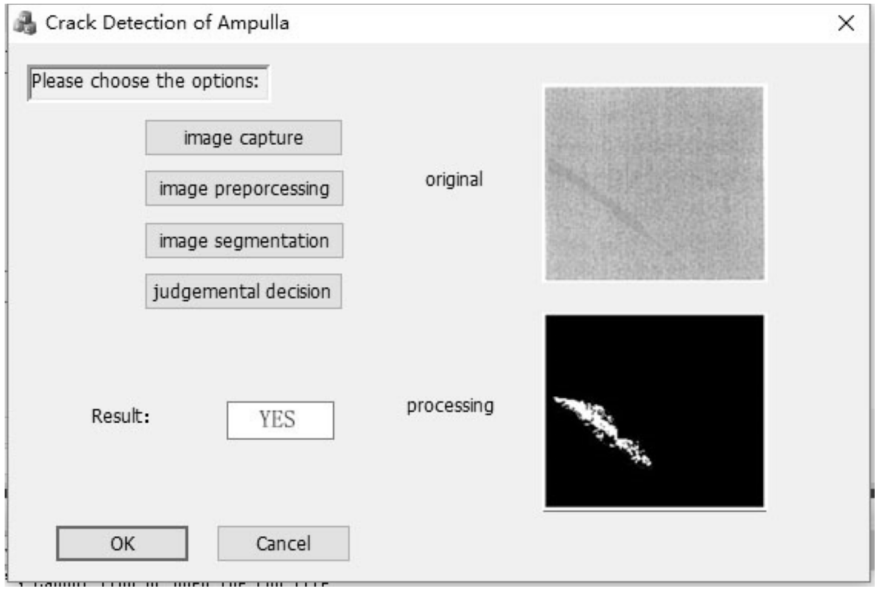

Fig. 6. Results of glass bottle crack detection system

The designed glass bottle crack detection system based on digital image processing technology can be widely applied in practical production, which breaks the limitations of traditional methods, such as time-consuming and long time, and improves the user's competitiveness in the industry. As the system is still in the initial stage of establishment, it cannot meet the realization and improvement of some functions, and there is a gap between it and the expectation. And the threshold chosen by the algorithm itself has to be proved by a great deal of practice. We hope that in future practice, the resolution of the image itself will be enhanced and the detection efficiency will be higher.

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