Acta Technica 62 (2017), No. 5A, 425–436

A New Method of Glass Fragments Detection

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Abstract. In order to protect the safety and health of widespread consumers, the Chinese government has implemented a product certification system to assess whether its safety performance is in line with national standards, this is the mandatory certification of safety glass products. At present, the determination of the fragmentation state is determined by the naked eye. Artificial detection is not only costly, time-consuming, but also fallibility, affecting the accuracy of the test results. In this paper, by analyzing the general process of traditional edge detection, a new edge detection method is proposed for glass fragments: Firstly, enhance the glass fragment images by histogram equalization. Then utilizing the background subtraction method and binarization algorithm to filter out most of noises in the image, next, utilizing Morphological Opening to remove noises in the gap line. Finally, it can be more accurately to detect the gap line position, divide the approximate area, and statistics the quantity of fragments.

Key words. Traditional edge detection, glass fragmentation, image enhancement, background subtraction.

1. Introduction

Since May 1, 2002, China began to implement the certification system of the mandatory product. More importantly, this certification system can ensure the health and safety of widespread consumers. Therefore, the production of glass in the safety inspection work has become an essential link. Through the data survey, it can be saw that there are nearly 400 safety glass certification enterprises in our country, for a long time, most glass manufacturers count the number of glass fragments through artificial visual method. In the test of broken glass, a great quantity of glass manufacturers spent a lot of manpower to improve the competitiveness of glass products. Many enterprises have specialized lab to test the safety glass products and the test results are frequently obtained by the naked eye. In the process of debris state test, the quantity and shape of fragments in the 50mm $\times$ 50mm square

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are required to be tested. The number of these fragments can be up to hundreds, and artificial is currently the main way to read and observe these experimental data. Under the influence of human vision, emotion and personality, the process of manual inspection will take longer time, which reduce the accuracy and make the experimental efficiency greatly reduced.

From above, after test the safety glass fragments, the image acquisition device can be used to obtain its image. In order to improve the accuracy and efficiency of the test, make the test automation gradually improved and in line with the requirements of Chinese industrial 4.0. The corresponding algorithm is designed to automatically identify, detect the glass fragments and apply it in the process of safety glass detection.

In foreign, some scholars have analyzed and discussed the image of the fragmentation state test. Gordon Gaile G[1] discussed the detection algorithm of glass fragments in depth. The detection of glass fragments involves the field of image processing. In the past fifty years, image processing has been developed for many years. A large number of scholars[2][3], have done in-depth research in this field, and summarized many segmentation algorithms that should be applied to different scenes. The image segmentation algorithm is divided into six methods based on the image targeted by the algorithm and the technique used. They are based on fuzzy sets[4], edge detection, color image segmentation[5], pixel segmentation[6], and threshold segmentation[7]. But so far has not formed a mature algorithm to portraying the gap line of glass fragment images accurately, this paper will do some discussions on this issue.

Tanaka[8] are the first to bring morphological operation into based image processing recognition of glass fragment. In order to detect and recognize glass fragment, Xueqin Zhouet al, firstly, using the traditional edge detection operator to get the gradient image and the OTSU algorithm to realize the binarization, by comparing with the original gray scale, it can ensure the uniformity and consistency of the slit image. Finally, carry through the gray inversion and reconstruction, and according to the division of the chain code to transform the segmentation image, so the quantity of fragments can be obtained.

2. Analysis and Application of Traditional Edge Detection

In this paper, the edge is defined as the regional boundary where the gray level changes rapidly. The transformation of gray level in the image can be reflected by the gradient, therefore the local image differential technique can be used to obtain the edge detection operator. The essence of edge detection[9] is to use some algorithm to extract the boundary between the target (such as the gap line) and the background (such as the fragment) in the image. The classical edge detection method is to construct an edge detection operator for a neighborhood of the pixels in the original image, the process is shown in figure 1. First of all, geting a smooth image by selecting the appropriate high-pass filter (filter operation); and then selecting the appropriate differential operator for first order differential or two order differential operation to obtain the maximum value of the first derivative or zero crossing of the two derivative. Finally, selecting the appropriate threshold to extract the boundary.

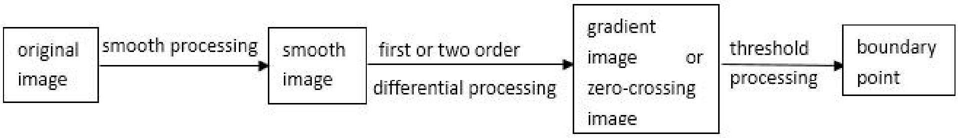

Fig. 1. Traditional edge detection method

2.1. Roberts edge operator

The Roberts edge detection operator is an operator that obtains an edge by local differential. It is given by the following formula:

$$g(x,y) = \{[\sqrt{f(x,y)} - \sqrt{f(x+1,y)}]^2 + [\sqrt{f(x+1,y)} - \sqrt{f(x,y+1)}]^2\}^{1/2} \quad (1)$$

Where: f(x,y) is the pixel value of the original image at the point(x,y). As a kind of 2×2 operator, the Roberts operator has a better effect on the low noise image with steep elements, the result of Roberts operator is shown in figure 2.

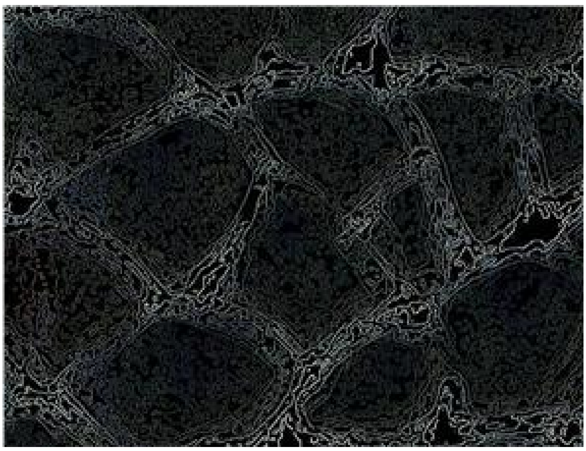

Fig. 2. Robert detection results

2.2. Sobel edge operator

Sobel operator is not the average posterior difference, but the weighted average posterior difference. Firstly, taking (x,y) as the center. And then in its eight neighborhood, respectively, calculate the x-direction partial derivative and the y-direction partial derivative, that is:

$$\begin{aligned} s_x = {} & [f(x+1,y+1) + 2f(x+1,y) + f(x+1,y-1)] \\ & -[f(x-1,y+1) + 2f(x-1,y) + f(x-1,y-1)] \end{aligned} \quad (2)$$

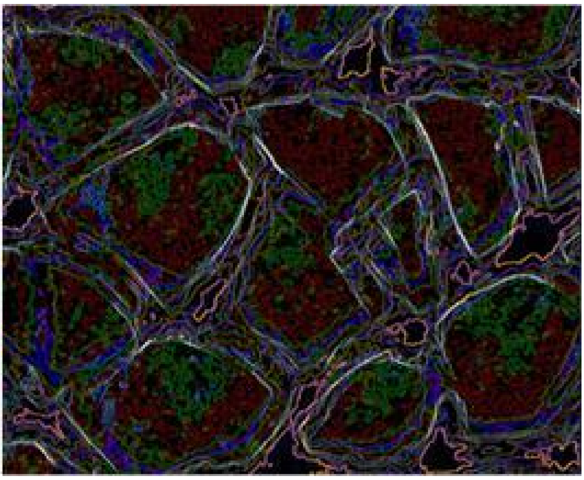

Fig. 3. Sobel detection results

$$\begin{aligned} s_y = & [f(x+1,y+1)+2f(x,y+1)+f(x-1,y+1)] \\ & -[f(x+1,y-1)+2f(x,y-1)+f(x-1,y-1)] \end{aligned} \tag{3}$$

The gradient amplitude:

$$g(x,y) = \sqrt{s_x^2 + s_y^2} \tag{4}$$

Since the influence of the neighboring pixels on the current pixel is equivalent, the influence of the neighboring pixels on the current pixel distance is different as well. In order to express the impact of neighborhood pixels accurately, the pixels in the neighborhood are given a certain weight. Under normal circumstances, the influence will gradually decrease with the increase of distance, that is, the closer the distance is, the greater the weight and vice versa. Sobel operator is easy to implement, and the Sobel edge detector can ensure the effect of edge detection. On the other hand, the Sobel operator is introduced in the local average to alleviate the influence of noise. If a large neighborhood is used, it will has better anti-noise performance, however, it will also lead to a rough edge, and make the computation increase.

By utilizing the gray-weighted algorithm of left and right, upper and lower adjacent points, in the process of edge detection, Sobel operator can take advantage of the phenomenon which the extreme value can be achieved at the edge. The Sobel operator can smooth the noise and make the peripheral information more precise, however, under the influence of the local average, many pseudo-edges will be detected, and the edge location does not has high accuracy. The Sobel operator can be applied in the process of edge detection where some precision requirements are not too high. The result of Sobel operator is shown in figure 3.

2.3. Prewitt edge operator

Like the Sobel operator, take the maximum of two convolutions as the output point, the result of the operation is also an edge amplitude image. For the noise, Prewitt operator can play an in hibitory effect, and the average pixel is the principle of noise suppression. However, the average pixel has the same principle as the low-pass filter, so in the edge location, the Prewitt operator is not as good as the Roberts operator. The result of Prewitt operator is shown in figure 4.

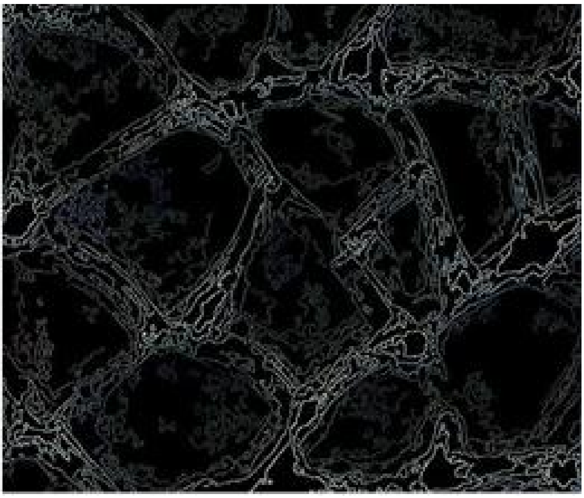

Fig. 4. Prewitt detection results

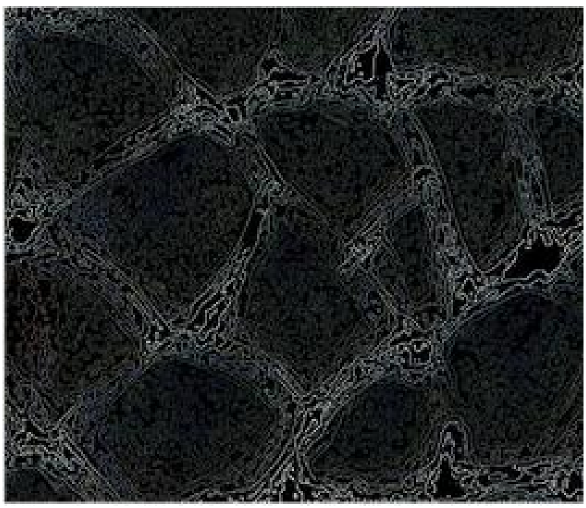

Fig. 5. Kirsch detection results

2.4. Kirsch edge operator

As a nonlinear operator, the Kirsch operator is an operation to improve the simple averaging algorithm as well. Meanwhile, in order to avoid the problem of losing the edge details, in the operation of the Kirsch operator, first of all, the value of the pixels on both sides of the edge and the values of the pixels in the neighborhood are calculated respectively, and then seeking the difference. The result of kirsch operator is shown in figure 5.

2.5. Analysis of Traditional Edge Detection Results

It can be seen from above results that the noise has a serious impact on the detection of the gap line of glass fragments. And through the calculation formula of each operator, in the process of applying the edge detection algorithm, the traditional edge detection operator needs to obtain the second derivative or first derivative of the glass fragment images. However, due to the derivative operation, the calculation of the first or second derivative in the process will enhance the noise, obviously, this is not what we want. On the contrary, the effects of noise should be avoided as much as possible, so the utilizing of filters is required for the improvement of noise-related detection performance. Typically, in the noise reduction, most of the filters will reduce the peripheral information of the image which led to the loss of edge strength, so considering the two factors, reducing noises and enhancing the edge is necessary. Based on the above analysis, in this paper, before selecting filters for noise reduction, first for image enhancement operation to enhance the peripheral information, which lays a good foundation for the subsequent edge extraction and image segmentation.

3. Improvement Method

In the process of conversion and transmission, a variety of causes contribute to the decline of image quality. The distortion of the optical system makes the image blurred when shooting. In the process of image digitization, noise is also be introduced. And as the noise pollution, the image quality is inevitably decline. Therefore, in order to improve the quality of the image to facilitate the subsequent processing and the accurate identification, the image enhancement is necessary. Then utilizing the background subtraction method and binarization algorithm to filter out most of noises in the image, next, utilizing Morphological Opening to remove noises in the gap line. Finally, it can be more accurately to detect the gap line position, divide the approximate area, and statistics the quantity of fragments.

3.1. Image enhancement

The enhancement of gray image can take different forms according to the transforming function of the enhancement operation, so as to get different results. Well-known gray transformation methods include: global linear transformation, piecewise linear transformation as well as logarithmic, exponential and other nonlinear transformation. In addition, histogram-based transformations include histogram equalization and normalization, etc.

Histogram equalization is a common method of indirect contrast enhancement. The “key thought” of histogram equalization is to change the gray histogram of the original image from a more concentrated gray scale to a uniform distribution over the entire gray scale. In the global sense, histogram equalization is essentially a nonlinear stretch of the image, redistribute the image pixels, so that the number of pixels in a certain gray scale range is approximately the same. Image enhancement and gray scale graph is shown in figure 6.

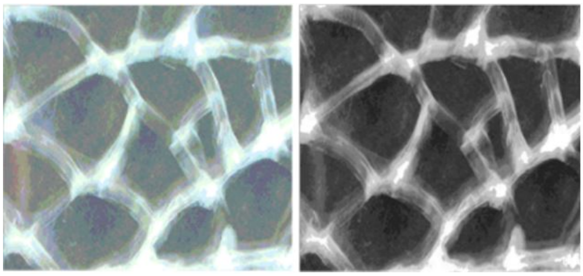

Fig. 6. Image enhancement and gray scale graph

3.2. Background subtraction

Background subtraction need to eliminate irrelevant factors, in fact, it is the difference of the current frame and the background of the gait sequences to extract the required profile information. Background subtraction is widely used in image segmentation and motion detection. First includes background model, then do a differential treatment with raw data source and background model, and finally convert the images into binary images. In the fixed background and weak background, the contour of the target images can be expressed efficiently, but when it comes to some external factors, such as the angle of light projection, background transient changes and other interference, there will be a poor extraction effect.

The essence of the background subtraction method is to make a difference between the image sequence and background. The background subtraction algorithm for slit image noise reduction is the difference between the original image and the smooth image, which achieves the elimination of non-sharp objects. For sharp objects similar to cracks, smooth operation will be more to change the gray value, however, for the noise with uniform gray level and edge blurring, the smoothing process will not have a large change in the gray value. Therefore, after the subtraction operation, most of the noise will be offset, but the sharp objects such as the gap line will be retained.

See the background subtraction:

$$P^{'}(x,y) = P(x,y) - Median[P(x,y)] \tag{5}$$

Formula: P (x, y) for the gray value of the image, generally an eight-bit integer, is the integer value in the range of 0-255; Median means median filtering operation. Figure 7 shows the background subtraction results .Figure 8 shows the binarization results.

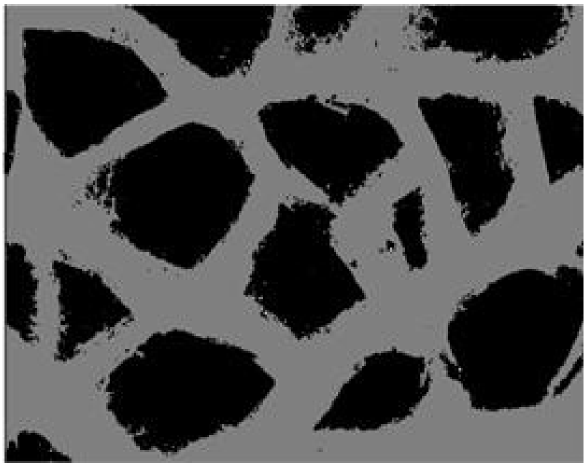

Fig. 7. Background subtraction results

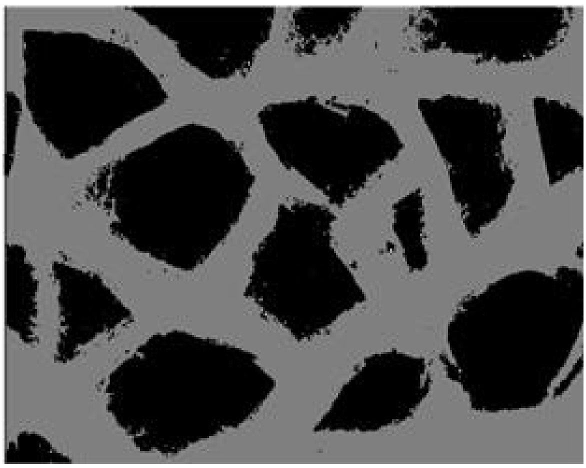

Fig. 8. Binarization results

3.3. Mathematical morphology

Mathematical morphology originated in 1964. Its basic idea is to use a certain form of structural elements to measure and extract the corresponding shape in the image in order to achieve the purpose of image analysis and identification. Mathematical morphology consists of algebra algorithm operator with a group of morphology, which have their own characteristics in binarization image and gray scale image. Mathematical morphology would be composed of a set of morphological algebraic operators, and its basic operations have four: corrosion, expansion, opening operation and closing operation. Using mathematical morphology for image analysis mainly in accordance with the following steps:

(**??**)1)The geometric structure of the object is extracted, which is equivalent to analyzing the geometric structure of the object;

(**??**)2)According to the model, select the appropriate structural element, and the structural elements should be selected as simple as possible;

(**??**)3)Transforming the image with the selected structural elements, which makes the feature information of the image more pronounced. The quantitative description of the structural pattern can be obtained after giving the corresponding variable;

(**??**)4)The information needed by the image can be reflected after the morphological transformation, and the information can be extracted conveniently.

Closing operation is a process, which first, the image is expanded, and then the expanded image is corroded. Closing operation can fill the small holes in the object, connect the adjacent objects, and also make the border of images smoother, but not transform its area significantly. However, opening operation is a process, which first, the image is etched and then the etched image is expanded. Opening operation can eliminate the tiny objects (dust, spot and other noise), separate the objects' fine points, smooth the boundaries of the larger objects in the image, but not transform its area significantly. Image processing, salt-pepper noise exists in the gap line, and due to shooting light and other reasons, two pieces are not completely separated, which will seriously affect the evaluation of glass safety performance.

Opening operation is generally used to remove the smaller granular noise and to interrupt the connection between two objects. Similar to corrosion, both have the advantage of being able to basically guarantee the size of the target object. However, the choice of structural elements' size in the process is critical as well, if the selection is too large, it will remove smaller debris image which affects the statistical results. As shown in the following two figures, figure 9 (b) is smoother than figure 9 (a), at the same time, two smaller images on both sides of figure 9 (b) are removed. This paper selects figure 9 (a) for subsequent processing. Therefore, in order to accurately depict the fragment of the gap and the exact statistics, in practical application, the appropriate structural elements should be used, so that it can effectively remove the noise in the fragments but not miss the tiny glass fragments.

4. Result analysis

In order to verify the efficiency of the algorithm, using the following table 1. The samples, which were obtained after the experiment of ten pieces of fragment state, were randomly selected to test, and compared with other methods. The detailed data are shown in table 2.

Table 1.Configuration table

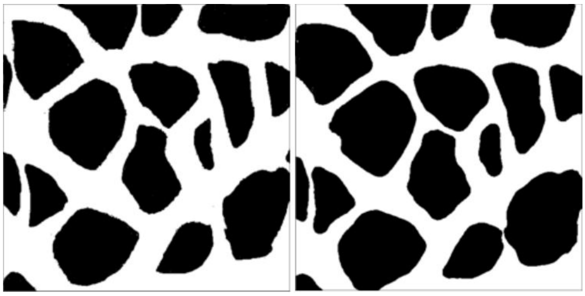

Fig. 9. Processing results of two structural elements

Configure	Specification
Mainboard	Lenovo 0578MDC
CPU	Intel i3 CPU 2.53GHz
Hard disk	HITACHI 320GB 5400 turn
Internal memory	Samsung DDR3 1066MHz 2GB
Video card	ATI Mobility Radeon HD 545v 512M

Table 2.Fragment state experimental data

Sample	Actual number of pieces	Traditional Algorithm		Literature1 Algorithm		Paper Algorithm	
		Number statistics	Run time (ms)	Number statistics	Run time (ms)	Number statistics	Run time(ms)
1	21	20	190.3	21	230.7	21	89.6
2	33	30	201.2	33	256.3	32	100.2
3	19	19	181.5	19	236.1	19	85.4
4	47	45	230.4	46	280.6	47	126.7
5	28	28	198.3	28	246.3	28	89.9
6	59	58	257.9	59	303.5	58	130.4
7	42	41	235.8	42	276.1	42	128.9
8	75	73	280.6	75	328.6	74	143.6
9	68	65	271.9	68	319.7	67	140.5
10	53	50	255.3	53	301.6	53	130.1

As can be seen from table 2, due to the sensitivity of the mathematical morphology, the image edge detection was affected, so that the error between the actual

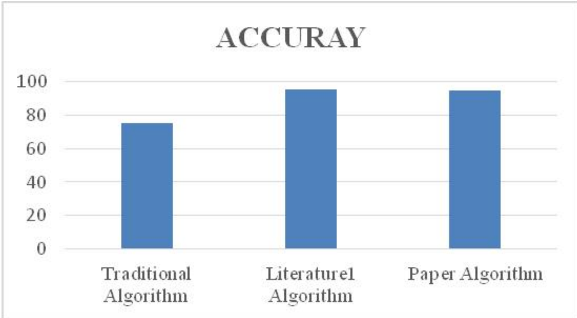

Fig. 10. Accuracy of three algorithms

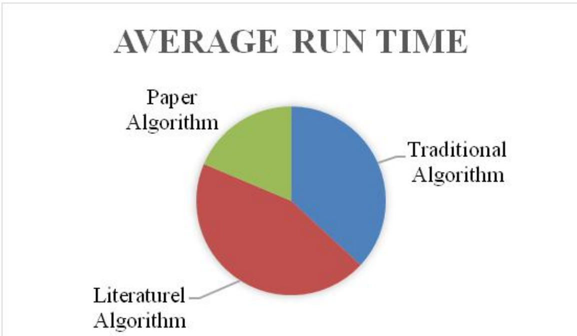

Fig. 11. Average run time of three algorithms

number of fragments and the number of detected fragments existed in the range. The results show that the average accuracy of the algorithm is 94.4%, which is slightly lower than the 95.1% of the algorithm in literature 1, but the running time is better than that algorithm. Figure 10 and figure 11 show the comparison between the accuracy of three algorithms and the average elapsed time.

5. Concluding remarks

In this paper, the glass debris detection system is able to enhance the glass fragment images by histogram equalization. Then utilizing the background subtraction method and binarization algorithm to filter out most of noises in the image, next, utilizing Morphological Opening to remove noises in the gap line. Finally, it can be more accurately to detect the gap line position, divide the approximate area, and statistics the quantity of fragments. In the whole system, the automatic detection and identification of the safety glass fragments can be automatically completed without manual intervention. When the glass products are inspected for quality safety, the degree of automation is greatly improved, and meet the requirements of accuracy and objectivity. It lays a solid foundation for further research and the application of production practice. However, in the collection of fragment images, the image may be distorted by the camera shooting angle or other reasons. In this case, the actual size and information of each point in the image are inconsistent, so the algorithm can not be directly used, the image should be corrected in the prophase.

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Received November 16, 2017