Research on Defect Detection in Rubber Rings

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Abstract. Defect detection is a largely critical step in the production of rubber rings. This paper presents a algorithm of edge detection based on digital image processing. Firstly, the target image should be preprocessed to eliminate noise; secondly, the Sobel operator is used for edge detection, and thirdly these images are dilated by an algorithm of mathematical morphology, and are emulated by the MATLAB software. The result indicates that this algorithm functions well in repairing fissures between fine defects, enhances the brightness of images, and has a better detection precision.

Keywords: Digital Image Processing, Rubber Ring, Adaptive median filter, Sobel operator, Dilation.

1 Introduction

The edge of image is a collection of points with disconnected or sharply-various gray level values of image, the edge detection of rubber rings is to draw the border line of defects and background. In the course of producing rubber rings on the industrial scale, various forms of defects will appear inevitably, such as rough cutting, uneven thickness, rough edges, bubbles, and soon. Taking bubbles---one kind of defects in rubber rings for example, in this paper we provide a method of defect detection algorithm based on digital image processing, and then analyses its course and list its result[1].

2 Algorithm Research

The target image generally includes noises, so the image preprocessing is necessary to eliminate noises before edge detection is carried out by the Sobel operator. Finally the mathematical morphology can be used to dilate the disconnected images and link the breaks between defects, for obtaining continuous edges, i.e. a better detection effect. The algorithm block diagram is drawn in Fig.1.

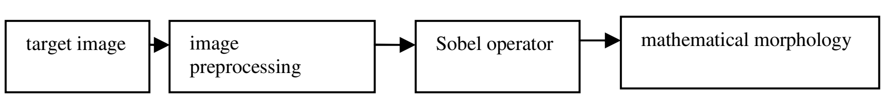

Fig. 1. Algorithm block diagram

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The noise pollution produced by shooting, saving, and transmitting images of rubber rings can result in degraded phenomenon of image, such as image distortion, image blurring. It can explained by many factors, for example, the motion blur that is produced by relative movement between cameras and rubber rings in the course of detection; noise existing in the imaging system; the surrounding effects of the detection system. Images preprocessing of rubber rings with defects is aimed at removing noise as much as possible for the convenience of image segmentation.

Mean filter, median filter and adaptive median filter are the three mostly-common algorithms to handle noise. Each of them has its typical features: mean filter is also called linear filtering and can effectively handle additive noise by replacing a previous pixel with the average of several pixels around it. However, it easily produces the image blurring.

Median filter replaces the value of a pixel by the median of the gray levels in the neighborhood of that pixel: $f^{'}(x,y) = \underset{(s,t)\in S_{xy}}{median}\{g(s,t)\}$ It can effectively handle impulse noise. Adaptive median filter, an upgrading median filter, compared with the traditional median filter, can handle impulse noise with probabilities even larger, and preserves details while smoothing non-impulse noise. So the latter is adopted to handle noise in the paper [2].

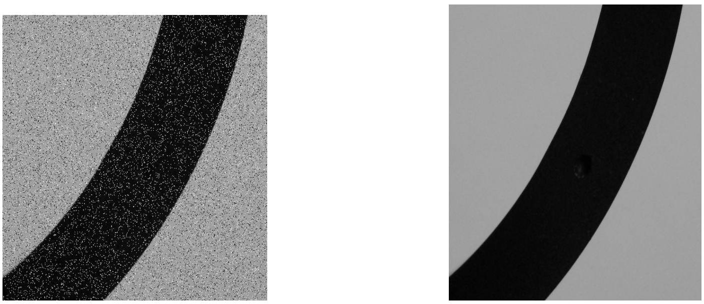
Adaptive median filtering algorithm works in two levels, denoted level A and level B, as follows:

level A : A1=Zmed—Zmin
A2=Zmed—Zmax
If A1>0 AND A2<0, Go to level B
Else increase the window size of Sxy
If window size ≤Smax, repeat level A
Else output Zxy
level B : B1=Zxy—Zmin
B2=Zxy—Zmax
If B1>0 AND B2<0, output Zxy
Else output Zmed
Here, Zmin=minimum gray level value in Sxy
Zmax=maximum gray level value in Sxy
Zmed=median of gray levels in Sxy
Zxy=gray level at coordinates(x, y)
Smax=maximum allowed size of Sxy

We can conclude from the algorithm that the purpose of level A is to determine if the median filter output, Zmed, is an impulse or not. If not, we go to level B to judge whether the coordinates (x, y) waiting for being processed is a noise or not. If B1>0 and B2<0 is true, then the coordinates (x, y) cannot be an impulse, the algorithm outputs the unchanged pixel value, Zxy. Distortion is reduced in the image. That means the coordinates isn't processed at all. If B1>0 and B2<0 is false, then the coordinates (x, y) is a noise, and the algorithm outputs Zmed.

If A1>0 and A2<0 is false, then the median value is a noise. The algorithm then increases the size of the window until a non-impulse is found. If the maximum window size is reached, and A1>0 and A2<0 is false, the algorithm returns the value of coordinates(x, y), Zxy.

The test indicates that adaptive median filtering can effectively eliminate the noise of rubber rings, and more importantly, it can also protect the image details[3]. Therefor, this paper uses adaptive median filtering to do the image preprocessing. The result of tests is indicated in the Fig.2, in which the Fig.2(a) is an image with salt and pepper noise, Fig.2(b) is the resulting image of adaptive median filtering.



(a) salt and pepper noise (b) adaptive median filtering

Fig. 2. Adaptive median filter

Edge detection is one significant part of digital image processing. The final aim of defect detection in rubber rings is to separate those edges with defects from all edges that are boundary lines where targets and background are to be extracted. The operators of edge detection based on the differential method include Roberts operator, Prewitt operator, Sobel operator, Candy operator, Laplacian operator, LoG operator and so on. The first four are operators based on first derivative, while the last two belong to those based on second derivative. In the process of algorithm, the appropriate threshold value can be selected to extract the edges through the convolution and operations of the template and every pixel in the image. What the first derivative differs from the second derivative is that the former corresponds the place of edge with its maximum, while the later does it with its zero crossing point.

Among edge detection operators based on differential method, Roberts operator adopts the difference of two adjacent pixels on the diagonal direction as the approximate gradient amplitude, to detect edges, with a higher positioning accuracy and the better detection effects on the vertical and horizontal edges than oblique edges. However it is sensitive to noise. Prewitt operator and Sobel operator, the two most popular in practice, both use the gray weighting algorithm of all adjacent points surrounding the pixel point, and detect edges according to the principle of reaching the extreme value on the edge point. Prewitt operator work much easier, but is inferior to Sobel operator in removing noise. Sobel operator can detect edge points more accurately and smooth noise, but the range of edges it detects is wider. Canny operator is the best one to detect step edges by relying on the traditional differentiation, with a higher capacity of de-noising. But it easily smoothes some information of edges away and has a slow calculation speed [4].

Laplacian operator, a linear second order differential operator, is very sensitive to noise, and generally not directly used for edge detection. LoG operator is an improved

Laplacian operator, adopts the Gaussian function to undergo the smoothing filter, and carries out the Laplacian operation to the smoothed images. The use of Laplacian operator is to provide a picture that can determine the location of the edge.

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Sobel operator is a group of directional operator, detects edges from different directions. The way it works is not to simply calculate the average value and then the difference, but to enhance weight of the central pixel's four directional pixels. [4].

Directional operator uses a group of template to do convolution with the same pixel in the image, and selects the biggest value as the edge intensity, and chooses the corresponding direction as the edge direction.

Its gradient:

$$Gx = (z_7 + 2z_8 + z_9) - (z_1 + 2z_2 + z_3),\ Gy = (z_3 + 2z_6 + z_9) - (z_1 + 2z_4 + z_7)$$

Prewitt operator is the average filtering, while Sobel operator is the weighted average filtering. In Prewitt operator the pixel neighborhood has the equal effect on the current image pixels, while in Sobel operator, there are different weights according to the distance between the current image pixel and the neighborhood pixels, that is to say, the smaller the distance, the bigger the weight. The weight 2 of Sobel operator achieves some smoothing effects by increasing the importance of the central point. Due to the introduction of average factors, it has some certain function of smoothing the random noise in images. Because Sobel operator is based on the calculus of two rows or two columns apart, edge elements on the both sides are enhanced, and the edge appears thick and bright [4]. The experimental result is shown in the Fig.3.

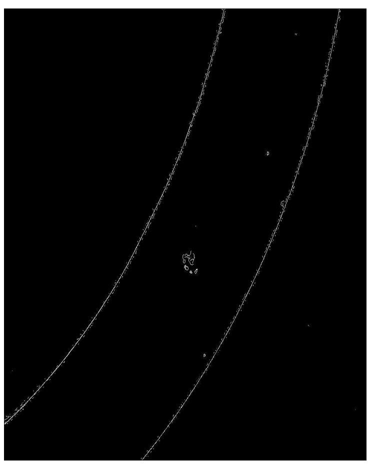

Fig. 3. Sobel operator's edge detection

Mathematical morphology is a subject established on the mathematical theory, its mathematical basis is the set theory, putting an image as a set. The fundamental idea is to use structural elements with certain shape to measure and extract the corresponding shape in the image, in order to achieve the purpose of digital image processing. The basic operations of the mathematical morphology are: dilation, corrosion, open and close.

Dilation is the most basic morphological transform of mathematical morphology. Assume A and B is a set of the Z^2, then the dilation of A by B can be defined by:

$$A \oplus B = \{z \mid (B')_z \cap A \neq \varnothing\}$$

in which B' is the mapping of the B, with its definition : $B' = \{x \mid x = -b, b \in B\}$. The dilation of A by B is first to get the mapping B' of B, and to use z to displace on the mapping B'. The dilation of A by B is the collection of the displacement z. Meanwhile, the intersection of B'and A rewarding can not be empty. So it can be rewritten as: $A \oplus B = \{z \mid [(B')_z \cap A] \subseteq A\}$, in which B'can also be called as the structural element of dilation. The schematic diagram is shown in Fig.4.

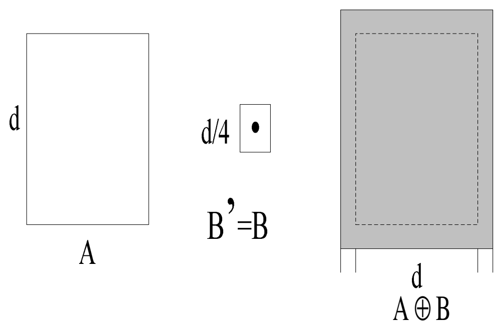

Fig. 4. Schematic diagram

In the above diagram, A is a collection, B is the structural element, the black spot is the original point of B. Because B is symmetrical around its original point, the mapping of B is the same as B. The method of dilation is to compare the original point of B respectively with the points in A, and if there is one point in B falling in the range of A, then the corresponding point of B's original point is the dilated point. Fig.5 is the resulting picture of the dilation, which includes all ranges of A (dashed part). The results of dilation vary according to different origin coordinates of structural elements.

As for the binary image, if the pixel point of B is represented by 1, then the dilation is to change the 0 value of B's neighboring pixel point as the 1 value of pixel point, expanding its ranges to all directions.

To repair the fissure is the most commonly-used application of dilation, such as the defect detection of black rubber rings this topic focuses. Although Sobel operator can better detect the edges of defects in image, these edges are neither continuous nor completely integrate, the morphological dilation can amend very well the fissures between defects.

3 Result

Compared with those before dilation, defects after dilation have apparently greater brightness, and fissures between fine edges are connected. A better detection is accomplished. The result is shown in Fig.5.

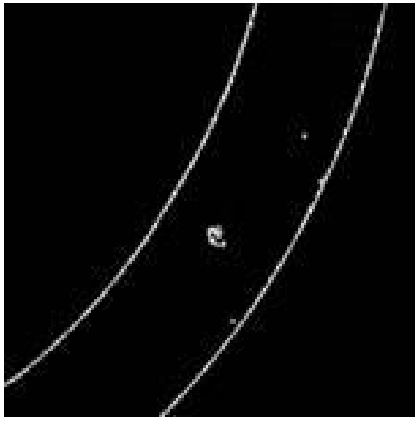

Fig. 5. Result

4 Summaries

This paper has discussed the algorithm of defect detection in rubber rings, analyzed advantages and disadvantages of several common algorithms, and finally presented a new defect detection algorithm, and carried out experimental emulation with MATLAB, whose result demonstrates its detection precision is higher than those traditional edge detection algorithms.

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