Defect Detection and Characteristics Description of Auto Hub Radiographic Image Based on SUSAN Operation

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Abstract:- The collected images' target object is faint in the auto hub real-time X-ray detection, so it is easily making the miscarriage of justice in the auto hub detection. Most of the current method of detection of defects is by manual detection, so it is very difficult to improve detection efficiency and detection accuracy. Aiming at these issues and combining with the characteristics that auto hub's image have so much noise source, it is adopted SUSAN operator for defect images' edge detection, which is based on the image second partition, and it is achieved good results in edge detection by this method . And then it carried through defect detected for the image, such as, the number, level, center of gravity, area, and circle degree of defects. This can effectively improve the detection efficiency and the accuracy of detection. The experimental results show that the method is feasible in practical applications, and it has strong anti-interference ability, good real-time detection and high efficiency compared with traditional methods.

Key-words:- auto hub；SUSAN operation；mask；edge detection; Feature Description; Geometrical features; Shape Features

1. Introduction

Auto rims is an important force components，whose quality directly impact the quality of whole vehicle. In order to ensure the quality of the automotive aluminum rims, we must carry out strict checks to the aluminum rims which have flaws during the radiographic film assessing. However, because of the large workload of manual assessment, coupled with the low clarity and resolution of much image, it is very difficult to accomplish accurate positioning on aluminum wheel defects in a short time. Therefore, it easily lead to misjudgment and omissions of the defect, thereby foreshadowing a potential risk of hidden dangers.

As one of the most important characteristics of images, Edge is the important basic of many research areas such as computer vision and pattern recognition. In the course of the study in the digital image processing, edge detection has been the focus of attention of most researchers, which occupy a very important position in engineering applications. However, the edge detection is a difficult problem in image processing, because the edge of actual image is the combination of various types of edge and the results of their fuzzy. Because of the presence of varying degrees of noise, various types' image edge detection algorithms have emerged, but when it comes to the accuracy of the results of different edge detection algorithms, there is not a unified standard.

Therefore, for the characteristics of X-ray rims image and the inadequacy of conventional detection methods, this paper used a more effective method - SUSAN operator to the rims defects for edge detection to meet the needs of industrial X-ray detect assessment, thus improve the efficiency and quality of detect.

2. Principle of SUSAN Operator

SUSAN (Small univalue segment assimilating nucleus) operator is put forward by Smith and Brady who are Oxford University scholars. It use the gray-scale features of images to detect.，which is applied to the image edge and corner detection, we can remove the image noise.

SUSAN operator template is different from the square template of the conventional convolution algorithm; it uses a quasi-circular templates, which move in the image on the mobile. The gray value of each image pixel within the template is compared with the center pixel gray value, if the margin of a pixel gray in the four different locations within the template and the central pixel gray of the template is less than a certain threshold value, then we consider the point pixel and nuclear pixel with the same (or similar) gray, so the region by the composition of the pixel value which meet above conditions is known as Univalue segment as-similating nucleus, USAN.

As shown in Figure 1, each pixel of image represents nucleus of a circular template, the template is divided into two independent regions. When the circular template completely in the image or background, USAN region have the largest area (Figure 1 a); When the template towards the image edge, USAN region became smaller (Figure 1 c); When the template center at the edge of the image, USAN region is very small (Figure 1 d); When the template center at the cornert, USAN region have its minimum value (Figure 1 e). As can be seen in the edges of image，USANvalue of the pixel are all less than or equal to half of its maximum value. Therefore, we can calculate the USAN value of each pixel in image, by setting a USAN threshold，search the pixel point which is less than the threshold，and it can be identified as the edge points.

Using a circular template to scan all pixels of the whole image, we compare each pixel gray value with the center pixel of the template, and then with comparison of a given threshold, to determine whether the pixels belong to USAN region, such as figure (1) follows:

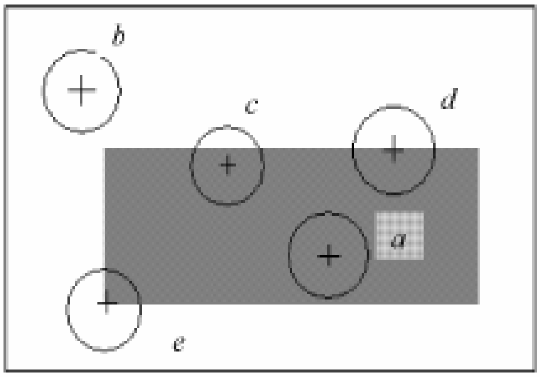


Fig1. Testing principle of SUSAN

$$C(r,r_0)=\begin{cases}1 & |I(r)-I(r_0)|\le t\\ 0 & |I(r)-I(r_0)|>t\end{cases}$$

………（1）

Where $C(r,r_0)$ as a discriminant function of the pixel belong to USAN region in the template; $I(r_0)$are the gray value of the central pixel in the template.; $I(r)$ as a gray value for other arbitrary pixel in the template; t is a grayscale threshold, through the formula (1) ,we will be able to judge whether each pixel within the template belong to USAN region, the USAN regional size of every point in image can be expressed by the following formula:

$$n(r_0)=\sum c(r,r_0)$$

……………（2）

In this formula, n (r0) express the size of USAN template, of which r0 is the center, that is, the value of C(r, r0) in the point is 1 in the template .we scan the entire image with a template, and then get the USAN region of each pixel, finally produce the features images of USAN by the following formula:

$$R(r_0)=\begin{cases}g-n(r_0), & n(r_0)\le g\\ 0 & n(r_0)\ge g\end{cases}$$

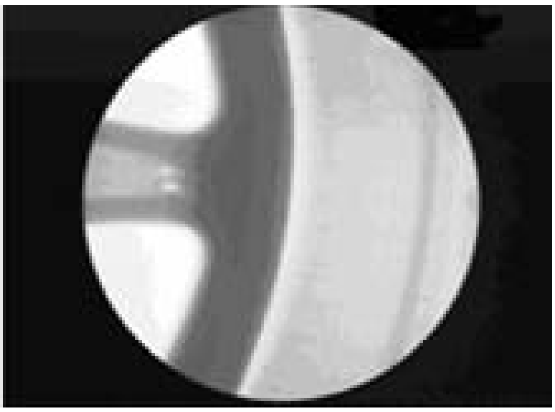
………………（3）

Where g is the geometric threshold, after getting the USAN value of each pixel by formula (2), we compare with the pre-set threshold g, when n (r0)<g, the pixel position r detected, can be regarded as a marginal point.

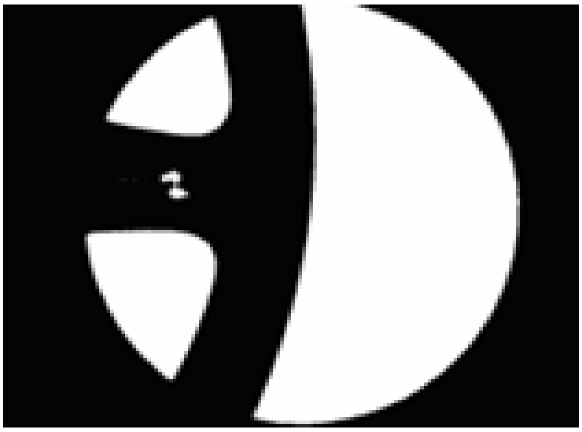
SUSAN detect principle has a prominent advantage that it is not sensitive to local noise and its strong anti-noise ability. Because the detect principle of USAN feature is not dependent on the early results of image segmentation and it avoid the gradient calculation, so it is easy to implement, and have a small amount of calculation. In addition, USAN region are cumulated by the pixels which have similar gray-scale with the template center pixel. In fact, it is an integral process, has a very good inhibitory effect for the Gaussian noise.

3. Edge Detection Applied to Rims Defects based on SUSAN operator

After researching the histogram of wheel casting images come from X-ray detection, we found that: the gray-scale is mainly made up of the five major sections, namely, the dark background outside the lens, wheel handle, tire region, wheel gap and the defect part. As can be seen from Figure 2 (a), the gray of lens background is very small, which concentrate between 0-20; the gray of wheel handle is also small, less than 100. Whenas the gray of defect part and tire region and wheel gap are very similar, all concentrate between 160-255. So that the defects information we are interested in is only part of the whole image, it brings much inconvenience to image analysis, and is not conducive to defect edge extraction.



(a)Original image



(b)The first partition image

(c) Second partition image

(d)Result of extraction

Fig2.Defect extraction of auto rims image

In the experiment, firstly use the obvious distinction between the tire region with other parts in the spatial domain, eliminate the interference of tire regional. And then carry on two partitions to defect image, after carrying one partition to the defect image region, it contains defects and the wheel gap region image 2 (b), another division bring images 2 (c) which only contains the wheel gap. and then proceed to cucoloris, to subtract the two, it will remove the interference of the rims region, and morphology processing is utilized to extract the defects of images after cucoloris, which can be seen from Figure 2 (d). Finally SUSAN operator is used to extract the contours of defect image, thereby to detect the edge of defects.

SUSAN algorithm uses a circular template, the purpose is to enable the isotropic reached when detecting. However, in practical application, because of the digitization of images, the real circular template could not be realized, generally used to the approximate circle to replace. This paper selected a 4×4 circular template, which the template moved in the image, then calculate USAN regional size and the discriminant function C(r,r0)of the pixel belong to the USAN area by formula (1) and (2) when arriving at each location, finally by the formula (3) we get the characteristics image R(r0) of USAN area. Give pre-determined threshold t before the calculation, adopt a adaptive extraction method of t value. For each pixel SUSAN template, we get the gray-scale difference histogram of the template by calculating the gray scale difference of each pixel in the template and the center pixel, and then determine the threshold t of the template through the iterative method, which is based on gray-scale difference histogram, then take the average of gray-scale difference as iterative initial value T0, such as formula (4):

$$T_{i+1}=\frac{1}{2}\left[\frac{\sum_{m=0}^{T_i} m\times h(m)}{\sum_{m=0}^{T_i} h(m)}+\frac{\sum_{m=T_i+1}^{C_{\max}} m\times h(m)}{\sum_{m=T_i+1}^{C_{\max}} h(m)}\right] \quad \ldots\ldots (4)$$

Where m as a gray-scale difference value of the pixel point and the center pixel of the template, h (m) is the number of points with gray-scale difference value, Cmax is the maximum value for gray-scale difference value. Judge after each iteration, if $\left|T_{i+1}-T_i\right|=0$, stop the iteration, and take Ti as the final gray-scale thresholds of SUSAN template.

During the testing, through a series of experiments we made g=nmax/2, nmax is the maximum value which n(r) can achieve, finally take g = 23, and calculate USAN value of each pixel point. When the USAN value of a point is less than or equal 23, then the gray value of the point is set to 255, otherwise to 0. Through this process the defects target can be detected.

Because it is inconvenient to observe defects in the whole image, in order to facilitate the observation, we only process the defects extracted, and then the edge extraction results based on various methods are shown in Figure 3,

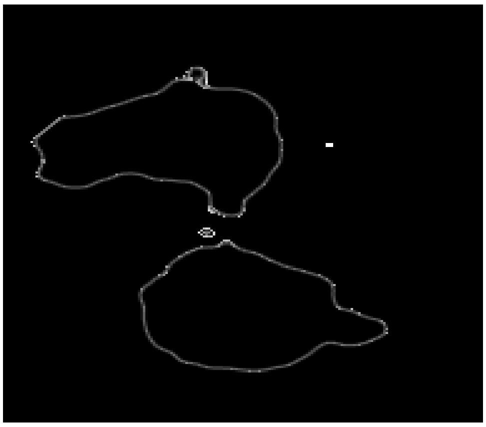
(a) Original defect

(b)Roberts detection

(c)Sobel detection

(d)Krisch detection

(e)Canny detection



(f) SUSAN detection

Fig3. Edge extraction base on various methods

As can be seen from Figure 3, the traditional operators brought a lot of pseudo-edge information when detecting the edge of target, but also lose a lot of the details information of objectives edge. The SUSAN algorithm can restrain isolated noise points commendably. The possibility of the edge points mixed with noise points is small, and gets the most complete information. It can thus be seen, SUSAN algorithm has good edge detection capability, at the same time the ability to resist noise is better, it is feasible for this paper to use SUSAN method.

4. Defect Detection

After in front of partition defects，defects can be seen more clearly, so further the defects are tested by intelligence, it is to automatically detect whether have defects , the number of defects and calculated in some parameters of defects automatically

4.1 Feature Description

In image recognition, it is unrealistic to directly recognize processing with the acquired image. First of all, the image data storage occupied a large space, time-consuming effort to identify directly, the computation can not be accepted; Secondly, the image contains many of the information has nothing to do with identification, such as background, so it need to feature extract and select.

This will be compressed on a lot of identified image data; it will help the image recognition. Feature Description is description and characterization with the extraction of the target image, said with the images for the follow-up identification and to lay the foundation for understanding. The Characteristic's extraction and selection is a linchpin, if the characteristic is not appropriate, that the classification can not be very accurate, indeed not impossible to classification.

4.2 Geometrical features

1. Barycenter

Barycenter is the average of the objects' coordinates pixel. Calculation formula is as follows:

$$\bar{X} = \frac{1}{A}\sum_{(x,y\in R)} x\,, \qquad \ldots\ldots(5)$$

$$\bar{Y} = \frac{1}{A}\sum_{(x,y\in R)} y \qquad \ldots\ldots(6)$$

2. Acreage

Acreage is the total area is the size of objects in a convenient metric. Acreage only with the object boundary, it has nothing to do internal changes in gray-scale.

It can be used a relatively short perimeter to surround the acreage which is occupied by the simple objects. The simplest (non-calibrated) acreage calculated is the method of statistical the number of pixels of the area inside the border (including border) . The area calculation is very simple under this definition. It is possible to obtain the sum of pixels in the borders domain; it can be calculated as follows:

$$A = \sum_{x=1}^{M}\sum_{y=1}^{N} f(x,y) \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (7)$$

The acreage is statistics the number of pixels of $f(x,y)=1$ to Binary image, if said object with 1, said background with 0.

3. Perimeter

Region's Perimeter is the length of the border region. It can be used a relatively short perimeter to surround the acreage which is occupied by the simple objects. The perimeter is the length of around these entire pixels outer boundary. Typically, the measurement of this length contains a number of 90° turn, thereby it is exaggerating the value of the perimeter. It is particularly useful to differentiate the shape of objects difference between the circumference of the region with simple or complex.

4. Long axis and short axis

When the objects' borders is known, it is simplest method to use its external rectangular dimensions to describe its basic shape. It is only need to calculate the object boundary points of maximum and minimum coordinate values to calculate the external rectangle of objects in the direction of the coordinate, it can be gained objects' horizontal and vertical span.

However, horizontal and vertical is not the direction that we are interested for the any move towards objects. At this time, there is a need to identify the principal axis of objects, and then calculated to reflect the characteristics of objects in the shape of the direction of the length of axis and the width of the vertical direction, so that the external rectangle is the object's Minimum Enclosing Rectangle(MER).

A method of calculating the MER is to circumgyrate the object's border around each 3 ° increment in the range of 90 ° rotation. Record the external rectangular boundary points' values maximum and minimum x, y with each time of rotating on its coordinate direction.

When it rotated to a certain point of view, the area of external rectangle achieve to the smallest. The smallest area of external rectangle's parameter is the length and width under principal axis's significance. In addition, the principal axis can be calculated by moments ,it can also be obtained by the calculation of best fitting of straight line .

4.3 Shape Features

1. Rectangular degrees: rectangular degrees are reflected the full extent of their objects' external rectangular; describe by the object's area compare with the smallest external rectangle's area, namely:

$$R = \frac{A_O}{A_{MER}} \quad \text{…… (8)}$$

Where, A_0 is the area of the object, A_{MER} is the area of MER. R's values is between 0 and 1. R is obtained the maximum value 1 when the object is rectangular; circular object's R is valued for $\pi/4$; slender, curved object's R is turn to smaller value.

2. Aspect ratio: it is the ratio of smallest external rectangle's length and width.

$$r = \frac{W_{MER}}{L_{MER}} \quad \text{…… (9)}$$

It can distinguish thin and circular shaped objects by use of r.

3. Circular degrees: it is a commonly used measurement of the region shape. The most commonly volume to measure circular degree is used density, that is, the ratio of perimeter square and area, $C = P^2 / A$ in which A is area, P is the perimeter

4. Moment: the moment of the region is interpreted a normalized gray-scale image function as a 2-D of random variables probability density. The characteristics of the random variable properties can be describe by the moment. By assuming the area's pixel value that non-zero, moments can be described for binary or gray-scale of the region.

Its $(j+k)$ moments as follows, for the duality function $f(x, y)$:

$$M_{jk} = \int_{-\infty}^{+\infty}\int_{-\infty}^{+\infty} x^j y^k f(x,y)\,dxdy \quad j,k = 0,1,2,\text{L} \quad \text{……(10)}$$

Because of that all non-negative integer value J and k can be adopt, thus creating an infinite sets of moment. Moreover, the collection function can completely determine $f(x, y)$ itself. In other words, the set $\{M_{jk}\}$ is the only for the function $f(x, y)$, only $f(x, y)$ is the moments with this particular.

In order to describe the shape of objects, assuming the values of $f(x, y)$'s target objects for 1, the background is 0, that function only reflects the shape of objects and ignores the gray level of its internal details. Parameters $(j + k)$ is called the rank of moments, in particular, the zero-rank moment is the area of the objects, namely:

$$M_{00} = \int_{-\infty}^{+\infty}\int_{-\infty}^{+\infty} f(x,y)\,dxdy \quad \text{……(11)}$$

Zero-rank moment can be expressed as follow for two-dimensional discrete function $f(x, y)$:

$$M_{00} = \sum_{x=1}^{M}\sum_{y=1}^{N} f(x,y) \quad \text{…… (12)}$$

After all the first-rank moment and higher-rank moment divided by the M_{00}, it has nothing to do with the size of objects.

When $j = 1$, $k = 0$, M_{10} is the sum of the X coordinates points of object for the binary image, similar to, M_{01} is the sum of the Y coordinates points of the object, so that $\bar{x} = \frac{M_{10}}{M_{00}}, \bar{y} = \frac{M_{01}}{M_{00}}$ is center of mass of the binary image.

5. Eccentricity

Eccentricity is also known as stretching region, it describes the compact region. There are so many formulas for eccentricity. A commonly simple method is used the calculation ratio of the long axis length A (diameter) and minor axis length B of the region. However, the calculation has resistant interference of objects, such as the shape of and noise. Better way is to use all the pixels in the region, that will have such resistant noise, anti-interference ability.

4.4 Feature selection criteria

The good features should have four characteristics as follow:

(1) It can be differentiated. Belonging to different categories of images, they should have significant difference characteristics value.

(2) Reliability. For similar images, their characteristics value should be more similar.

(3) Independence. The various characteristics used should not relate to each other.

(4) A small number.

4.5 Characteristics selected

Perimeter and area are two basic fixed parameters. These two parameters can reflect the basic characteristics of defects. Circular degree is an important parameter; through the circular degree you can generally determine the shape of defects. The value of circular degree is between 0 and 1, the maximum is 1. Circular degree is bigger the defects is closer to the circular, the more complex shape, it is the smaller circular degrees. Center of gravity is key parameter to reflect the position of deficiencies. After the analysis of defect parameters, select the perimeter, area, circle, center of gravity as the characteristics of defect parameters.

4.6 Determine the type and level of defects

Through a large number analysis of defects, based on the relevant casting defects standards level, then the lever of defects is determined. Defects can be divided into four level roughly according to the size of the defect: 4, defects is in an area of more than 10 less than 50; 3, defects is in an area of more than 50 less than 150; 2, defects is in an area of more than 150 less than 600; 1, defects is in the area more than 600. If an area of less than 10 is considered as noise.

For the above analysis, Figure 4, we partition the image after the noise reduction and defect region ,and then the automatic detection, test results as shown in Figure 5:

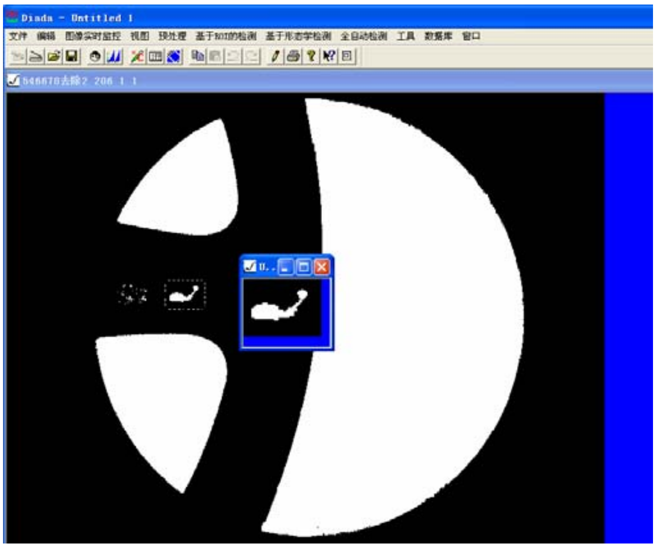


Fig 4 select defect region

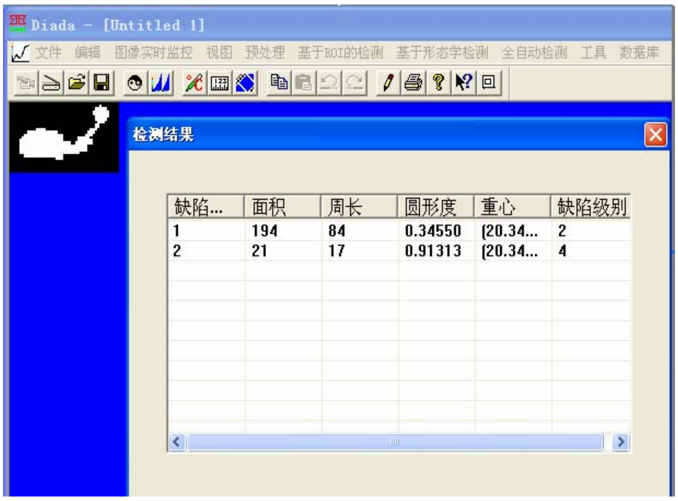


Fig 5 Defect Detection results

The results are shown in the table below:

Table 1 Testing results

Defect	area	perimeter	Circular degrees	Center of gravity	lever
1	194	84	0.3455	(20,34,25)	2
2	21	17	0.9131	(20,34,25)	4

It is can be seen from table 1, this detection method can detect the number of defects, as well as to determine the level of defect. Although the manual testing can detect the area and perimeter of defects, but it were unable to measure the center of gravity, circular degrees, and can not be observed for smaller defects by naked eye. Its automation degree and testing efficiency is much better than artificial.

5. The results of analysis

SUSAN algorithm only carries through addition operations; therefore the computational speed is very fast. Compared with traditional algorithm, this method has strong ability to anti-noise characteristics, but also for a variety of shapes it can accurately detect the edge, and the measurement accuracy can basically reached the pixel level. Experimental results show that the method is suitable for the target edge detection of the ray image like aluminum wheels which have low contrast, large noise interference, and the detected object have irregular shape. In the auto detecting of aluminum wheels, we applied this approach, it can be able to extract goals better, and then improve the efficiency and accuracy of detection.

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