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An Image Processing Based Method for Welding Defect Detection under Complex Environment

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ABSTRACT: Recognition and identification of weld defects dimensional position by computer vision is a key technology for practical industrial applications, especially under complex background. Aiming at this requirement, a method for weld defect detection under complex environment is proposed. Firstly, pre-location process is executed, in which filter technology, morphological technology, some geometrical features and edge detection are used to obtain the object in the vision. Secondly, line scan and a cluster algorithm are applied to find out the defect candidates. In the end several features are adopted to find out the real weld defect. The experimental results show that our method is effective in detecting weld defect under complex environment.

KEYWORDS: Welding detection; Image process; Morphology, Cluster.

INTRODUCTION

Welding is an important process in industrial production, like aerospace, machinery manufacturing, nuclear industry, energy, transportation and petrochemical field. During welding process, due to the influence of parameter setting and operation process, the defects of welding components will inevitably appear, such as crack, weld residual temperature is too high, slag inclusion, porosity, pinch of tungsten, incomplete penetration, incomplete fusion and so on, which will be a serious threat to production safety. Therefore, it is necessary to detect the defects of the welded parts, so that the engineers and technicians can deal with it in time [1]. Traditional detection methods mainly focus on X - ray detection and ultrasonic testing. These methods have many drawbacks, like high cost, missed detections and false due to the longtime of assessment caused by eye fatigue and so on. Therefore, it is very important to provide a welding defect detection method which is fast, efficient and not affected by human factors [2, 3].

In recent years, the rapid development of digital image technology provides the possibility of automatic detection of welding defects [4-6]. Through the treatment of inspecting the welding image, segmentation of the image of the target achieved. Feature extraction combined with image processing technology show a way to detect welding defects, which attract many researchers [2]. However, most of them focus on details process rather than practical problems. In practical industrial applications, the complex background is the most serious problem in defects detection.

In this paper, we propose an image based method in finding weld defects under complex environment. The proposed method deals with practical usage, so there are 3 steps in this method to fulfill the task to find out defect. First, pre-location of object; second, find defect candidates; in the end, true defects obtain.

This paper is organized as follows. In Section 2, we describe the framework of our work flow. In Section 3, we apply the proposed method to the problem of defect detection in images of steel chain weld parts and discuss experimental results. In Section 4, we got the conclusion of our proposed method.

FRAMEWORK OF DEFECTS DETECTION

The proposed method was applied to solve the problem of detecting welding defects. The images are taken from practical industrial production which contain many information, such as lights, connecting workpiece, steel chains, noise spots and so on. The complexity of practical usage shows the difficulty of finding defects. In order to solve these problems, we sue 3 steps to achieve the aim. First, pre-location of object; second, find defect candidates; in the end, true defects obtain.

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Figure 1. Framework of weld defects detection.

Pre-location of Object

In many practical industrial application, images captured by CCD always contain many objects(substance) which greatly influence the detection of welding defects, therefore the first step of detection is to locate the objects that have defects on, which is called pre-location step in this paper. There are 2 steps in pre-location procedure, firstly, filter process is used to reduce the effect of noise and binary image is obtained with proper threshold choose, secondly, morphological technology combined with some geometrical features and edge detection method are used to obtain object.

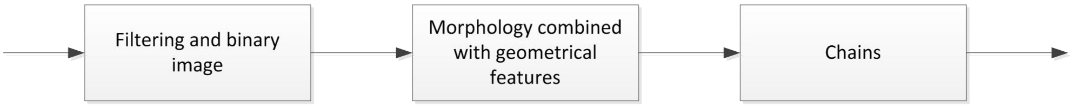


Figure 2. Pre-Location step.

Median Filtering

In image processing, it is often desirable to be able to perform some kind of noise reduction on an image. The median filter is a nonlinear digital filtering technique, often used to remove noise. Such noise reduction is a typical pre-processing step to improve the results of later processing (for example, edge detection on an image). Median filtering is very widely used in digital image processing because, under certain conditions, it preserves edges while removing noise, which is of great value to weld defects detection.

The method of obtaining the median value is as follows: let each point in the n pixel range be arranged according to its numerical value. The median value may then be obtained. If the number of points within the mask is an even number, then the median value is the average of the two numerical values.

Objects Obtain

After the filtering procedure, the noise is slightly decreased. Then, Otsu algorithm is used to get binary image. In this process, background is filtered, foreground which include object and some other substances is the part of the image that need to be processed. In this part, objects which could have defects should be located, in order to find the target, morphological filter, geometrical features and edge detection method are used.

Morphological filter:

In grayscale morphology, images are functions mapping a Euclidean space or grid E into $\mathbb{R}\cup\{\infty,-\infty\}$, where $\mathbb{R}$ is the set of reals, ∞ is an element larger than any real number, and $-\infty$ is an element smaller than any real number.

Grayscale structuring elements are also functions of the same format, called “structuring functions”.

Denoting an image by $f(x,y)$ and the structuring function by $b(x,y)$, the grayscale dilation of f by b is given by

$$(f \oplus b)(x,y) = \max\{f(x-s,y-t)\} \quad (s,t)\in b \tag{1}$$

Similarly, the erosion of *f* by b is given by

$$(f \ominus b)(x,y) = \min\{f(x+s,y+t)\} \quad (s,t)\in b \tag{2}$$

- Geometrical features:

Since the foreground is obtained, objects which could have defects on and some substances are included in foreground. In order to segment objects from foreground some geometrical features are used in this paper.

Aspect ratio is a geometrical feature to filter bigger parts of foreground, local gray level threshold is used to segment chains.

Aspect ratio: ratio of length to width. $R_{le} = L / e$, L; the big axis, e: the small axis.

Symmetry: the symmetric condition for pillars of chain, to find further location of pillars of chain.

- Edge detection

In order to locate the exact steel chain pillars, edge detection methods are applied.

The Prewitt operator is used in image processing, particularly within edge detection algorithms. Technically, it is a discrete differentiation operator, computing an approximation of the gradient of the image intensity function. At each point in the image, the result of the Prewitt operator is either the corresponding gradient vector or the norm of this vector. The Prewitt operator is based on convolving the image with a small, separable, and integer valued filter in horizontal and vertical directions and is therefore relatively inexpensive in terms of computations, what's more it has the ability of smoothing image noise.

The canny operator is an optimized operator and has better performance. The process of Canny edge detection algorithm can be broken down to 5 different steps:

1. Apply Gaussian filter to smooth the image in order to remove the noise

2. Find the intensity gradients of the image

3. Apply non-maximum suppression to get rid of spurious response to edge detection

4. Apply double threshold to determine potential edges

5. Track edge by hysteresis: Finalize the detection of edges by suppressing all the other edges that are weak and not connected to strong edges.

After the edge detection process, final processes are needed to segment object from background. In order to solve this problem, we proposed an algorithm, shown as below:

Step 1. Scanning each line (line scan) and counting the number of point that belongs to edge;

Step 2. Sorting the number in a descending order;

Step 3. The first four numbers are regarded as edge of pillars

Defect Detection

After previous process, main objects obtained, from which weld defects could be detected. However, on steel chain, there are many potential defect candidates. So find out true defects are the main purpose of this part.

In order to find true defects, effective features are needed, in this paper, 7 features are used and shown as follows:

1) Area : the area of defect candidates, A;

2) Aspect ratio: ratio of length to width. $R_{le} = L / e$, L; the big axis, e: the small axis.

3) Length/Area ratio : e/A

4) Area/bound. Rect. ratio : A/A_r, A_r: the area of the minimum rectangle that includes the object

5) Rectangle ratio : W / H^* W / H^* :the width/height of minimum rectangle that includes object

6) Symmetry : the symmetric condition of gray value along the axis.

$$K = \frac{1}{n}\sum_{i=1}^{n} \quad = x_1^i + x_3^i - 2x_2^i \tag{3}$$

Where, x_2^i is the point with minimum gray value at line i , x_1^i and x_3^i are Symmetric points at line i which subject to constraints $\frac{1}{4}\sum f = \sum_{j=0}^{x_1^j} f_j$ and $\frac{3}{4}\sum f = \sum_{j=0}^{x_3^j} f_j$, f_j is gray value along the short axis at line i.

The algorithm consists of the following parts:

step 1. Morphological filter is applied to segment defect candidates;

step 2. For all region of interesting (candidate zones), calculate every line that candidates belong to, to find out the point that with minimum gray value of the line; calculated as follows:

$$defect_{\text{Suspected}} = \min_{i=1,\cdots,m}\left\{ f(i,j) - \frac{1}{n}\sum_{j=1}^{n} f(i,j) \right\},\ f(i,j) \text{ is the gray value of image.}$$

step 3. A cluster based method is used to rebuild defect candidates with minimum value from step 2;

step 4. Combining with features mentioned above, real defects obtained.

The cluster method mentioned in step 3:

1) Initialize the set of clusters to the empty set, $S = \phi$

2) Find a cluster C in S, such that for all C_i in S $dist(C, x_i) \le dist(C_i, x_i)$

3) If $dist(C, x_i) \le w$, then associate x_i with the cluster C. otherwise a new cluster is created $S \leftarrow S \bigcup \{C_n\}$, where C_n is a cluster with x_i ,and $dist(C, x_i) = \min_{x_j \in C, x_j \ne x_i} \left\| x_i - x_j \right\|$

4) Repeat step 2 and 3, until now instances are left.

Where x_i is data samples, C_i is the cluster in S. After this step all defect candidates should be identified.

RESULTS AND DISCUSSION

Experiments are performed to demonstrate the effectiveness of the proposed method. In this paper, practical industrial images are used which is captured by an industrial camera and stored in the computer. The resolution is 1292x964 pixels. In this image, 2 illuminants are used for lighting steel chain, the background include table, nut and other workpieces. For detecting the potential defects on chains, filtering, pre-location, object obtain, getting candidates and true defects finding are carried out step by step.

Pre-Location

As fig 4 shows, the first step of pre-location is image filter, which median filtering technology is applied, after that, morphological filter is used to get binary image, which is shown is fig 5.

In fig 6,morphological filtering is used to separate lights and steel chains, from fig 6 we can tell that 2 lights location and basic geometric region are obtained, by cutting this parts off, we can focus on steel chains, which is shown as fig 7. With proper parameters setting, we can get the main part of the image, which defects could exist on, shown as fig 8.

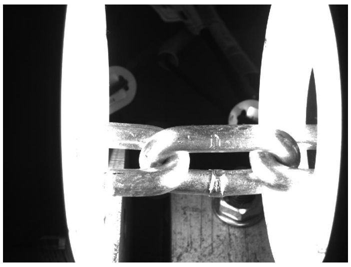


Figure 3. Raw image.

Figure 4. filtered image.

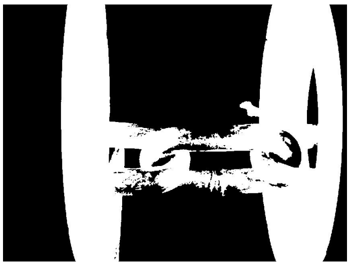


Figure 5. Binary image with proper threshold.

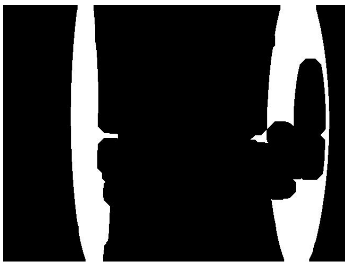


Figure 6. Morphological filter to filter illuminant.

Figure 7. Further location1.

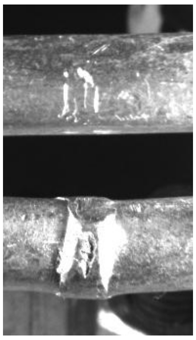


Figure 8. Further location 2.

After steps metioned above, the last process is locating steel chain pillars of both side. In order to find edges of pillars, several edge operators are tested as fig 9. From the test, it was found that the results using the individual operator was not acceptable, since some of the image pixels were lost at the edge of the chain pillar. However, prewitt operator and canny operator could keep edge of pillar well relatively, therefore, we combined these two edge operators together and use it on binary image to find better edge of steel chain pillars, which is shown in fig 10.

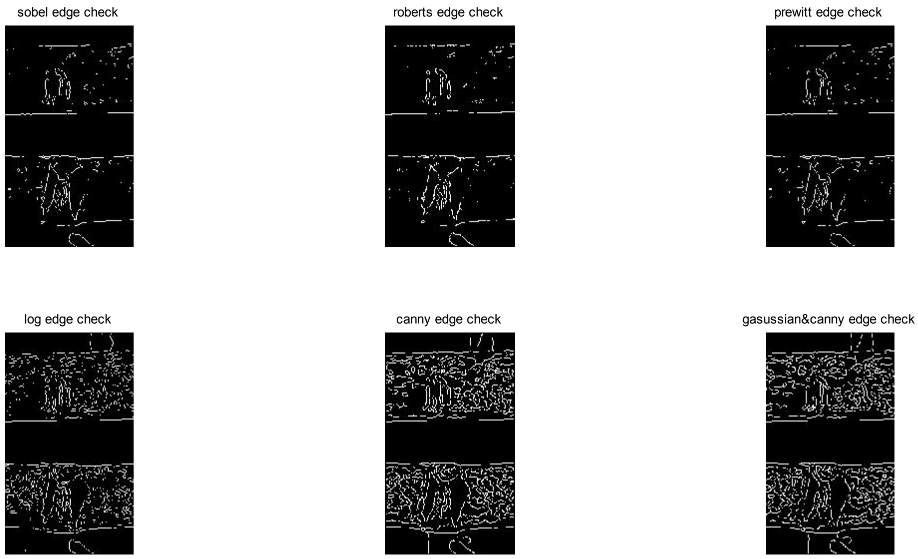


Figure 9. Edge operator.

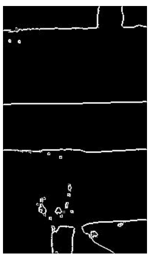


Figure 10. Finial edge detect.

From fig 10, we can tell the edge of both pillars of chain, how to segment chain pillar from this image is the last step of pre-location procedure.

With algorithm mentioned above, the object are obtained as follows:

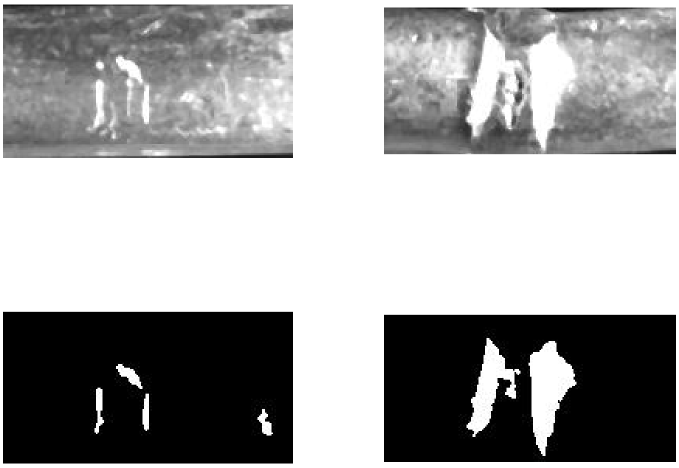
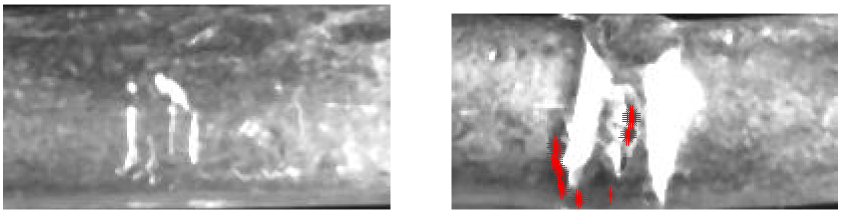


Figure 11. Final object obtain.

From fig 11, some defect candidates are gotten. How to get true defect is the second process of proposed method. By scanning and finding minimum gray value points, defect candidates obtained, shown as fig 12. With clustering algorithm mentioned at detection part, we can get fig 13.

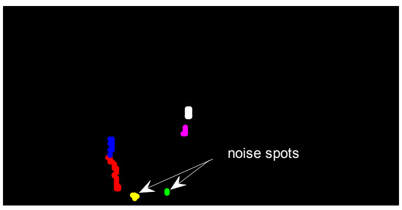


(a) (b)

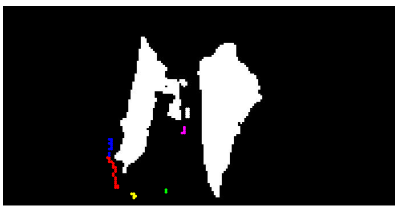
Figure 12. Suspect defect on both pillars.

Figure 13. Defects candidates.

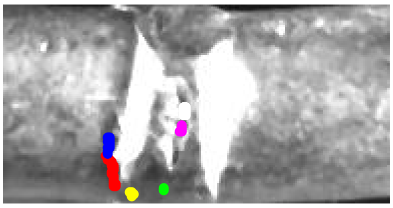
According to algorithm mention above, there is no defect candidate in fig 12 (a). Fig 13(a) shows potential defects of fig 12(b). By clustering process, the candidates point in fig 13 are clustered into 6 clusters, which is shown as fig 14



(a)



(b)



(c)

Figure 14. 6 defect candidates clusters.

Combining with features presented above, true defects are detected, which is shown in fig 14 as pink points and white points. The yellow points and green points are noise spots which are easy to filter. However, the most confused points shown as blue points and red points are so much like real defects. From fig 14(c) we can see that the area around blue points and red points do not show the feature symmetry. The both side of faked defects show different gray value, whose gradient changing does not match normal defects. Therefore, what left are real defect, shown as follows.

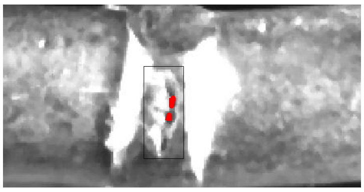


Figure 15. Defect detected.

CONCLUSIONS

In this paper, we present a method for detecting welded defect under complex environment. In order to detect weld defect under such condition, three procedures are executed, pre-location, candidates defect detection and true defect detection. Several basic images processing technology is applied combined with features and proposed algorithm. In the end, the experimental results show that the method proposed in this paper is effective.

In the future, we aim to investigate the method in many more images and eventually create a public dataset which will be able to be used for algorithm evaluation.

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REFERENCES

[1] X.G. Zhang, J. J. Lin. “Research of Image Processing and Defect Recognition for Industrial Radiographic Weld Inspection.” Journal of East China University of Science & Technology 30.2(2004): 199-202.

[2] R.Vilar, J.Zapata, R. Ruiz, (2009). An automatic system of classification of weld defects in radiographic images. NDT and E International, 42(5), 467–476.

[3] Valavanis, Ioannis, D. Kosmopoulos. “Multiclass defect detection and classification in weld radiographic images using geometric and texture features.” Expert Systems with Applications 37.12(2010): 7606-7614.

[4] V. Lashkia, “Defect detection in X-ray images using fuzzy reasoning.”Image & Vision Computing 19.5(2001): 261-269.

[5] Q.M. Shen, J. Gao, L. I. Cheng. “Recognition of Weld Defect Types.” Journal of Xian Jiaotong University (2010).

[6] Nacereddine, N., Zelmat, M., Belaïfa, S. S., & Tridi, M. “Weld defect detection in industrial radiography based digital image processing.” In: Proc. of World Academy of Science Engineering & Technology (2005): 112.