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An Algorithm for Defect Detection in Metal Plates Using Improved Gabor Filter

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Abstract - Defect detection in metal plates is one of the most important steps in the production of metal sheet to improve the product quality and maintaining the position in market. Surface defects such as cracks, pits, holes, etc on raw metal sheet are difficult to detect at early stage. If such defected metal is used in the equipment then correction cost after production will be more. High percentage of quality control is maintained by surface defect detection itself. In this paper, we proposed an algorithm to detect various kinds of defects in metal plates. We used an image processing with the Gabor Filter method to detect defects. In this technique we combine unique image obtained after adding pixels of same scale with single image obtained after addition of pixels of same orientation. So this improves the accuracy of defect detection. To examine the performance of proposed algorithm, we tested number of defective and defect free images of metals. The results show that proposed method is suitable for detecting defects in metals with high accuracy.
Keywords- Surface defect, Quality control, image processing, Gabor Filter

I. INTRODUCTION

In metal sheet manufacturing process quality control is an important issue. So, the production inspection should carry out to evaluate the product. Today, in most of sheet product lines, quality control is performed manually by expert people. The lack of an automatic quality control system causes reduction in efficiency, lack of sufficient precision, and increasing the expenditure. Image processing is the dominant technology in the field of inspecting different textures and recognizing available diversity. Capability of this technology, especially in these two contexts of detecting and categorizing the sample, opens the way to utilize this approach for quality control in industries such as textile, paper, ceramic So far a great deal of research has been made in automatic detection of defects available on the surface of metal sheets. [13] Surface degradation is the factor that causes most (70%) of machine failure. Therefore, it is important to realize and classify the defects in surfaces automatically at early stages of production.
There are many approaches for defect detection in the production industries. Some of them are listed below. There are three approaches for defect identification. [4]
1. Statistical Approach: - Morphological operations Normalized correlation Edge detection Co occurrence matrix
2. Spectral Approach: - Discrete Fourier Transform Optical Fourier Transform Gabor Filter Wavelet Transform Wigner Distribution
3. Model Based: -
Poison Model
Gauss Markov random field Model based clustering
This paper deals with an implementation of efficient Gabor Filter technique for defect detection in metal surfaces at high accuracy and within a short time. The rest of the paper is organized as follows. The earlier work of defect detection is presented in section II. An introduction to Gabor Filter is given in section III. Gabor Filter based proposed approach is discussed in section IV. Experimental results and conclusion is given in section V and VI respectively.

II. LITERATURE REVIEW

In the previous years, some defect detection techniques have been proposed. The knowledge of these detection techniques has been collected from various resource materials. [1] M. Ghazvini, A. Monadjemi, K. Jamshidi uses detail matrices which consist of median, max and min points for defect detection.[2] J.L .Sobral emphasized wavelet sub band and optimized gabor filters can be used for texture defect detection. [3] Hamid Alimohamadi highlighted the use of filter banks and optimized filter for defect detection and extraction of feature image. [4] Ajay Kumar and Grantham Pang revealed gabor filters can be deployed for fabric defect detection using bernoulli's rule of combination. [5] Kaicheng Yin and Weidong Yu used segmentation for defect detection in garments production system. [6] Henry Y. T .Ngan, Grantham K. H. Pang, S. P. Yung, Michael K. Ng proposed patterned fabric defect detection using golden image subtraction method. [7] Jun Xie, Yifeng Jiang,Hung-tat Tsui proposed the use segmentation technique in medical application. [8] Yi-leng chen, Tse-Wei Chen,Shao-Yi Chien revealed how wavelet trans-form can be used for fast texture feature extraction. [9] J. P. Yun, S. H. Choi, S. W. Kim proposed an algorithm using Laplacian and edge preserving filter for real time defect detection for Bar in Coil.[10] J. W. Kim , S. W. Kim developed a technique in which Gabor Filters are optimizes using univariate dynamic encoding algorithm for searches (uDEAS). The algorithm finds the minimum value of the cost function related to the energy separation criteria between the defect and the defect-free regions. [11] C. H. Park, S. H. Choi, S. W. Won highlighted the use of wavelet transform for periodic defects in steel wire rod production. [12] D. C. Choi, Y. J. Jeon, J. P. Yun proposed an algorithm using Gabor Filter and morphological features for detecting pinholes in steel slabs.

III. REVIEW OF GABOR FUNCTION

Gabor filters are linear filters obtained from the modulation of sinusoidal function by Gaussian envelope. Gabor filter represents the best compromise between frequency localization and spatial localization, as measured by the product between spatial extent and frequency bandwidth of the filter.

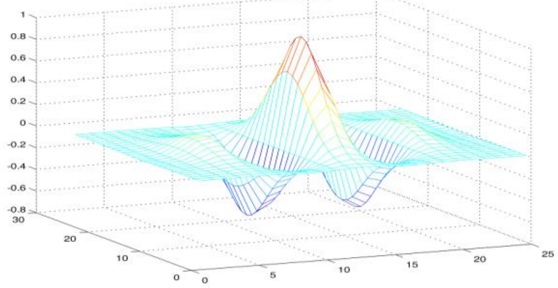

Fig. 1 Assymetric 2 D Gabor function

Gabor filters are multi-scale, multi-resolution and tunable band pass filters. They are similar to a STFT or windowed Fourier transform and satisfy the lower-most bound of the time-spectrum resolution. It has selectivity for orientation, spectral bandwidth and spatial extent. The response of Gabor filter is similar to that of the human visual cortex. The impulse response of Gabor filter is obtained by sinusoidal wave plane multiplied by Gaussian function. The filter function is a complex which is divided into a real and an imaginary component.

Complex

$$g(x,y;\lambda,\theta,\psi,\sigma,\gamma) = \exp\left(-\frac{x'^2+\gamma^2 y'^2}{2\sigma^2}\right)\exp\left(i\left(2\pi\frac{x'}{\lambda}+\psi\right)\right)$$

Real

$$g(x,y;\lambda,\theta,\psi,\sigma,\gamma) = \exp\left(-\frac{x'^2+\gamma^2 y'^2}{2\sigma^2}\right)\cos\left(2\pi\frac{x'}{\lambda}+\psi\right)$$

Imaginary

$$g(x,y;\lambda,\theta,\psi,\sigma,\gamma) = \exp\left(-\frac{x'^2+\gamma^2 y'^2}{2\sigma^2}\right)\sin\left(2\pi\frac{x'}{\lambda}+\psi\right)$$

Where $x' = x\cos\theta + y\sin\theta$ And $y' = -x\sin\theta + y\cos\theta$

In this equation, λ represents the wavelength, θ represents the orientation, ψ is the phase offset, σ is the standard deviation of the Gaussian envelope and γ is the spatial ratio. Fig. 2 shows a real and an imaginary part of the Gabor function in spatial domain.

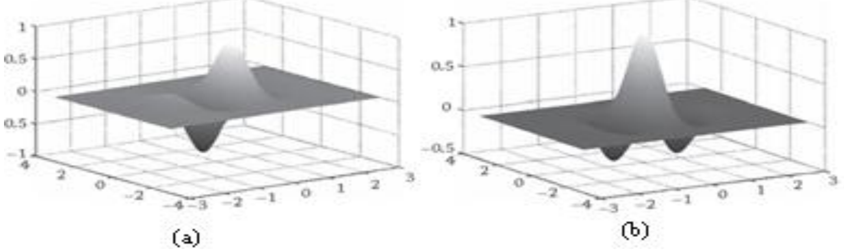

Fig. 2 (a) real and (b) imaginary part of Gabor function

IV. PROPOSED ALGORITHM

In this paper, we developed an unsupervised defect detection technique. In supervised defect detection segmentation of defect is performed with priory knowledge of size and orientation of sample defect. But dimensions and orientation of defects generated vary randomly so automation process requires unsupervised defect detection technique. The following processes are used in an algorithm for defect detection in metal surface.

A. Creation of Gabor filter bank:

Various images of metal plates are taken for automatic defect detection purpose. Each of these images is subjected to filtering with bank of self similar Gabor filters. Every Gabor filter is tuned to narrow range of orientation and frequency. Real and imaginary part of Gabor filter is implemented as spatial mask of M×M size. Generally M is preferred to be an odd number for symmetric region of support. We create 18 asymmetric Gabor filters with three scales (S=3) and six orientations (L=6). Each input image I(x, y) is filtered with 18 Gabor filters and magnitude of filtered image is calculated using following question.

$$I_{pq}(x, y) = \left\{ [G_{pq}(x, y)_e * I(x, y)]^2 \quad + [G_{pq}(x, y)_o * I(x, y)]^2 \right\}^{1/2}$$

Then nonlinear function is used to convert both positive and negative amplitude into positive amplitude. These 18 images represent features of image.

B. Determining feature difference:

Reference i.e. defect free image and test image are subjected to multichannel filtering to create feature I'pq(x, y) and I"pq(x, y) respectively. To locate defects in image mean υ'pq and standard deviation σ'pq is computed. Decision rule is now applied for pixels in I"pq(x, y). This decision rule assumes that the feature of reference image is distributed according to Gaussian distribution. The decision rule is given as

Dpq(x, y) = I"pq(x, y), I"pq(x, y) - υ'pq ≥ Γ. σ'pq

Dpq(x, y) = 0, Otherwise

Where, Γ determines sensitivity and it is chosen to value of Γ=3.

C. Image fusion:

The aim of image fusion is to combine all pixels of 18 images having probability of being defected into a single image. There are many approaches are available for data fusion but here we use Bernouli's rule of combination because of its computational simplicity. This involves two steps 1) Vector addition of all pixels having same scale p but different orientations q. It generates six images 2) Geometric mean of resultant pixels of successive orientations create five images. A single unique image H(x, y) is produced by taking average of pixels from five images. The above two steps are repeated to calculate H'(x, y) of same orientations. H(x, y) and H'(x, y) have some different information between them. Therefore, we have added pixels of both images and performed averaging so that the overall information of image must be maintained. Following equations are used for image fusion.

D. Thresholding:

Thresholding is the basic step for image segmentation. The fused image is subjected to thresholding to suppress the non defective pixels. The limit of thresholding is computed from reference image. The magnitude of filtered image F(x, y) is obtained by filtering reference image with Gabor filter [4]. Thresholding limit is obtained as follows:

$$\psi_{th} = \max_{x, y \in W} |F(x, y)$$

Where W is window centered at the image. The value of threshold limit is such that the unwanted pixels from image are completely isolated in output image.

V. RESULT

Various images of metal plates are used to determine the defected area in image. Large numbers of image samples have been analyzed using proposed algorithm. The following figures show the result.

Table I shows the comparison between different techniques available for defect detection

Table I. Comparison of defect detection technique

Author	**Method**	**Percentage of detection**
Sunil Kumar[15]	GLCM	98.33%
Faezeh Memarzadehzavareh [14]	Gabor wavelet	90-98%
D.Gnanadurai [16]	Gabor and Gaussian Filter	85-93%
Rashmi S Deshmukh [17]	Feature extraction and Segmentation	90-95%
Proposed approach	Gabor filter	95-97%

Following Fig. 3 shows the results obtained by applying proposed algorithm.

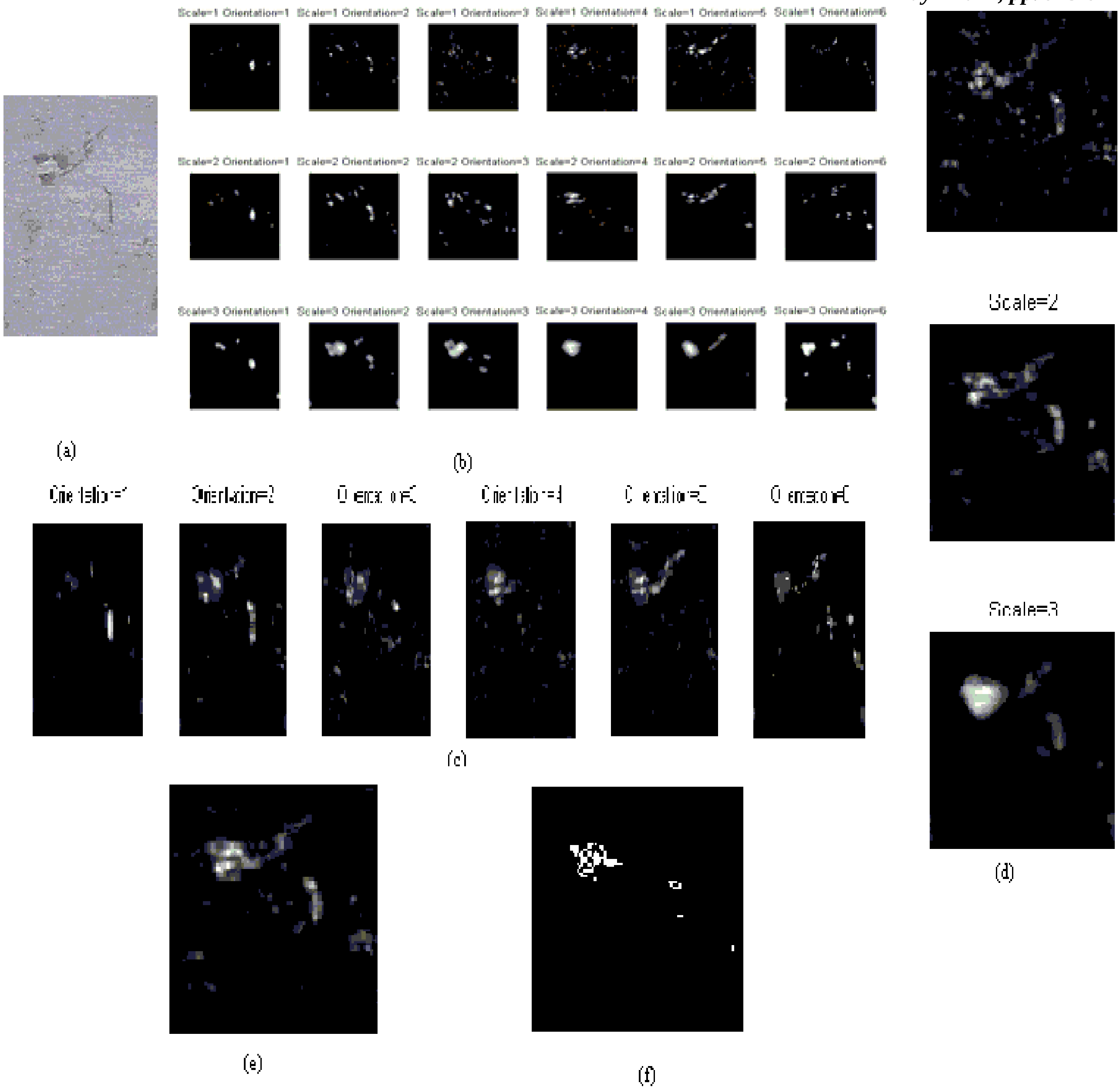

Fig. 3 (a) Test image (b) Feature difference of 18 Gabor filter images (c) images after adding same scales (d) Images after adding same orientations (e) combination of H(x, y) and H'(x, y) (f) threshold image

VI. CONCLUSIONS

We have proposed defect detection technique to identify the various defects in metal surface. We also compared the proposed method with existing methods of defect detection. The method also required less time of computation. We have achieved 95% to 97% of accuracy in all collected samples.

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