Research Article

Applying Gabor Wavelet in Image Processing for Defect Detection on Steel plates

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ABSTRACT:
Quality control of steel sheets for the purpose of optimizing product quality and maintaining market competition is very important. Detection of surface defects a high percent of quality control process to itself. in this paper a fast and highly accurate approach for detection of this kind of defects is offered by using image processing with the aid of Gabor Wavelet and without any need to normal image or determining the quantity of images which are to be deleted The accuracy and speed of applied approach has been indicated by offering test samples ;

Keywords: Image Processing, Automatic Inspection, Quality Control, Defects Segmentation, Gabor Wavelet.

INTRODUCTION

Quality control is one of the most important issues in the industry of steed sheet production. Detection of surface defects allocates a high percent of quality control process to itself. Nowadays in most production lines of steel sheets, quality control is executed manually by expert personnel. The lack of an automated system for quality control causes a decrease in efficiency, increases costs and makes inaccuracy. Image Processing is dominant technology today for inspection of different tissues and recognition of available diversity. The power of this technology, especially in two fields of detection and classification of the template, makes it possible to utilize in quality control of such industries as textile, paper and ceramic. With regard to such practical background of techniques for image processing and the sort of surface defects available on the steel sheets, lots of researches has been made so far for the purpose of automatic detection of defects [1&2].

The majority of attempts so far made, focused on the features of color and figure in color to offer appropriate methods, In [3] the feature of tissue has been used, in which by utilizing Gabor wavelet for signal processing by MSMD method, tissue features of steel sheets are extracted. Since the availability of a normal image is vital for defect detection and proper selection of normal image is important (it must have the same background as that of defective image) and the comparison of normal image with defective ones is time – consuming and whit regard to the fact that detection of partial image which must be deleted is performed manually, in the new method the

necessity to normal image is removed and the quantity of partial images to be deleted is determined automatically, so that the speed of defect detection is increased, whit accuracy maintained as before. To verify the ability of suggested method and compare it with the method mentioned in [3], a set of tests has been applied on real images. These tests verify increasing in speed while maintaining accuracy.

In this paper, as well as introducing the advantages of utilizing automatic system for quality control, some of fundamental concepts required for this study are introduced concisely, in section 2. Similar attempts performed in the domain do utilizing image processing techniques for detection of steel defects are studied in section 3. Suggested model and results achieved is offered in section 4. In section 5 the results of the tests is indicated in two forms, namely table and figure. Finally in section 6 we conclude the paper.

BACKGROUND

In this section, first we survey defects, then introduce basic concepts in concise. During different phases of producing steel sheet, a lot of defects are provided on the sheet surfaces. producers of steel sheets are willing to recognize unexpected defects so that not to allow them to take place, frequently and make sure that quality of products coincides whit customer's need [4].In Mobarakeh steel complex about 210 defects are coded for appearance similarity, features of illuminance and imaging and processing algorithms and divided in 10 groups. These groups are surveyed in detail.

Based on the outcome of this study and by considering such parameters as high frequency of defect occurring, diversity of defects and importance of their classification, 4 kinds of defect (hole, scrape, lateral pleat and corrosion) are chosen for study.

Image processing and techniques of feature extraction

Today dominant technology for detection and classification of products based upon appearance feature is the technology of image processing.

Generally this operation is performed in two main phases, namely feature extraction and classification. In the former by determining the required features and by choosing parameters and method of extraction, the features are detected from a raw image and then optimized. In the latter phase, the regions with similar tissues are determined and the border of different tissues is detected.

The main goal of feature extraction of tissues is to provide a criterion for detecting tissue properties of image, such as softness and roughness, cognation, flatness, frequency, being in order and so forth. There are different methods for extraction of tissue features; each one has its pros and cons with regard to its application, speed, accuracy, etc. Techniques like concurrent matrices or self –correlation function and approaches based on model are not applicable, because of complexity of calculation time for real – time inspection systems.

Nevertheless, in most studies, these are used as methods with high accuracy. In this paper; the method of signal processing is utilized. The application is possible in two ways:

Filtering in time domain, analysis of Fourier domain and discrete transformations;

Directional multi frequency method (MSMD).

The most applied method used in extraction of tissue features and their classification is MSMD [7, 8].

Gabor Wavelet

Gabor filters are widely utilized in Directional multi frequency methods. These filters have high efficiency in feature extraction for tissue classification [10,11,12].Their main advantage is tissue analysis, simplification of directional band pass filtering in tissue image which allows the filter to extract a great deal of tissue features that includes both different directions and different frequencies. Gabor wavelets can be utilized in both frequency and locality domain. If Gabor wavelet is defined in locality domain, it convolves with under working image to produce the partial image. If Gabor wavelet is defined in frequency domain, first we apply the FFT on image to convert the

locality domain to frequency domain and then multiply it with Gabor wavelet. Finally, by converting the response from frequency domain to locality domain, the partial image is produced. In this paper we use Gabor filter in locality domain.

Feature extraction is performed by a bank of Gabor filters. Because of different frequencies and different directions in Gabor filter's bank, the extracted features include high amount of information about the image tissue and so it is possible to detect the defects in different frequencies and directions.

Since the major defects of steel surface occur in production period and in a random way, the special type of Gabor filter can not be applied in detection of any kind of defect.

A 2-dimensional Gabor filter in locality domain is defianed by (1):

$$w(x, y, \theta, \lambda, \varphi, \sigma, \gamma) = e^{-\frac{x'^2 + \gamma^2 y'^2}{2\sigma^2}} \cos(2\pi \frac{x'}{\lambda} + \varphi)$$

(1)

where:

$x' = x \cos\theta + y \sin\theta$

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

There is not any analytical method to optimize the Gabor filter's bank. Therefore a long process for test and evaluation to yield the best configuration of this bank is needed. In our tests after computations, we conclude that a filter bank comprising 12 Gabor filters with frequencies $\left\{ \frac{\Omega m}{8}, \frac{\Omega m}{4}, \frac{\Omega m}{2} \right\}$ and angles $\{0°, 45°, 90°, 135°\}$ can extract tissue feature very well. Ωm is the highest image frequency equal to half of the image size in frequency domain.

In this paper by using the above frequencies, the highest level of accuracy is prepared. Increasing the number of filters upper a limit cannot improve the efficiency and just leads to computation overload.

RELATED WORKS

Due to capabilities of image processing in the field of assessment of different tissues and their classification, So far in most industries such as

textile, Ceramic and paper, this technology has been used for QC and defect detection [1,2,3].

The concentration of last works has been on features such color and shape. In [4, 5] the tissue feature is used, too. In detection of steel sheet defects, this technology has been used [13]. Among the most important methods for image processing are edge detection and utilizing smart sensors [6] and zoning the images [9]. In these methods with focus on color and shape features, the surface defect is detected. Due to imperfect information yielded from these methods (especially in shape feature) the type of defect is not recognizable. Unlike the color and shape feature, the tissue feature can give us the needed information to detect the defect and its type [10]. Some methods to combine the color and tissue features are presented in [11, 12]. These methods have treat to tissue and color as a common phenomenon. In [13] a new method is presented to extract the steel surface features by using arithmetical method like LBP.

In [4] by application of image processing technology with the aid of Gabor wavelet for extraction of tissue features and comparison with normal image, as well as manually determining the quantity of partial image to be deleted, a good solution is offered. The problem of this method is the selection of appropriate normal image (s) with the same background; regarding the fact that determining number of partial images for deletion is done manually.

SUGGESTED APPROACH

In this paper a method is suggested in which the defects are classified based on dispersal in partial images so that is no need to have normal image (s) or specify the number of deleted images. At first, feature extraction is performed by a bank of Gabor filters comprising 12 filters.

After yielding the 12 partial images, the energy of them is computed. The normalization process is performed according to relation (2):

$$f_{norm}(x, y) = \frac{f(x, y) - \min(f)}{\min(f) - \max(f)}$$

(2)

Where f(x, y) is the value of pixel in point (x, y) of partial image matrix. Min (f) and Max (f) are the minimum and maximum value of pixels in partial image, respectively.

After this normalization, the value of pixel converts to a new value in [0, 1]. After this, the quantization is done. The goal of quantization is mapping the normalized value of each pixel to several values. We need n-1 threshold level to map each normalized value to n grey level. This process is according to (3):

$$for \; k \in \{0,1,...,n-1\}$$

$$if \; \frac{k}{n} \le f(x,y) \le \frac{k+1}{n} \quad then \quad f_q(x,y) = k$$

$$(3)$$

Where f(x, y) is the grey normalized value of each pixel in normalized partial image and f_q is the quantized image with n grey level.

In this point, the partial images that more distinctly have defective region are selected for combination because this region or zone causes the features of these pixels to be more sensible than rest of the image which somehow includes non – defective region. In the image in which defect is not observed, usually the balance of calculated energy is approximately zero and dose not lie in the region of calculated dispersal. With algorithms offered, images are selected whose data dispersal is small. In a defective image, it is possible to select all partial images or no partial images. Thereby, in this method there is no need to know how many partial images must be eliminated. Also the need to select the normal image(s) for comparison is absolutely removed.

After the best partial images are selected, the combination step must perform to produce the feature plan. This work leads to detection of more defected regions and increasing SPC and SNS percentage. For combination of images, three methods are usual:

Simple addition rule
Bernoulli's combination rule
SBA rule

For three variables a, b and c, these three rules are defined as following:

Simple Addition rule

$$comb(a,b,c) = a + b + c$$

Bernoulli's rule

$$comb(a,b,c) = 1 - (1-a)(1-b)(1-c)$$

SBA rule

$$comb(a,b,c) = \frac{abc}{abc + (1-a)(1-b)(1-c)}$$

However we must note that the denominator of SBA formula can be zero and leads to unacceptable results.

Between these three methods, SBA and simple addition have the minimum and maximum percentage of defect detection, respectively.

Finally, after combining partial images, feature plan is made up. The computations in this method for dispersal criterion are based on variance. In these experiments after extraction of features by Gabor filter bank, making partial images and calculating the energy, variance of each partial image is calculated. Variance determines the square of differences between each vector and the average and divides it by the number of elements. The experiments were conducted in MATLAB. For calculation of variance in this software we used (4).

$$\sigma^2 = \frac{1}{n-1}\sum_{i=1}^{n}(x_1 - \bar{x})^2$$

$$(4)$$

The variance is calculated in 3 ways:

Total variance: pixels of each partial image are considered like a vector and the variance for all of them is calculated. This is called "total variance ".

Vertical variance: Each column of pixels is considered as a vector and variance of each column is calculated separately. Then the variance of resulted vector is achieved and called vertical variance.

Horizontal variance: Each row of pixels is considered as a vector and variance of each row is calculated separately. Then the variance of resulted vector is achieved and called horizontal variance. Each variance is divided into its maximum value in all partial images in each direction in order for all variances to be in the same limit and in the border

of [0, 1]. The reason is that in some partial images, especially those with lower frequency, the amount of pixels is less than that of other partial images and if in this partial image there is a defect, because the quantity of its pixels is small, the resulted value for variances will be small too. This won't have a good outcome. After normalizing the values of variances for selection of partial images in order to be combined with each other and establish a feature plan, a threshold, that partial image is chosen for addition. This threshold is selected 0.2 with regard to images. Feature plan is established with combination of quantized partial images by means of simple addition rule.

Now we create the binary image from the feature map. The binary image is produced by replacing the value "0" for the safe pixels and "1" for the defected pixels. Also, we can detect the edge of defect region using edge detection function and then by some morphology operation can bind the piece-wise and adjacent regions together to prepare an explicit image. Finally we should eliminate the alone pixels of defection, because they don't give useful information about the defection.

SET OF DATA AND EXTRACTION

By means of Gabor filter bank, establishing partial image is computed. The algorithm for selection of partial images having defective region is based on different values achieved for variance. Naturally, the image lying within the limit of our variance includes defective region.

In Fig. 1, right hand shows the feature plans and left hand indicates related zoned selected images. The resulted feature plan is established by means of simple addition.
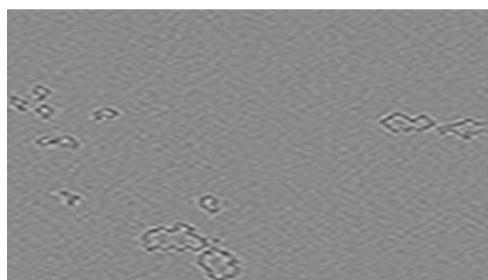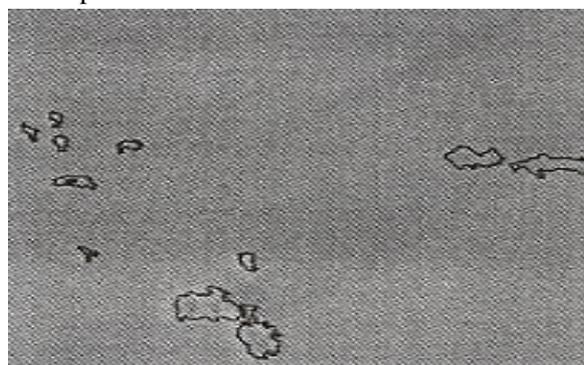
feature plan and zoned image

The average of results achieved from this algorithm is shown in table 1. In this table, SNS is the percent for correct detection of defective regions and SPC is the same percent for non-defective regions. The images on which experiments were conducted are divided two groups. Group 1 includes images on which the defects really exist. In group 2 there are images on which we made the defects manually. Results of both groups are offered. In showing the results, partial images are considered non-normalized and variances are normalized between 0and 1 by dividing them in to their maximum value. The threshold is considered 0.02 and the method used for combination of partial images is simple addition.

THE RESULTS OF SUGGESTED ALGOURITHM

Data set	Simple addition	
	SNS	*SPC*
Main data set	93.14	94.71

CONCLUSION

Regarding the importance of normal image in defect image in defect detection and also importance of proper selection of normal image (which must have the same background as defective image) and since the comparison of normal image with defective ones is a time consuming process and determining the number of partial image to be deleted is done manually [3], in the new approach by removing the need to normal image and automatic determining the number of partial images to be deleted, the speed of defect detection increases and mean while maintains the accuracy. In this paper quantity of partial images was inspected in 3 modes: normalized, non – normalized and quantized with the threshold value

of 5. Three variances were calculated for each mode and all partial images. The best deletion algorithm was where variances of partial images were calculated in non – normalized mode. That is, normalizing and quantization causes the variances to be impressed and selection of proper partial images from them becomes impossible. All together, the amount of SNS in this approach has increased in comparison with other approaches.

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