euspen's 17th International Conference & Exhibition, Hannover, DE, May 2017
www.euspen.eu

Efficient Wavelet-based Discriminant Measure for Surface Defect Detection on Steel Plate

Gyung-Bum Kim [1] , Soon-Hwan Moon [2]

[1]Aeronautical & Mechanical Design Eng. Korea National Univ. Of Transportation, [2] Chungbuk Health & Science Univ. KOREA

kimgb@ut.ac.kr

Abstract
Low-contrast, uneven, noisy and featureless characteristics are included in surface images of steel plates. It has been reported that it is very difficult for previous methods to discriminate defect region from defect-free one in those steel images. In this paper, a new discriminant measure based on wavelet transformation is applied to efficiently detect surface defects in noisy and inhomogeneous steel images. The discriminant measure is designed to not only enlarge defect area but also reduce defect-free one, and then it can easily detect surface defect. The measure consists of several coefficient images and normalized energy. The efficient discriminant measure is selected by its performance evaluation. The proposed method is verified through typical steel surface images.

Discriminant measure, Steel plate, Surface Defect Detection, Wavelet transformation

1. Introduction

Steel plate is probably the most important of all metals in terms of its quantum and variety of use. The inspected surface in manual inspection is about 0.05% of the total steel surface produced. Due to high line speed, fatigue and other adverse factors, inspection process is hardly satisfactory. Thus the manual inspection process is not sufficient to guarantee defect-free surface of steel products with reasonable degree of confidence. Today, vision-based automated surface inspection systems [1,2] are produced by many reputed companies. Technology of vision-based automatic inspection of steel products, even though not 100% accurate, has matured and developed so far. Real-time inspection of steel surfaces faces a number of challenges, which may be enumerated as hazardous site, operating speed, varieties of surface defects, large number of cameras. In addition, three characteristics including noise such as low-contrast, inhomogeneous and featureless, are included in steel surface image.

In this paper, a wavelet-based discriminant measure is modelled to efficiently detect surface defects in those images. Wavelet-based methods have the advantage of better performance against noise compared to spatial domain-based methods. Further, wavelets can localise defects in spatial and frequency domain unlike purely frequency domain methods. The proposed discriminant measure performance is verified through typical surface defects images with three properties.

2. Wavelet-based discriminant measure

2.1. Wavelet transformation

Wavelet transform, a powerful tool for localized frequency analysis, decomposes an input signal into smooth and detailed parts with low- and high-pass filters on multiresolution levels. It is ideally suited for representing both spatial and frequency characteristics of steel surface images. The 1-D wavelet transform is defined as a decomposition of a signal s(t) with a family of orthonormal bases $\psi_{j,k}(\mathrm{t})$ generated from a kernel function $\psi(t)$ by dilation j and translation k as follows[3]

$$\psi_{j,k}(\mathrm{t}) = 2^{-j/2}\psi(2^{-j}t - k) \quad (1)$$

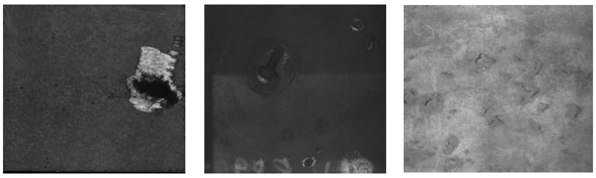
Since $\psi_{j,k}(\mathrm{t})$ forms an orthonormal set, the wavelet coefficients $a_{j,k}(\mathrm{t})$ of the signal s(t) can be calculated by the inner product in Eq. (2)

$$a_{j,k}(\mathrm{t}) = \langle \mathrm{s(t)}, \psi_{j,k}(\mathrm{t}) \rangle = \int \mathrm{s(t)} \cdot \psi_{j,k}(\mathrm{t})\, dt \quad (2)$$

The 1-D wavelet transform can be easily extended to a two-dimensional one. The 2-D wavelet decomposition of an image $\mathrm{f(x,y)}$ consists of filtering and down-sampling along the image axis using the 1-D lowpass filter and highpass filter to generated the coefficients matrices $f_l(\mathrm{x,y})$ and $f_h(\mathrm{x,y})$. For one level of decomposition, four images $f_S(\mathrm{x,y})$, $f_H(\mathrm{x,y})$, $f_V(\mathrm{x,y})$, $f_D(\mathrm{x,y})$ are generated [3].

2.2. Modelling of discriminant measure

Figure 1 shows surface defect images of steel plate, which have low-contrast, uneven and featureless properties. For those defect images, the successful defect detection method is to effectively separate defect region from defect-free one using wavelet transformation and its coefficient tuning.



(a) Scale (b) Foreign material (c) Crack
Figure 1. Surface defects of steel plate

The discriminant measure is developed to not only enlarge defect region but also reduce defect-free one. It can make easy defect detection. The proposed wavelet-based discriminant measure is modelled through following steps. The extraction of representative features of surface defect images is calculated using the normalized energy [3] of each decomposed detail sub-image within a small neighbourhood window of size $w \times w$ with $w = k + 1$ at a resolution level l.

The normalized energies of decomposed horizontal, vertical and diagonal detail sub-images are in Eg. (3).

$$E_{H,V,D}^{l}(x,y) = F_{H,V,D}^{l}(x,y) \Big/ F_{S}^{l}(x,y) \quad (3)$$

The discriminant measure is proposed for detecting defects in the steel surface images based on the normalized energy and weights at three levels. The weights in Eq. (4) are used to adjust the importance of the energy at a resolution level $l + 1$.

$$C_{H,V,D}^{l,l+1}(x,y) = 1 - \exp\left(-\Delta F_{H,V,D}^{l,l+1}\right) \quad (4)$$

Where

$$\Delta F_{H,V,D}^{l,l+1} = \frac{1}{w^2} F_{H,V,D}^{(l+1)} - \frac{1}{w^2} F_{H,V,D}^{(l)}$$

The discriminant measure is presented in Eq. (5).

$$S_i^l(x,y) = E_i^{(1)}(x,y) + C_i^{(1,2)}(x,y)E_i^{(2)}(x,y) + C_i^{(2,3)}(x,y)E_i^{(3)}(x,y) \quad (5)$$

$$i = H, V, D$$

This equation is described as 21 discriminant measures(DM) including the last one $S_{HVD}^{123}(x,y)$ in Table 1

Table 1 Calculated discriminant measures

No.	1	2	3	4	5
DM	$f(x,y)$	$S_H^1(x,y)$	$S_H^2(x,y)$	$S_H^3(x,y)$	$S_V^1(x,y)$
No.	6	7	8	9	10
DM	$S_V^2(x,y)$	$S_V^3(x,y)$	$S_H^{12}(x,y)$	$S_H^{123}(x,y)$	$S_V^{12}(x,y)$
No.	11	12	13	14	15
DM	$S_V^{123}(x,y)$	$S_{HV}^1(x,y)$	$S_{HV}^2(x,y)$	$S_{HV}^3(x,y)$	$S_{HV}^{12}(x,y)$
No.	16	17	18	19	20
DM	$S_{HV}^{23}(x,y)$	$S_{HV}^{123}(x,y)$	$S_{HVD}^1(x,y)$	$S_{HVD}^2(x,y)$	$S_{HVD}^3(x,y)$

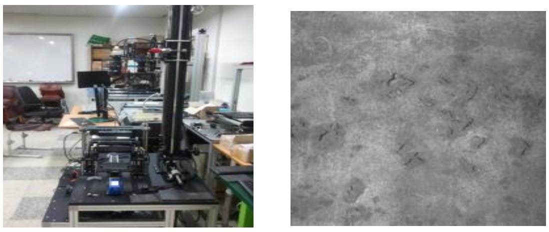
In this paper, the efficient discriminant measure is determined by the evaluation function(EF) presented in Eq. (6).

$$EF = \frac{\mu_d}{\mu_{df}} \quad (6)$$

Here, μ_d, μ_{df} are mean pixel values in specified defect and defect-free region, respectively. When the evaluation function is maximum, the efficient discriminant measure is regarded.

3. Experiment

Figure 2 shows experiment device and a surface defect image. A part of surface defect images calculated by 20 discriminant measures is presented in Figure 3.



(a) Experiment device (b) A defect image for crack

Figure 2. A surface defect image for crack

Figure 4 is represented using Eq. (6) and Figure 3. The discriminant measure with the maximum evaluation function value is No. 3, that is $S_H^2(x,y)$, in which horizontal feature components are considered. In case of considering both horizontal and vertical components, $S_{HV}^3(x,y)$ (No. 14) is available. The evaluation values for No. 4-5 is relatively large compared with other ones, and it means that the selected discriminant measure can effectively detect a kind of cracks

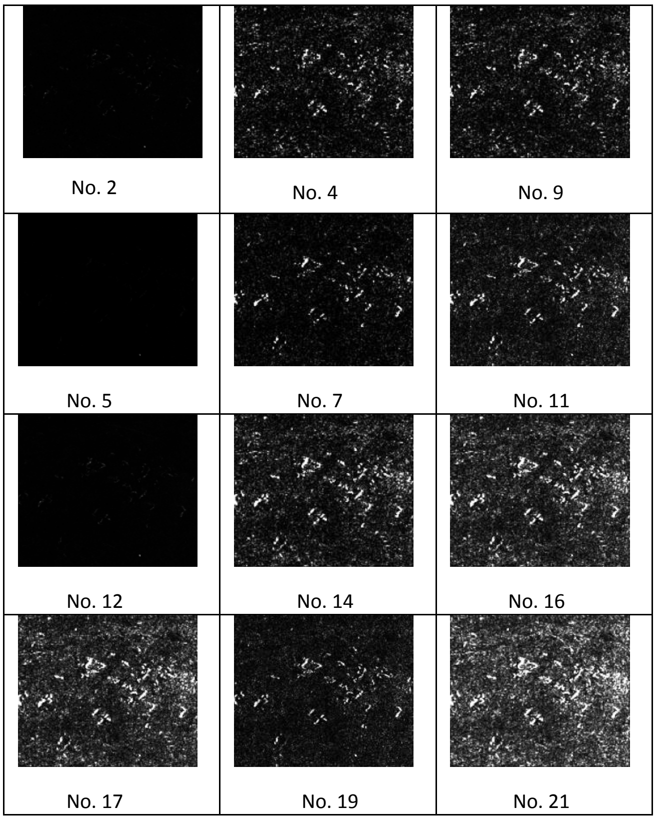


Figure 3. Surface defect images calculated by several discriminant measures

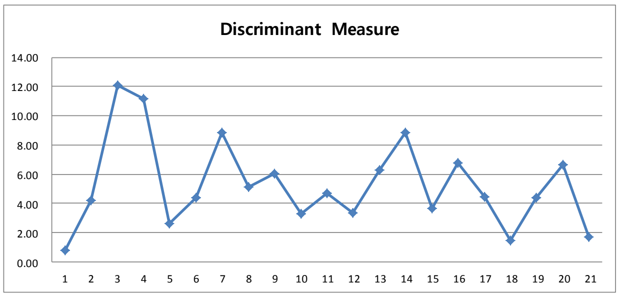


Figure 4. Evaluation function values according to 21 discriminant measures for a scab defect image

among various surface defects. In this paper, a new discriminant measure based on l wavelet transformation is proposed to efficiently detect surface defects in low-contrast, uneven, noisy and inhomogeneous steel images. The discriminant measure is selected and modelled by its performance evaluation. It is shown that the efficient proposed method gives good results for typical steel surface images

Acknowledgement

This research was supported by Basic Science Research Program through NRF funded by the Ministry of Education (2015R1D1A1A01056691)

References

[1] Nirbhar N, Dusmanta K M and Pranab K D 2014 Review of vision-based steel surface inspection systems *EURASIP Journal on Image and Video Processing* **DOI:** 10.1186/1687-5281-2014-50

[2] Chaitali T and Chitode J S 2014 Metal surface inspection for defect detection and classification using garbor filter *Int. J. of Innovative Research in Science, Engineering and Technology* **Vol.3 Issue 6** 13702-13709

[3] Wei-Chen L and Du-Ming T 2012 Wavelet-based defect detection in solar wafer images with inhomogeneous texture *Pattern Recognition* **45** 742-756