Achievements in Mechanical and Materials Engineering

COMMENT Worldwide Congress on Materials and Manufacturing Engineering and Technology

16th - 19th May 2005 Gliwice-Wisla, Poland

COMMITTEE OF MATERIALS SCIENCE OF THE POLISH ACADEMY OF SCIENCES, KATOWICE, POLAND
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ASSOCIATION OF THE ALUMNI OF THE SILESIAN UNIVERSITY OF TECHNOLOGY, MATERIALS ENGINEERING CIRCLE, GLIWICE, POLAND

13th INTERNATIONAL SCIENTIFIC CONFERENCE
ON ACHIEVEMENTS IN MECHANICAL AND MATERIALS ENGINEERING

A problem of emphasizing features of a surface roughness by means the Discrete Wavelet Transform

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Abstract: When we are interested to the detection of the roughness features by means the 3-D reconstruction, based on photometric stereo techniques, an important problem is the elimination of the brightness variation due to different light conditions which can alter the response.

This paper will concentrate on presenting results of a new method for eliminating this problem. In this work we will show how the application of the Discrete Wavelet Transform (DWT) to the processing of some images, captured on different light conditions, permits to solve the problem of emphasizing roughness features of a metallic surface.

Here we propose, also, a non-parametric method, based on the wavelet theory, for the estimation of the threshold level of a gray levels distribution, obtained from the intensity image matrix.

Keywords: Image processing, Surface roughness, Wavelet transform, Optimum threshold.

1. INTRODUCTION

The study of criteria for evaluating the surface roughness represents, to day, one of the most important problem for the production of some critical mechanical organs in order to confer them some specific and functional characteristics. For that reason many authors consider the roughness as the fourth dimension of the design.

Since, in many cases, the roughness determines the level of brightness of a metallic surface, its reflectance can be studied by a specific model, based on some hypotheses and solving the image irradiance equation using some algorithms [1] and [2].

In this paper we will show a new method of image processing for emphasizing the features of a surface roughness, captured on different light conditions. It is based on the properties of the Wavelet Transform to detect the presence of details which, usually, are loss when we apply to the signal a filtering process in order to reduce the noise.

2. A TREDSHOLD ESTIMATOR BASED ON HAAR WAVELET

We follow an approach similar to [10].

Let X1, X2,…, XN be N independent identically distributed random variables whose density (unknown) is f(x). In this case, a wavelet estimator of f is given by [11] and [12].

$$\hat{f} = \sum_{k} \hat{a}_{j_{0k}} \varphi_{j_0 k}(x) + \sum_{j=j_0}^{j_1} \sum_{k} \hat{b}_{jk} \psi_{jk}(x), \tag{1}$$

where $j_0, j_1 \in \mathbf{Z}$,

$$\hat{a}_{j_0 k} = \frac{1}{N} \sum_{i=1}^{N} \varphi_{j_0 k}(X_i), \qquad \hat{b}_{jk} = \frac{1}{N} \sum_{i=1}^{N} \psi_{j\,k}(X_i),$$

$\varphi_{jk}(x) = 2^{j/2} \varphi(2^j x - k), k \in \mathbf{Z},$ and $\psi_{jk}(x) = 2^{j/2} \psi(2^j x - k), k \in \mathbf{Z}$.

Finally, $\psi(x)$ is a function (mother wavelet) whose first $h (h \in \mathbf{N})$ moments are zero and $\varphi(x)$ is a function (father wavelet) orthonormal to $\psi(x)$, according to the L^2 norm. In our work we choose :

$$\varphi(x) = \begin{cases} 1, x \in (0,1] \\ 0, x \notin (0,1] \end{cases} \quad \text{and} \quad \psi(x) = \begin{cases} -1, x \in \left[0, \frac{1}{2}\right] \\ 1, x \in \left(\frac{1}{2}, 1\right] \\ 0, x \notin [0,1] \end{cases}$$

They are called Haar Wavelets. It is easy to prove that, if $\psi(x)$ is a mother wavelet, then also $\psi_{j,k}$ is a mother wavelet.

Figures should be presented as in Figure 1. They should be clearly displayed by leaving at last single line of spacing above and below them.

3. APPLICATION OF DWT AND RESULTS

The Fig. 1 shows the images of the same metallic test piece captured on different light conditions. It is evident the difference of brightness caused by the position of the lamp. The images are converted into intensity matrix containing the values in the range 0 (black) to 1 (full intensity or white) (Fig. 2a and Fig. 2b).

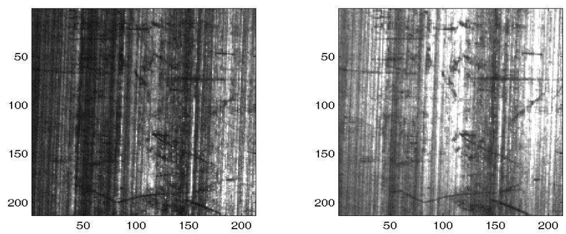

Figure 1. Image of surface roughness of the same metallic test piece obtained on different light conditions

The evidence of prevalence of darkness on the first image (left) with respect to the second one (right) is illustrated by comparing their histograms bar plot of gray levels.

Since exists a large difference in brightness level for the same image it would be difficult to base a quantitative measure of surface roughness on such data by means the 3-D reconstruction by photometric stereo techniques.

The shape of the curves referred to the approxmation coefficients, in terms of qualitative response, is quite similar, while, in terms of entropy, a common concept in many fields, mainly in signal processing [16], is more different: 24.0990 and 54.9523 respectively for the first (left) and the second (right) image.

The improvement of the response obtained by choosing a good thresholding level is illustrated in the Fig.5 and Fig. 6, where the value of the entropy is of 48.5104 and 48.3762 respectively for the first (left) and the second (right) image.

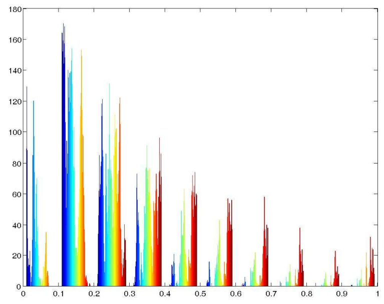

Figure 2a. Gray levels histogram referred to the first image (left).

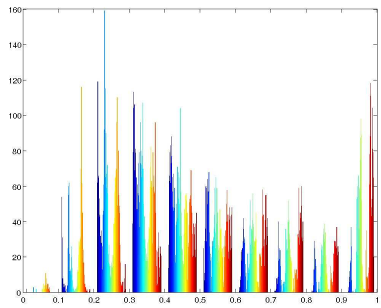

Figure 2b. Gray levels histogram referred to the second image (right)

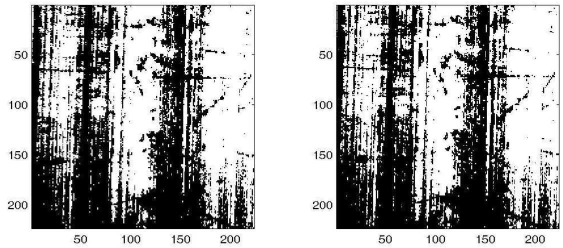

Figure 5. An example of the better performance obtained with DWT

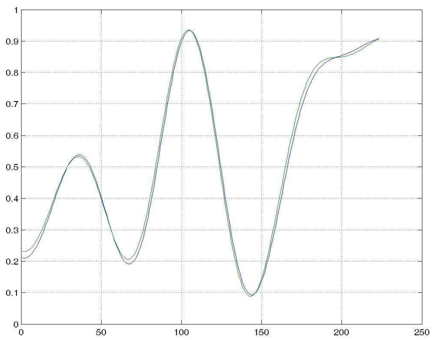

Figure. 6 Grand average of the approximation coefficients calculated on images of Fig. 5

4. CONCLUSION

It was discovered that the brightness of a metallic surface produces disturbances of two types. The first type consists of the high-frequency oscillations which determine the main features of the processed image. The second type consists of relatively low-frequency oscillations which are associated with the energy content of the image as well as his entropy. Both the information are useful for detecting the resolution in terms of denoising and enhancement of the image.

The preliminary results demonstrate that the signals obtained from the images can be decomposed into a finite set of distinct crests without any loss of overall information, when averaged across all signals. The crest detection method has generated a set of peaks that are characterised by position, scale and amplitude. This allows them to be analysed in more refined ways than just the usual methods and , of course, it assumes that the method used in this paper represents the first step in order to eliminate the error due to the brightness influence to measure the surface roughness.

In this manner the progress of metal machining, grinding and polishing operations can be monitored, in real time, until the desired surface finish is achieved.

ACKNOWLEDGEMENT

We are grateful to Dr. Roberto Fusco for the computing support.

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