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QUALITIVE SURFACE ROUGHNESS EVALUATION USING HARALICK FEATURES AND WAVELET TRANSFORM

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Abstract: *The research presented in this paper is aimed at the development of an automated vision system for classification of surface finish in turning parts. Haralick features in the frequency domain have been used to characterize finish roughness of metallic parts by means of the wavelet transform. First, the wavelet transform was applied to two sets of images, one belonging to parts with low roughness and other belonging to parts with high roughness. Haralick features were worked out for the image description. Then, a classification was performed using knn. Others simple and based on moment features were also calculated to compare the results against Haralick features.*
Key words: *surface roughness, quality inspection, machine vision, wavelet transform, texture features*

1. INTRODUCTION

The quality of surface roughness is one of the most important tasks of the manufacturing industry. An automated system with low costs and high speed is needed for surface inspection and quality control. This led to many researchers to pay attention to computer vision techniques for solving this problem. The use of computer vision techniques for monitoring of machining operations has proved (Lee et al., 2002; Castejón et al., 2007; Barreiro et al., 2008a) an important reduction in the cycle time and the required resources.

Traditionally the image analysis has been applied in the spatial domain, but nowadays many authors work in the frequency domain. The most common techniques for texture analysis are Fourier Transform, Gabor Filter Banks and Wavelet Transform.

(Grzesik & Brol, 2009) proved that the wavelet transform can be used for the analysis of roughness profile. (Arivazhagan & Ganesan, 2003) carried out a texture classification using wavelet statistical features, wavelet co-occurrence features and a combination of wavelet statistical features and co-occurrence features of one level wavelet transformed images with different feature databases. (Hiremath & Shivashankar, 2008) proposed a texture feature extraction method based on the co-occurrence histograms of wavelet decomposed images, which capture the information about relationships between each high frequency subband and that in low frequency subband of the transformed image at the corresponding level. (Latif-Ameta et al., 2000) developed a visual inspection system of textile products by an algorithm based on wavelet transforms and co-occurrence matrices.

In the present paper Haralick features, based in the co-occurrence matrix, have been calculated on wavelet sub-images for the texture analysis of images. The goal is develop an automated system which evaluates the finish roughness for quality inspection in parts machined by turning.

2. MATERIALS AND METHODS

2.1 Description of machining tests

Test parts were of AISI 6150 steel. A MUPEM CNC multi–turret parallel lathe —ICIAR/1/42 model— was used for the machining of parts. Cutting tools were coated carbide inserts TNMG 160408PM GC4035 from Sandvik. The covering quality of this insert was chosen in such a way that the tool wear rate were relatively high to accelerate the machining tests. Dimensions of stocks were 40 mm diameter and 60 mm length. The stocks were turned until 25 mm of diameter with 5 passes.

2.2 Image acquisition

The images of parts were captured using an AVT Oscar F-810C camera. The part was positioned over a 'V'- shape support. The lighting system provided diffuse illumination in the camera axis and was composed by a FOSTEC regulated light source DCR RIII.A NER SCDI-25-F0 diffuse illumination SCDI system was used to avoid shines. A Matrox Meteor II frame grabber card was used to digitize the images. The optic assembly was composed of an OPTEM industrial zoom 70XL, with an extension tube of 1X and 0.5X/0.75X/1.5X/2.0X OPTEM lens. A 2X magnification was used.

Eight images were captured for each part, obtaining a total of 3960 images. Each image was labeled with its correspondent Ra roughness value measured with the perthometer, calculated as the median of three repeated Ra measuring. Roughness values were in a wide range between 0.89 and 21.29 μm, depending on the machining parameters used.

The whole set of images was divided in two subsets, one containing 100 images of parts with acceptable values of roughness and another subset containing 100 images of parts with unacceptable values of roughness, that is, the two subsets constitutes the two ends of the spectrum of data. The image resolution is 3272x1600 pixels.

3. IMAGE PROCESSING AND FEATURE EXTRACTION METHODS

A vertical Prewitt high pass filter was applied to the complete set of images in order to enhance contrast and make easier the description of roughness (see Fig.1). This filtering was applied because in previous works (Barreiro et al., 2008b) it resulted useful for the interpretation process. However, in this work the result was not enough good.

A wavelet transform of type 'Haar' and one level of decomposition was applied to the two sets of images. Four sub-images were obtained from the wavelet coefficients of approximation, horizontal, vertical and diagonal details. With these sub-images and the original ones Haralick features were calculated from the Gray Level Co-occcurrence Matrix (GLCM) which stores the relative frequencies of gray level pairs of pixels separated by a distance d in the direction θ.

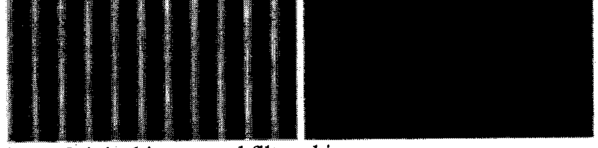

Fig. 1. Original image and filtered image

Contrast, correlation, energy and homogeneity		14 Haralick features	
Values of k	Global error (%)	Values of k	Global error (%)
1	13	1	30
3	10	3	39
5	12	5	38
7	12	7	35
9	10	9	32

Tab. 1. Error rates of four features of Haralick

Descriptor	Global error knn (%)
Moments of Hu	13
Moments of Flusser	40
Legendre moments	9
Moments of Taubin	42
Moments of Zernike	6.5

Tab. 2. Error rates of features based on moments

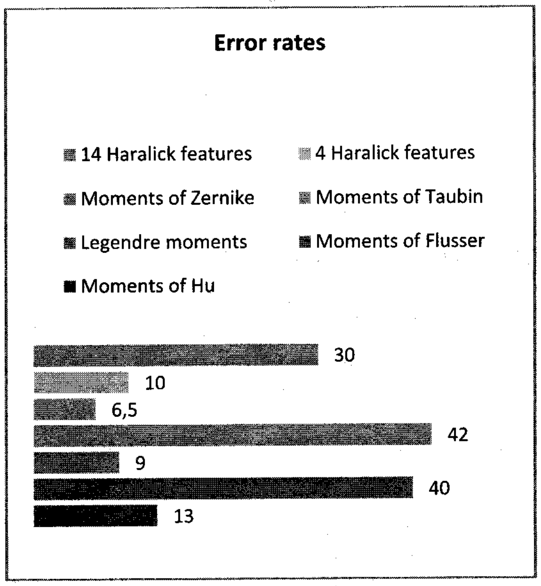

Fig. 2. Summary of error rates for all descriptors

Also five feature vectors based on moments were worked out for the images: moments of Hu, moments of Flusser, invariant moments of Taubin, invariant moments of Zernike and Legendre moments.

To compare these features and measure their validity, a description by first order statistics was achieved with a feature vector formed by mean, standard deviation, skewness and kurtosis from another set of finish roughness images under coaxial, angular and lateral illumination.

4. CLASSIFICATION METHODS

The former feature vectors were classified by k-nn algorithm. The method of validation is a 'leave-one-out' cross-validation for k-nn classification. By means of the feature vectors the algorithm had to differentiate between images from parts with low roughness (good quality) and images from parts with high roughness (bad quality).

5. RESULTS

Tab. 1 shows the results obtained by applying the four features of Haralick (contrast, correlation, energy and homogeneity) in the frequency domain to the prepocessing images and the four sub-images corresponding to the wavelets coefficients. This table also shows the error rates obtained when the fourteen features of Haralick are used for the image description.

The classification with the features based on moments gave the results summarized in tab. 2.

6. CONCLUSIONS

This paper proposes a method to perform a quality test on the roughness of metallic turning parts. The performance of three different sets of descriptors was analyzed, one based on Haralick features of sub-images from wavelet transformation, other based on features based of moments and the last one based on first order statistic features. Filtered images provided worse description of the images. The contrast, correlation, energy and homogeneity descriptor presented better results than the fourteen Haralick features. Moments of Zernike and Legendre moments provided a good description of the surface finish images.

Future works will analyze the performance of other descriptors in the frequency domain based on the wavelet transform and Gabor Filters Banks.

The obtained results show that it is feasible to use texture descriptors to evaluate roughness of metallic parts in the context of product quality.

7. ACKNOWLEDMENTS

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