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Defect Detection of Tiles Using 2D-Wavelet Transform and Statistical Features

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***Abstract*—**In this article, a method has been offered to classify normal and defective tiles using wavelet transform and artificial neural networks. The proposed algorithm calculates max and min medians as well as the standard deviation and average of detail images obtained from wavelet filters, then comes by feature vectors and attempts to classify the given tile using a Perceptron neural network with a single hidden layer. In this study along with the proposal of using median of optimum points as the basic feature and its comparison with the rest of the statistical features in the wavelet field, the relational advantages of Haar wavelet is investigated. This method has been experimented on a number of various tile designs and in average, it has been valid for over 90% of the cases. Amongst the other advantages, high speed and low calculating load are prominent.

***Keywords*—**Defect detection, tile and ceramic quality inspection, wavelet transform, classification, neural networks, statistical features.

I. INTRODUCTION

TODAY thanks to advances in the machine visions and hardware, monitoring and classification process of industrial products can be performed automatically using digital high speed hardware and intelligent software. In the tile and ceramic industry it is possible that some different defects are appeared in tiles over different stages of the production line. Some defects such as deflection or error in size will be easily detectable by certain automatic systems. However, some other defects including those of color, dump, projections, pin holes and notches, and stains and cracks are largely detected by human operators that due to routine and wearing process of quality controlling by means of eyes will lack the needed precision more or less.

Since this issue involves different aspects and applications of machine vision, pattern recognition, and image processing, it has recently taken a large amount of work and experiments to deal with. Some of them have taken advantage of image detection, image enhancement; color segmentation, shape analysis, feature extraction, and clustering.

For example, Monadjemi et al. [3] have proposed a method based on special filters which do classification with high accuracy and precision. It does not also need a large number of defected tiles to get result while reduces the training stage as well. In [1] reflective detection has been used to detect reflective surface defects by which a large number of surface defects can be detected on tiles. But this method is not able to detect some defects including print shapes and color spectrum.

In recent decade, multi-precious techniques such as wavelet transform and Gabor[4] have been used largely for structure and texture analysis. Despite wavelet transform that uses fixed filter parameters for analyzing image in different scales, Gabor transform demands appropriate adjustments of filter parameters in different scales. References [5-13] include different methods for defect detection and classification of different textual images based on wavelet transform and texture features, using co-occurrence matrices of detail images and approximation resulted from wavelet transform and similar methods. Reference [2] used light fluctuation of the tile with aid of 2-dimensional wavelet transform to detect high contrast defects of the tiles in which with consideration to histogram diagram and definition of a threshold surface and its application on the image, defects in the tile is detected.

Rimak. et al [14] proposed a method for ceramic defect detection based on wavelet transform and probable neural network with radial basis. They have segmented image of tile into at least two parts and for each segment have created a neural network. Vector of used features includes max of details coefficients in three points and average of approximation coefficient resulted from wavelet transform. The advantage of this method is the small size of its features vector while its disadvantage is using at least two neural networks for classification.

In this study a viable algorithm with high precision and low calculating load was proposed to classify intact from defected tiles using wavelet transform and its combination with statistical features of resulted images and using a Perceptron neural network. Second part involves a review of wavelet transform and proposed algorithm for features deduction. The result appears in part three and finally part five concludes the article.

II. WAVELET TRANSFORM

In a kind of wavelet transform used in this study, the transform uses two filter sets of high pass and low pass and applies them on the given signal (image) in some layers. As the image crosses theses filters for the first time, four new images are acquired; approximation (result of the low pass filter), details in horizontal point, details in vertical point, and details in diameter. In order to calculate wavelet coefficients

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in two layers (scales), for second time the approximated image from previous stage should be transmitted from those filters. This process can be also repeated for the rest of scales. In each wavelet transform application, the dimensions of resulted image cut into two halves. Figure 1 shows image of a tile along with approximation images and horizontal, vertical, and diameter details after wavelet transform in a scale with Haar wavelet has been applied.

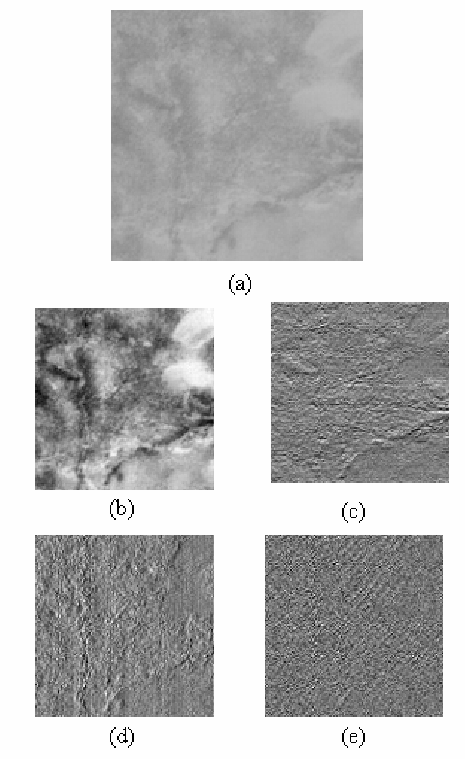

Fig. 1 (a)a defect tile. and its wavelet decomposition (b)approximation (c)horizontal details (d)vertical details (e)diagonal details

After tile images were provided, wavelet transform filters were applied on the image to deduct vector of image features and three details matrices (image) were obtained in three different points as well as an approximation matrix. Wavelet transform of an image, measures light fluctuation in different scales. Wavelet coefficients in edges of image structures turn max because of improvement in local contrast. Therefore, max points of details coefficients can be used as an index for probable errors [14]. To avoid segmentation of the image and to decrease calculation load, median of max points was calculated. Also to increase sensitivity and precision, median of each image min was calculated along with average and standard deviation of approximation matrix as well as standard deviation of details matrices and then was added to image features. The mentioned method for determining features vector is demonstrated in figure 2.

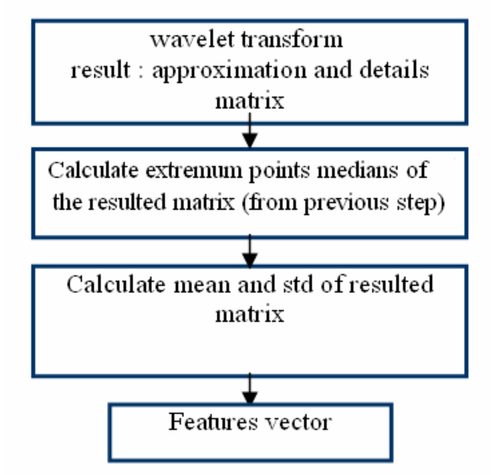

Fig. 2 Proposed algorithm for features vector extraction using wavelet transform

III. RESULTS AND EXPRIMENTS

The used database involves about 200 images from 5 different pattern of tiles in 256x256 sizes and the number of intact and defected tile images is equal in each design. An image from each tile sample is shown in fig 3.

The total tiles of each design were divided in 5 sects and vector of all images features was calculated. Finally a Perceptron neural network with a medial layer and 3 neurons was used for classification and features vector was fed into this network. To increase precision and not to let a lot of training samples, k-folding [15] method with k=5 was used. The process was in this way that each time 80% of images were selected as training set and the reminder 20% for testing the network.

To assess the result of this algorithm, 4 criteria of precision, accuracy, specificity, and sensitivity defined in table 1 were used. The number of True positives (T.P.) and true negatives (T.N.) respectively shows the number of intact or defected samples classified correctly. Instead false Positives (F.P.) represents the number of defected samples that are classified falsely as intact samples. Also the number of False Negatives (F.N.) equals the number of intact samples classified falsely as defected ones. SPC shows accuracy across intact (positive) samples.

TABLE I
PERFORMANCE EVALUATION CRITERIA

CRITERION	DESCRIPTION
Sensitivity(SNS)	T.P./ Total positives
Specifity(SPC)	T.N./ Total Negatives
Precision(Prec.)	T.P./ (T. P.+ F. P.)
Accuracy(Acc.)	(T.P.+T.N.)/ Total samples

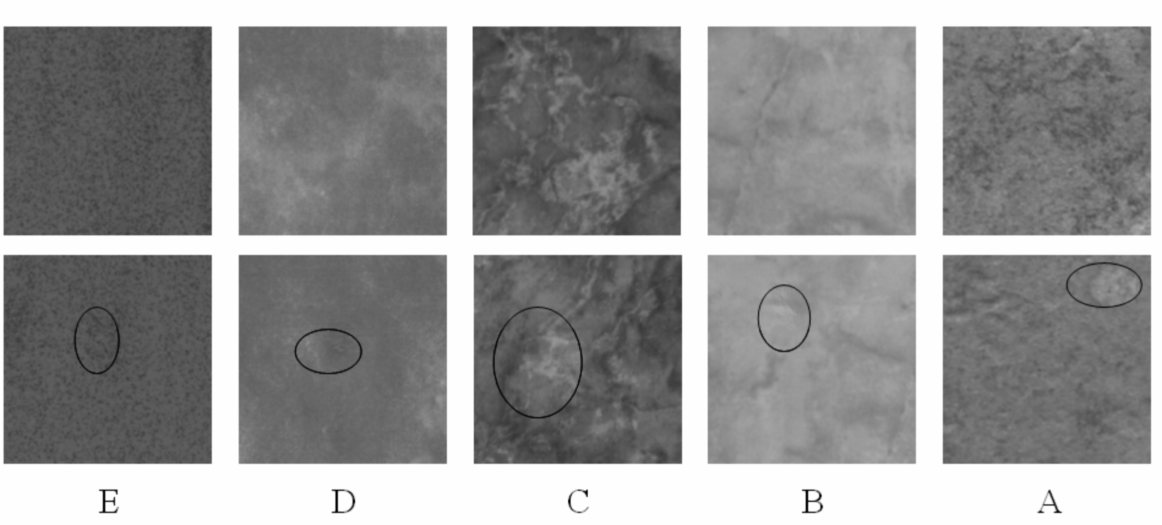

Fig. 3 Five types of experimented tiles: top(normal), down(defect)

In other words, it determines how well the classifier detects defected samples.

Finally standard averages of 5 kinds of tiles were calculated to give a view of general quality of classification system. The result from application of this algorithm on some of different tile designs has been assessed with mentioned standards and is revealed in table 2. Experiments with some different wavelets revealed that Haar wavelet gives better results. Haar wavelet is the oldest and simplest orthonormal wavelet which is prominent in terms of memory consumption and despite other wavelets, without any influence of edge, is completely recursive. Harr wavelet does not possess overlap windows and only reflects the changes between two adjacent pixels. Also since it uses just two scales and wavelet, it calculates average and difference of a pair.

As it is shown in above table, tiles sorted as A are classified at best with accuracy of 100% and tiles sorted as C at worst with accuracy of 80%. Specificity parameter (SPC) which represents probable good function of classifier is 95% in average that is totally acceptable. In different experiments with neuron numbers of 3, 5, 10, and 15 in medial layer, it was revealed that increase in number of neurons does not improve response of network. Therefore, considering small number of training samples, using three neurons in medial layer is sufficient that in turn speeds up network training stage.

TABLE II
PERFORMANCE OF PROPOSED ALGORITHM

type	%Spc.	%SNS.	%Prec.	%ACC
A	100	100	100	100
B	100	68.75	100	84.38
C	80	80	80	80
D	95	90	94.74	92.5
E	100	81.25	100	90.63
Average	95	84	95	90

IV. CONCLUSION

In this article a new method for classifying defective and normal randomly textured tiles was proposed. In this method, a 2-dimensional wavelet transform is applied on the initial image and then features such as median of max and min points and the standard deviation of each detail image resulted from the wavelet is deducted. Then a small Perceptron neural network is used to classify the normal and defective tiles. This method has a low computing load compared to the prior methods and it has very high speed and precision since it uses discrete wavelet transform in one level and not a pixel-to-pixel procedures. It also is rotation invariant. Experiments on some various wavelets also revealed that the Haar wavelet shows better results and higher speeds compared the other tested wavelets. In case of some complicated designs or materials with complicated textures, it may be effective to use higher scale levels in the applied wavelet analysis. It seems that applying this method, on other data sets or problems can also be useful and effective.

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