CERAMIC TILES QUALITY INSPECTION USING STATISTICAL METHODS AND NEURAL NETWORKS APPROACH

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Abstract:

The image processing described in this paper is used for visual quality inspection in ceramic tile production. The tiles surface quality depends on the surface defects and has the influence to the tile quality classification. The described image processing is based on the neural network approach. The described diagnostic algorithm is presented to detect surface failures on white ceramic tiles. The tiles are scanned and the digital images are pre-processed and classified using neural networks. Pre-processing of the image data is used to keep the number of inputs of the neural networks performing the classification relatively small. It is important to reduce the amount of input data with problem specific pre-processing. Statistical methods are used in the pre-proccesing of the image data. For classification purposes, a probabilistic neural network and a standard feedfoward neural network are used and the results obtained are compared. The analysis of the detection capabilities is done also. Simulation was performed in Matlab using the Neural Network Toolbox. The results obtained were satisfactory considering the fact that the images were scanned under the normal conditions using an ordinary scanner. The developing and testing of this method is used for early design of the computer aided visual control.

Keywords: *image processing, multilayer feedforward neural networks, statistical methods, probabilistic neural networks, ceramic tiles, quality inspection*

1. INTRODUCTION

The surface quality of ceramic tiles is described by the surface defects and the intentional effects such as cracs, crazing, dry spots, pin hole, glaze devitrification, blister, etc. On-line testing of the surface defects is done at the tile factory by the visual testing performed by workers. This way of testing is liable to mistakes produced by human errors and subjectivity. Therefore the visual quality testing should be done more objectively by machine vision [1]. The image processing methods are developed for this purpose. Using the singular value decomposition (SVD) of the matrix of variations of the original image makes the image comparison duration shorter. The number of computer operations decreases by using SVD approximation by a lower rank matrix. But the too low rank of the matrix could yield bad comparison results [2].

The another method using the discrete wavelet transform - DWT was also used in failure detection [3]. To achieve robustness as well as good sensitivity of the algorithm, the images were divided into the segments. The analysis of detection capabilities is done for different segment sizes, different detection sensitivity levels - DSL and for two orthogonal wavelets. Furthermore, we investigated the influence of different wavelets to the diagnostic results and we found out that short wavelets are suitable for analysis (such as the Haar wavelet) and the optimal DSL depends on the wavelet too [4]. For the plain surfaces DSL has to be chosen depending on the visibility of the failure. The proposed algorithm could be used not just for detection but also for the classification of the tiles, so that our further research is planned to be carried out in that direction. [5][6]

So we tried to find the better method which is described in this paper. In the image processing neural networks are used increasingly. The main application in this case is the classification of images. With the algorithm described here, errors on ceramic tile surfaces can be detected. The neural networks are based on replicating the functions and structure of the human/animal brain. The neural networks are able to make decisions that are similar to the human inference after a training period with several examples and the output desired for each example. They can be used for prognosis of complex situations, intelligent controlling or robot operation and recognition of object [7]. In this project an Multilayer Feedforward Neural Network is used for feature generation and selection and the results are compared with those produced by the Probabilistic Neural Network.

2. NEURAL NETWORKS IN IMAGE PROCESSING AND CLASSIFICATION

With the help of neural networks an error classification could be realised if the system is trained to make the correct decisions. For the use of neural networks it is always important to have knowledge about the input data. In the image processing, the enormous amount of data are another problem for the use of neural networks. In the case of large networks, an enormous number of connections have to be handled. The number of connections controls the necessary amount of memory for the network and the calculation time and therefore the amount of data and the calculation time could be extremely high [8].

2.1 Feature Generation

In order to make the classification process easier, the amount of input data has to be reduced. It is necessary to get rid of redundant information in the images. This is done by generating appropriate and relevant features from the pictures during the preprocessing stage. Due to the fact that it was neccessary to detect errors on the same type of tiles (white tiles to be exact), only the first order statistics of the image histogram is used. It is important to note that the different images could give similar image histograms and give the same results. However

during the tile classification on the production line, only the same type of tiles are classified on the same production line, so that such one situation will never arise.
The first order histogram *H(I)* is defined as:

$$P(I) = \frac{number\ of\ \ pixels\ with\ gray\ level\ I}{total\ number\ of\ \ pixels\ in\ the\ region} \tag{1}$$

where I is a random variable representing the the gray levels in the image. Based on the equation (1) the following quantities are defined:

Moments: $$m_i = E\left[I^i\right] = \sum_{I=0}^{N_g-1} I^i \cdot P(I), \quad i = 1,2,\ldots \tag{2}$$

Central moments: $$\mu_i = E\left[(I - E[I])^i\right] = \sum_{I=0}^{N_g-1} (I - m_1)^i \cdot P(I), \quad i = 1,2,\ldots \tag{3}$$

N_g represents the number of possible gray levels in the image. The moment $m_1=E[I]$ represents the mean or average value of I, whereas the central moments μ_2, μ_3 and μ_4 are also referred to as the variance, the skewness and the kurtosis respectively.

The measure of histogram uniformity or entropy can also be obtained from the first-order histogram [9]:

$$H = -E[\log_2 P(I)] = -\sum_{I=0}^{N_g-1} P(I) \cdot \log_2 P(I) \tag{4}$$

For each image, the generated features were the moments (m_i, i=1,2), central moments (μ_i, i=1,2,3,4) and entropy, H. The maximum of 7 input values were used for classification purposes. Due to the different data range of the input values the scaling of the input was neccessary before the data were introduced to the neural network.

2.2 Quality Classification.

The artificial neural networks were used for the classification purposes. The standard Multilayer Feedforward Neural Network with one hidden layer was used and the results obtained were compared with those produced by the Probabilistic Neural Network. The Probabilistic Neural Network consists of two layers. When an input is presented, the first layer computes distances from the input vector and the training input vectors, and produces a vector whose elements indicate how close is some input to the training input. The second layer sums these contributions for each class of inputs to produce as its net output a vector of probabilities. Finally, a complete transfer function on the output of the second layer picks the maximum of these probabilities, and produces the value 1 for that class and the value 0 for the other classes.

3. PROCESSING STAGES

The processing stages are described on Fig.1. The total number of 105 white tiles were taken from the production line after inspection. Five of them were classified as good tiles, while 100 tiles were classified as defective. The grey scale digital images of the tiles were then acquired using a colour scanner having a spatial resolution of 150 dpi. The features generated from the digital image then served as the input to the neural network where they were classified.

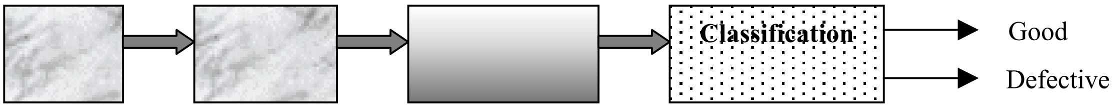

Figure 1. The processing stages

4. EXPERIMENTAL RESULTS

The simulation was performed in Matlab using the Neural Network Toolbox. Two good tiles and 25 defective tiles were chosen at random and used to train the Multilayer FeedFoward Neural Network (FFNN). The same tiles were also used in defining the Probabilistic Neural Network (PNN). The trained neural networks were then used to classify the remaining tiles. The best results obtained are shown in the table below.

Table 1. The classification results

		Good Tiles (5)	Defective Tiles (100)
Number of tiles correctly classified	FFNN	4	93
	PNN	3	97
Number of tiles wrongly classified	FFNN	1	7
	PNN	2	3

The Multilayer FeedFoward Neural Network had a better capabilty of detecting good tiles while the Probabilistic Neural Network proved better in detecting the defective tiles (Figure 2.). Increasing the number of inputs (features) did not show increase in classification performance, rather the classification performance of the Multilayer FeedFoward Neural Network was noticed to deteriorate (Figure 3.).

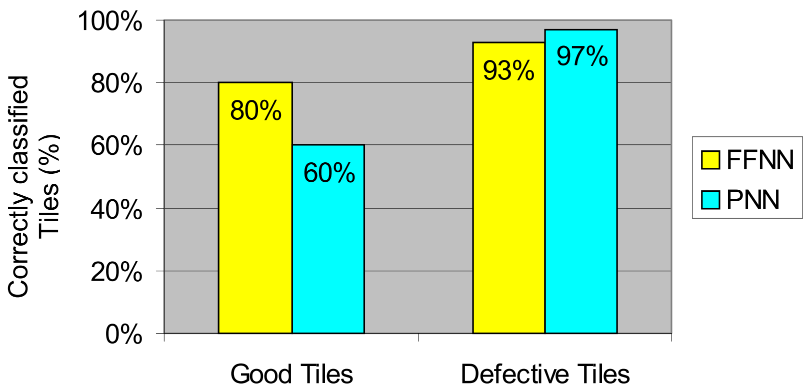

Figure 2. The results of classification using 4 features.

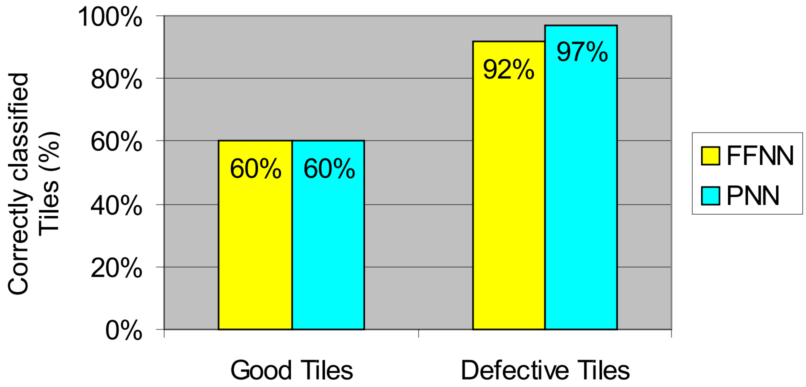

Figure 3. Results of classification using 7 features.

5. CONCLUSION

The image processing described in this paper is used for visual quality inspection in ceramic tile production. The visual quality testing is used to be more objectively by machine vision than the human eye. The described image processing is based on the neural networks approach. The described diagnostic algorithm is presented to detect the surface failures on the white ceramic tiles. The pre-processing of the image data is used to keep the number of inputs of the neural networks performing the classification relatively small. The simulation was performed in Matlab using the Neural Networks Toolbox. The algorithm is evaluated experimentally using the real tile images. The analysis of the detection capabilities and sensitivity expressed in non-detected failures and false proclaimed defect is done also. The Multilayer Feedforward Neural Network had a better capabilty of detecting good tiles while the Probabilistic Neural Network proved better in detecting the defective tiles. Increase in the number of inputs (features) did not show any increase in the classification performance rather the classification performance of the Multilayer FeedFoward Neural Network was noticed to deteriorate. The developing and testing of this method is used for early design of the computer aided visual control. It is necessary to continue the experiments with pattern tiles.

6. REFERENCES

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