A Survey on Various Defect Detection

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***Abstract*— Ceramic tiles having great demands in the field of infrastructure and building development because of its affordable cost, easy installation, maintenance, moisture resistant property and comes in a wide variety of colors, textures, and sizes so it's a good option for many environments. However this required large volume production which is performed by automated plants which generates thousands of tiles per segments. Visual inspection is an important part of quality control in industry. In decades ago, this job has been heavily relied upon manual inspection by human inspectors. Defect detection using manual inspection of an object is not a reliable approach because of fatigue and inattentiveness of an inspector. This manual inspection system has been replaced by automated visual inspection systems. Defect detection is a technique which is used in automated visual inspection system for quality control of the product. In this paper, we are going to review various defect detection methods to detecting the defects from different types of images which are used in automated visual Inspection System and also compare all these methods.**

***Keywords*— Automated Defect Detection, Artificial Neural Network, Automatic Visual Inspection, Gabor Filter, Wavelet Transform.**

I. INTRODUCTION

Digital imaging is a process aimed to recognize objects of interest in an image by utilizing electronic sensors and advanced computing techniques with the aim to improve image quality parameters. It contains intrinsic difficulties due to the fact that image formation is basically a many-to-one-mapping, i.e., characterization of 3-d objects can be deduced from either a single image or multiple images. Several problems associated with low-contrast images, blurred images, noisy images, image conversion to digital form, transmission, handling, manipulation, and storage of large-volume images, led to the development of efficient image processing and recognition algorithms. Digital imaging or computer vision involves image processing and pattern recognition. Image processing techniques deal with image enhancement, manipulation, and analysis of images. The advantages of digital imaging are shown in Table 1.

Table 1: Advantages of Digital Imaging

Accurate data acquisition
Better combination of spatial and contrast resolution
No degradation with time or copying
Compact storage/easy retrieval
Data correction/manipulation/enhancement
Fast accurate image transmission

Digital image processing methods arise from two principal application areas:

a) improvement of image content for human interpretation and processing, and

b) processing of scene data for machine perception.

Some of their image processing methods include:

i) digitization and compression
ii) enhancement, restoration, and reconstruction, and
iii) matching, description, and recognition.

On the other hand, pattern recognition deals with object identification from observed pattern and images. In the last few years, significant advances have been made in pattern recognition, through the use of several new types of computer architectures that utilize very large-scale integrated circuits (VLSI) and solid state memories with a variety of parallel high-speed computers, optical and opto-digital computers, as well as a variety of neural network architectures and implementations.

Artificial neural networks have shown great strength in solving problems that are not governed by rules, or in which traditional techniques have failed or proved inadequate. The inherent parallel architecture and the fault tolerant nature of the ANN is maximally utilized to address problems in variety of application areas relation to the imaging field.

Artificial neural networks find their application in pattern recognition (classification, clustering, feature selection), texture analysis, segmentation, image compression, color representation and several other aspects of image processing with applications in medical imaging, remote sensing, aerospace, radars, and military applications.

Artificial neural network (ANNs) is programs designed to solve any problem by trying to mimic structure & function of our nervous system. Neural network are based on simulated neurons. Which are joined together in a variety of ways to form networks. Neural network resembles the human brain in the following two ways:-

- A neural network acquires knowledge through learning.
- A neural network's knowledge is stored within the interconnection strengths known as synaptic weight.

Neural network are typically organized in layers. Layers are made up of a number of interconnected 'nodes', which contain an 'activation function'. Patterns are presented to the network via the 'input layer', which communicates to one or more 'hidden layers' where the actual presenting is done via a system of weighted 'connections'. The hidden layer then link to an ‘output layer’ where the answer is output as shown in the graphic below in fig.1.

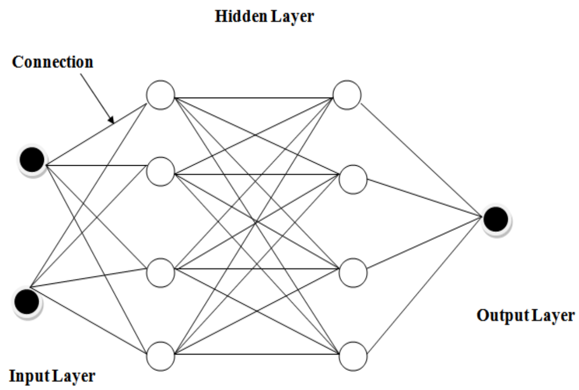

Fig.1 Basic structure of Neural network

Each layer of neural makes independent computation an data that it receives & passes the result to the next layers(s). The next layer may in turn make independent computation & pass data further or it may end the computation & give the output of the overall computation. The first layer is the input layer & the last one, the output layer. The layers that are placed within these two are the middle or hidden layers.
A neural network is a system that emulates the cognitive abilities of the brain by establishing recognition of particular inputs & producing the appropriate output. Neural networks are not "hard-wired" in particular way; they are trained using presented inputs to establish their own internal weights and relationships guided by feedback. Neural networks are free to form their own internal working and adapt on their own. Commonly neural network are adjusted, or trained so that a particular input leads to a specific target output.

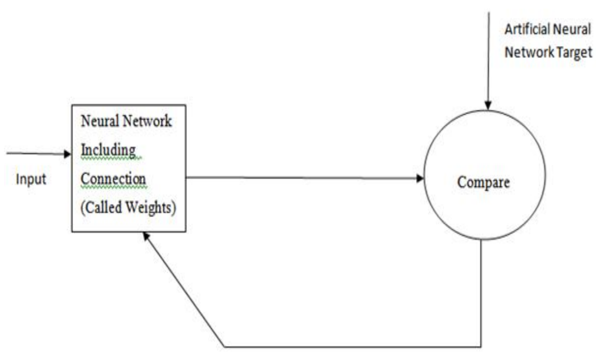

Fig.2 Adjust of neural network

There, the network is adjusted based on a comparison of the output and the target, until the network output matches the target. Typically many such input/target pairs are used to train network. Once a neural network is ‘trained’ to a satisfactory level it may be used as an analytical tool on other data. To do this the user no longer specifies any training runs and instead allows the network to work in forward propagation mode only. New inputs are presented to the input pattern where they filter into and processed by the middle layers as though training were taking place, however at this point the output is retained and no back propagation occurs.

II. Various Defect Detection Techniques:

In these sections, we review different defect detection methods that have been proposed to find out the different type of image defects. These techniques can be described briefly as follows:

In 2000, A.L Amet et al. proposed an efficient algorithm, which combines concepts from wavelet theory and co occurrence matrices, is presented for detection of defects encountered in textile images. Detection of defects within the inspected texture is performed first by decomposing the gray level images into sub-bands, then by partitioning the textured image into non-overlapping sub windows and extracting the co-occurrence features and finally by classifying each sub-window as defective or non-defective with a Mahalanobis distance classifier being trained on defect free samples a priori. The experimental results demonstrating the use of this algorithm for the visual inspection of textile products obtained from the real factory environment are also presented. Experiments show that focusing on a particular band with high discriminatory power improves the detection performance as well as increases the computational efficiency.

In 2005, H. Elbehiery et al. presented some techniques to detect the defects in the ceramic tiles. They divided their method into two parts. In the first part, Existing method consisted with the captured images of tiles as input. As the output, they showed the intensity adjusted or histogram equalized image. After that, they used the output of first part as input for the second part. In the second part of their algorithm, different individual complementary image processing operations have been used in order to identify various kinds of defects. Prevailing task emphasized on the human visual inspection of the defects in the industry. But their system is not automated which is very much necessary in the manufacturing process. Again their proposed method is operation redundant because they apply their second part on every test image to identify various types of defects. Moreover, their proposed method is very time consuming.

In 2005, S. Rimac-Drlje et al. proposed a method which is based on the probabilistic neural network with radial basis. To improve sensitivity of the detection procedure an image of the tile is divided into segments and one neural network is made for each segment. The discrete wavelet transform (DWT) is used for the feature extraction in every segment. Maximums of the wavelet coefficients as well as the mean value of the approximation coefficients form an input vector for the neural network. Training vectors are of great importance for successful operation of this algorithm. Two classes of training vectors areused: class 1 - vectors of defect free images; class 2 -vectors of images with defects. The number of trainingvectors defines the number of neurons in the hidden layerof the networkSegmentation of the tile image is necessary for thetextured image and the size of a segment influences theefficiency of the detection procedure. A drawback here is the number of neural networks. This method can identify a larger group of defect but it's not suitable for random texture patterns.

In 2006, A. Serdaroglu *et al*. proposed the method based on the use of Independent component analysis method along with wavelet transforms for identifying defects in textile fabric images. In this method, Different sub-bands of the wavelet packet tree scheme of the defect-free sub-windows are obtained and independent components of these sub-bands are calculated as the basis vectors. The true feature vectors corresponding to these basis vectors are computed. In this paper, they presented that applying wavelet analysis prior to ICA increases the defect detection rate compared to the use of wavelet transformation or ICA alone. The idea behind this ICA method is to find the mean value and standard variance for the whole image. These two features are extracted to identify the defects. The original image pixel values are subtracted from the mean value and then will be divided by the standard variance. The intensities which are below certain value will be classified as a defected area.

In 2006, C. Boukouvalas et al. concerned about the problem of automatic inspection of ceramic tiles using computer vision. They applied techniques for pinhole and crack detectors for plane tiles based on a set of separable line filters, through textured tile crack detector based on the wigner distribution and a novel conjoint spatial-spatial frequency representation of texture, to a color texture tile defect detection algorithm which looks for abnormalities both in chromatic and structural properties of texture tiles. But, using separate filtering techniques for different types of defects is not a good idea at all, because in such case high computational time is a major issue for applying a large number of operations. Again, their procedure is an automated visual inspection system where they only show the defects making them clear to detect the defects found on image.

In 2007, Xianghua Xie et al. present an approach to detecting and localizing defects in random color textures which requires only a few defect free samples for unsupervised training. It is assumed that each image is generated by a superposition of various-size image patches with added variations at each pixel position. These image patches and their corresponding variances are referred to here as textural exemplars or texems. Mixture models are applied to obtain the texems using multiscale analysis to reduce the computational costs. Novelty detection on color texture surfaces is performed by examining the same-source similarity based on the data likelihood in multiscale, followed by logical processes to combine the defect candidates to localize defects. The proposed method is compared against a Gabor filter bank-based novelty detection method. Also, it compare different texem generalization schemes for defect detection in terms of accuracy and efficiency. The method needs to learn normal texture on tiles using a no. of sample in advance. Number of tiles, provided to the training module for the defect detection is less. It is not suitable for Printed tiles.

In 2008, D.O .Aborisade et al. describe an automated computer vision system for plain ceramic wall tile surface inspection. In the system Hardware implementation for the system consists of a monochrome CCD area scan camera ,right light illuminating unit & an IBM- PC compatible computer. This approach to cracks detection involves the application of image edge enhancement & detection algorithm to the captured digitized image of the inspected tiles using Prewitt masks & development of efficient image thresholding algorithm to segment out the crack from image background. With the decision theoretic network, classification rules was built very easily by simply training the network with enough number of sample defective tiles image & implement the nature of decision function classification into ceramic tile quality. In this method Cost & time is reduced .It gives error rate in image. But it detects only crack defect detected..

In 2009, M.Ghazvini et al. proposed 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. 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. Amongst the other advantages, high speed and low calculating load are prominent. The efficiency of this system is less.

In 2009, Hamid Alimohamdi *et al*. presented an automated system based on optimal Gabor filter for online defects detection in various fruits. The proposed method works based on analysis of fruit skin as a texture image. This method works as follows: First a bank of Gabor filters is applied on fruit image. Then based on the response of the filters the optimal filter is selected among the filter bank. By thresolding the response of the optimal filter, the skin defects are detected. This method is also well suited for inspection of any other texture materials such as steel rolls, plastic, wood and tile etc. This algorithm is robust, scalable and computationally efficient for detection of fruits defects. This algorithm is also considered the selection of filter parameters especially center frequency and mask size which heavily relates with the texture characteristics. The estimate of parameters is important for improving detection rates and reducing false alarm rates. The parameter used in this algorithm is not works very well on every individual image.

In 2010, K.N.Sivabalan *et al.* adopted the technique of feature extraction and segmentation to identify the defects in the digital image. The proposed research work was carried out in three different stages: feature extraction, elimination of high frequency components, and identification of defected area. In Feature Extraction, the minimum, maximum and median values are calculated for each row of the image to frame the feature vector. After the extraction of feature vector, the median value is used to eliminate the high frequency components in the digital image. Traditionally the texture components in the image have high frequency spectrum and defect is assumed to be in low frequency spectrum. The extracted image and the median value of each row of the original image are used for identifying the defected area. This proposed defect detection technique which is fast and simple compared to other defect detection algorithms. This Algorithm has the capacity to be used in various types of images. This Algorithm is most suitable for the defects which have low frequency. This algorithm is not suitable for all forms of defects and the efficiency of this algorithm is low.

In 2011, K.N.Sivabalan *et al.* presented technique to identify the defects in various digital images in industries. In this technique Gabor filter and Gaussian filter is used to eliminate the texture elements in the digital image by isolating the defected area. Then a fast searching algorithm is used to identify the defected pixels and to effectively segment it. The proposed technique is suitable for texture and non-texture images. This Algorithm is used to identify the defects in the digital texture image using non texture methods. The Algorithm has proved to be 85% efficient in detecting the defects. However this algorithm is suitable for images which have defects in low intensity levels. This algorithm is not suitable for detecting defects in high intensity levels.

In 2012, Wei-Chen Li *et al.* proposed a defect detection scheme based on wavelet decomposition techniques to identify various defects in multicrystalline solar wafers containing inhomogeneous grain patterns. The defects found in a solar wafer surface generally involve scattering and blurred edges with respect to clear and sharp edges of crystal grains in the background. This method uses the wavelet coefficients in individual decomposition levels as features and the difference of the coefficient values between two consecutive resolution levels as the weights to distinguish local defects from the crystal grain background, and generates a better discriminate measure for identifying various defects in the multicrystalline solar wafers. This method performs effectively for detecting fingerprint, contaminant, and saw-mark defects in solar wafer surfaces. It can be applied successfully to any types of defects that involve relatively scattering and blurred edges on inhomogeneous solar wafer images. However, asevere micro-crack defect showing thin and sharp edges in the multicrystalline solar wafer cannot be effectively detected by this method.

In 2012, Meenakshi Sharma , Gurleen Kaur et al. adopted a technique of extracts the texture features & these features together with the colour features are used for analysis in classifier such as SVM, KNN & Bayesian. In this method Harris corner detection is used which avoid the explicit computation of eignvalues of the sum of squared differences matrix. This method extracts more features but the efficiency of this method is small.

In 2012, Md. Maidul Islam et al. proposed model which play an important role for automatic revealing of surface flaw during production & packaging. This proposed model includes three levels:
In first step, focuses on performing several image preprocessing operations on captured tiles image.
In second, applied proposed flaw detection technique on tiles image to verify whether the tiles is faulty or not. In third step, finally applied defect classification algorithm on captured image to categorize all defects. This method has more computational time & less efficiency.

In 2013, Yadraj Meena **,** Dr. Ajay Mittal et al. Presented the techniques which detects the surface defects such as blobs and cracks on ceramic tiles in a very short period of time with high accuracy. To get a particular realization of proposed defect detection method, the proposed method is applied to a number of flat ceramic tiles images. After that, it is checked whether there is any kind of defect exists in the original image or not by applying the proposed processing operation like image acquation, enhancement, noise removal using median filter then edge is detected with the help of edge detector the thresholding is done for the segmentes the image & after that apply the morphological operation perform on the test image. This method has tested only for Blob & Crack. This havenot categorization of defects.This method does not detect on random textures tiles.

Table 2 Comparison of Various Defect Detection Techniques

S No.	Technique	Purpose	Image type	Calculation Parameter	Interpretation
1	Wavelet Theory & Co-Occurrence Matrices. (A.L Amet et al. 2000)	Identifying defect in textile product	Gray level image	Entropy, Contrast, Angular Second Moment ,Inverse Difference Moment	This method improves the detection performance as well as increases the computational efficiency.
2	Image Processing & Morphological Technique.(H.Elbehiery et al. 2005)	Detection of surface defect in tiles	Gray level image	Histrogram, intensity, noise	This method is very Time consuming
3	Discrete Wavelet Transform. (S. Rimac et al. 2005)	Detection of defect on Plain & Textured Surface	Gray Level Image	Maximum of Wavelet coefficient as well as mean value	This method can identify a larger group of defect but it's not suitable for random texture patterns.
4	Independent Component Analysis and wavelet Transform (A. Serdaroglu *et al.2006)*	Identifying defect in textile fabrics	Gray level Digital Image	Mean, Standard variance	It uses defect free sample for more accuracy & the method extracted less features.
5	Wigner Distribution & Cojoint Spatial Frequency (C Boukouvalas et al. 2006)	Detection of defect in plain & Textured Tiles	Gray Level Image	Contrast, Wigner spectrum component	High computational Time
6	TEXEMS: Texture Exemplars (X. Xie et al. 2007)	Detecting & Localizing Defect in random colour textures	Gray level & colour image	Specificity, Sensitivity & Accuracy	The method needs to learn normal texture on tiles using a no. of sample in advance.Number of tiles, provided to the training module for the defect detection is less.Not suitable for Printed tiles.
7	Prewtt edge technique (D.O. Aborisade et al. 2008)	Detecting of Surface Crack on inspected tile	Digital Image	Mean, Variance	Cost & time is reduced. It gives error rate in image.But it detects only crack defect detected..
8	Two dimensional wavelet transform & artificial neural network(M. Ghazvini, S.A Monadjemi) et al.	Identifying defects in Tiles.	Digital Image	Maximum, Minimum, Median as well as standard deviation & average	The efficiency of this system is less.

	2009				
9	Optimal Gabor Wavelet Filter (Hamid Alimohamdi *et al* 2009)	Detecting skin defects in fruits	Gray level Digital Image	Frequency, Orientation	It gives error rate in image. Execution speed is high.
10	Feature Extraction and Segmentation (K.N.Sivabalan *et al* 2010)	Detecting defect for various image with varied size	Gray level Digital Image	Maximum, Minimum, Median	No error rate is detected. It is most suitable for defects which have low frequency .Execution speed is low.
11	Gabor Wavelet filter and Gaussian filter (K.N.Sivabalan *et al* 2011)	Detecting defect for various digital image	Gray level Digital Image	Gabor wavelet function, Gaussian filter, median , Standard deviation	This algorithm is suitable for images which have defects in low intensity levels. This algorithm is not suitable for detecting defects in high intensity levels.
12	Wavelet-based defect detection(Wei-Chen Li *et al.2012*	Identifying various defects in multicrystalline solar wafer images containing inhomogeneous grain patterns	Solar Wafer Image	Wavelet Decomposition	It is successful on any types of defects that involve relatively scattering and blurred edges on inhomogeneous solar wafer images. This method cannot detect the thin and sharp edge of the defects in multicrystalline solar wafer images.
13	Harris Corner technique (Meenakshi Sharma , Gurleen Kaur et al. 2012)	Detecting of Surface defect	Digital Image	Contarst, Correlation, Energy, Homogeneity, Variance, Entropy Average	The efficiency of this method is small.
14	Image processing & Morphological operation (Md. Maidul Islam, Md. R Sahriar& Md. B. Hossain et al. 2012)	Identifying defect in Flat & Textured ceramic tiles.	Digital Image	Intensity, Contrast , Maximim, Minimum	This method has more computational time & less efficiency
15	Image processing & Morphological operation (Yadraj Meena, Dr.	Detecting defect on Plain tiles	Digital Image	Contrast, Sensitivity, Specificity	This method has tested only for Blob & Crack. This havenot categorization of defects.This method does not detect on random textures

	Ajay Mittal et al. 2013)				tiles.

III. Conclusion

From the above reviewed papers, it can be concluded that different defect detection techniques have been employed to find out the defects from various types of images. Initially different individual complementary image processing operations were used in order to identify various kinds of defects. But the problem which arises while using simple image preprocessing tools was that the system lacks in defect detection accuracy and the computational time increases. Afterwards various artificial intelligence techniques were employed to overcome the above lacunas. Some of the techniques are KNN, Bayesian, SVM, Radial basis function, PNN etc. The KNN, Bayesian and SVM techniques results in low detection accuracy while the PNN and Radial basis function technique shows high accuracy and less defect detection time. But when Radial basis function and PNN are combined the system becomes complicated and with the increase in segment size the layers in neural network increases. This problem can be overcome by implementing the techniques individually.

REFERENCES

1] Yadraj Meena, Dr. Ajay Mittal, *" Blobs & Crack Detection on Plain Ceramic Tile Surface"*, International Journal of Advanced Research in Computer Science & Software Engineering, Volume 3, Issue 7, July 2013.

2] Md. Maidul Islam, Md. Rowshan Sahriar, Md. Belal Hossain , *" An Enhanced Automatic Surface & Structural Flaw Inspection & Categorization using Image Processing Both For Flat & Textured Ceramic Tiles"*, International journal of Computer Applications(0975-888) ,Volume 48- No 3, june 2012.

3] Afsane Fathi,Amir Hassan Monadjemi,Fariborz Mahmoudi, *" Defect Detection of Tiles with Combined Undecimated Wavelet Transform & GLCM Features"*, International Journal Of Soft Computing & Engineering 2231-2307,Volume-2, Issue-2, May 2012.

4] Meenakshi Sharma, Gurleen Kaur, *"Integrated Approach For Defect Detection In Ceramic Tiles"*, International Journal Of Computer & Technology, Volume 3 No. 2 , October 2012.

5] Sunpreet Singh, Maninder Kaur , *" Machine Vision System For Automated Visual Inspection Of Tiles's Surface Quality,"* IOSR Journal Of Engineering, Volume 2, March 2012.

6] F.S. Najafabadi , H. Pourghassem, *" Corner Defect Detection Based On Dot Product In Ceramic Tile Images,"* IEEE 7th International Colloquium On Signal Processing & its Application, 2011.

7] Deshpande G. , Borse M. , *" Image Retrieval With The Use Of Different Colour Spaces & The Texture Feature,"* International Conference On Software & Computer Applications, Volume. 9 , IACSIT Press, Singapore, 2011.

8] Alvarezj, GonzalezE. ,BianconiF. , Armesto, FernandezA., *" Colour & Texture Features For Image Retrieval In Granite Industry"*, March, 2010,ISSN0012-7353.

9] Shahrood, Iran , *" A novel Approach For Detecting Defects Of Random Textured Tiles Using Gabour Wavelet"*, World Applied Sciences Journal 7, IDOSI Publications, 2009.

10] D.O. Aborisade , *" Computer Vision System For Automated Surface Inspection Of Plain Ceramic Wall Tile"*, Journal Of Engineering & Applied Sciences 3, 2008.

11] S.C.Kim & T.J. Kang, *" Texture Classification & Segmentation Using Wavelet Packet Frame & Gaussian Mixture Model,"* Volume 28, 2007.

12] X. Xie & M. Mirmehdi , *" Texture Examplers For Defect Detection On Random Textured Surfaces,"* IEEE Transaction On PAMI, Volume 29, August 2007.

13] Boukouvalas C., Kittler J., Marik R., Mimehdi M., & Petrou M., *" Ceramic Tile Inspection For Colour & Structural Defects"*, project no. BE5638, University Of Survey ,2006.

14] H.M Elbehiery, A.A Henfnawy, M.T Elewa, *"Visual Inspection For Fired Ceramic Tile's Surface Defects Using Wavelet Analysis"*, ICGST-GVIP Journal, Volume 5, Issue 2, January 2005.

15] S.Rimac , A. Keller, & Hocenski, *" Neural Network Based Detection Of Defects In Texture Surfaces"*, IEEE ISIE, 2005, Dubrovnik, Croatia.

16] H. Elbehiery, A. Henfnawy & M. Elewa, *" Surface Defect Detection Of Ceramic Tiles Using Image Processing & Marphological Operation,"* Proceedings Of World Academy Of Science, Engineering& Technology, Volume 5, ISSN 1307-6884, April 2005.

17] A. Monadjemi, B. Mirmehdi, & T. Thomas, *" Reconstructured Eign filter Matching for novelty Detection In Random Texture,"* In Proceedings Of The 15 British Machine Vision Conference, 2004.

18] Richard Bridge, *"Computer Image Processing"*, Tessella Supportservices PLC, Oxon, England, Issue V1.R2.M0, June, 2003.

19] Vincent Lebrun , *"Quality Control Of Ceramic Tiles By Machine Vision ",* Flaw Master 3000, Surface Inspection Ltd. 2001.

20] A.L Amet, A. Ertuzun, & A. Ercil, *" An Efficient Method For Texture Defect Detection : Sub- band domain Co- occurrence Matrices,"* Volume 28, 2000.