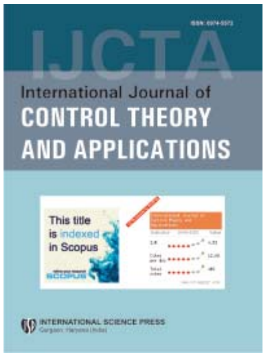

International Journal of Control Theory and Applications

ISSN : 0974–5572

Volume 10 • Number 27 • 2017

Literature Survey on Various Types of Surface Defect Detection Techniques

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Abstract: Titanium coatings are widely used for improving the surface characteristics because of its corrosion resistance property, hardness, biocompatibility and golden color. The properties of titanium coatings make it as suitable for many application areas such as medical implants and instruments, aerospace components, cutting tools, wear components, navy ships etc. So there is a need for analyzing the defects as early as possible. The earlier detection of defects provides an easy way to obtain defect free coating surfaces. This will also help to avoid possibility of future damage of the product. So a novel method for surface defect detection technique is needed for assuring the quality of coated surfaces. In industries visual inspection techniques are more convenient for analyzing surface defects, image processing and analysis can be applied for perceiving imperfections in coated surfaces. A survey of various surface defect detection techniques based on visual inspection system is the discussion area in this paper.

Keywords: *Image Segmentation, Defect Detection Techniques, Transform, Thresholding, Surface Defect.*

1. INTRODUCTION

The digital images are captured using high resolution cameras and the various features in the images are extracted using digital image processing techniques. The surface defect detection process simplifies the image analysis by drastically reducing the number datas processed and simultaneously store helpful geometric data concerning object. There is definitely a good deal of selection in surface defect detection applications, however it is felt that a lot of applications share a common set of requirements, so the solution of which may be applied in any of the problem domains.

The coated metal surfaces are widely used in various field for different applications, so that the defect detection in coated surfaces become a challenging area for research. The analysis and identification of faults on coated sides are the preliminary step within the primary evaluation of coating method [1]. The detected defects are then changed and check whether or not it satisfies the preset quality needs, if it doesn't satisfy the planned quality estimates, the coatings would be inacceptable. The close scrutiny of corporal irregularities within the layers would help to determine the contrivance behind defect formation. The information achieved by this inspection can be utilized for improving the coating process. In the production line, industries normally adopt visual assessment skills to identify the flaws along the manufacturing process. These detection methods use image processing for determining the defected areas in the surfaces based on prearranged gauges and has successfully used to identify the defects on numerous surfaces.

In this paper several sorts of surface fault recognition measures based on image processing are discussed. There are various non-destructive techniques existing for external fault recognition, like the fault recognition based on the Eddy Current Testing [2] fluorescence emission [3], electrostatic methods [4], infrared thermography [5], etc. Most of the manufacturing industries give more importance for the quality control of their products. Visual inspection was used for quality checking and verification in the past. But the defects in the coating regions are not easily observed by naked eye, so that high resolution images are required for defect detection, and digital image processing is also in cooperate with high resolution images to obtain defects in coating surfaces. The industries consider quality control as a fundamental part of their production process and they follow various defect detection techniques also. This review focuses on different types of defect detection techniques for various applications because no individual technique can be considered optimal. As a result, several techniques have been analyzed with the aim of improving the quality of products.

The paper is organized as follows; section II affords a slight outline of the procedures used for external fault recognition. The major phases within the external fault recognition procedures are stated throughout this segment. In section III, several kinds of procedures employed for external fault recognition are discussed. In table 1, a comparison of various defect detection techniques are discussed. In section IV, a conclusion of the literature survey is conferred.

2. TECHNIQUES AND METHODS

The Surface Defect Detection is a multistage process. The main stages of Surface Defect Detection process are (1) Image Acquisition (2) Preprocessing (3) Image Segmentation (4) Feature Extraction and classification.

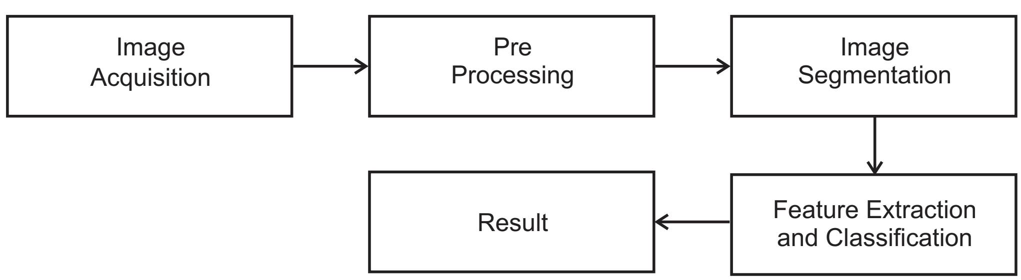

Figure 1: Stages in surface defect recognition

2.1. Image Acquisition

Image acquisition is a crucial method in visual inspection. Different types of techniques are employed for capturing high intention facsimile. The high resolution pictures may be procured using high resolution scanning. A high resolution camera of great spatial exactitude and color fedility could be preferable for this type of image acquisition, where the sample capturing should be done on altered resolutions and their consistent greyscale image.

2.2. Preprocessing

This is the primary step of any image processing technique, during this stage, we tend to create the input image compatible for process. There are innumerable distractions that afflict the input image like illumination variations, noise, backgrounds, variations in image sizes etc. So the first processing phase in external fault detection is noise removal, input image enhancement, which is completed in the preprocessing phase. Also the process of external fault recognition take grey scale image instead of color image, therefore a conversion from color to greyscale is needed for the process, which is done in the preprocessing stage. Images are systemized for further processing in the preprocessing stage.

2.3. Image Segmentation

The procedure of segregating an image into its essential areas or objects is called image segmentation. The inputs of segmentation are image but unlike other image processing methods, the outputs of segmentation are attributes *i.e.* natural qualitative extracted from those images. Also the segmentation process should be stopped as soon as the objects or regions of interest are detected. Different types of segmentation techniques are used for external fault recognition like thresholding, template matching, boundary detection texture matching and so on.

2.4. Feature Extraction and Classification

Feature extraction involves reducing the quantity of resources needed to describe large set of information, it can be transferred in to a reduced set of features. Classification algorithms aim at finding similarities in patterns of empirical information. The classification process is based on the features extracted, it classifies the features and makes result. The most commonly used classifiers are neural network classifier, SVM, Bayesian etc.

3. DIFFERENT METHODS FOR SURFACE DEFECT DETECTION

In this segment various types of fault recognition procedures in various surfaces are reviewed and described briefly as follows.

The titanium coated surfaces may contain small defects, which can be detected by contrast adjusted Otsu's method [1]. Here, the defect can be analysed by thresholding method, converting the grey scale image into binary in the preprocessing. The areas of the image containing similar properties are segmented initially, so that a black and white binary image is obtained. The thresholding converts the image pixels in terms of zero and one, a specific value less than zero is considered as black and pixel values beyond certain standards are assumed as one (white). The above mentioned thresholding method calculate a maximum cut off value for image dissimilarity and then calculate the threshold using Otsu's thresholding. The threshold is calculated by separating the image in to two sections based on the threshold value as the extreme cut off value for image which provides a unimodal histogram. Then the image is transferred to a binary illustration, the otsu's approach espouses that the histogram of the image is bimodal and split the unimodal distribution. This thresholding technique separates the segmented image into two regions, coated regions and uncoated regions.

The various kinds of cracks in TFT LCDs (Thin Film Transistor Liquid Crystal Display) can be identified by optical interference pattern sensing technique and neural network classification technique [6]. The optical interference pattern sensing scheme [7] identifies the interfering borders, then further processing can be done by image processing tools. The various types of defect occurred in TFT LCDs can be identified based on the neural network classification method [8]. For producing the interference patterns in TFT LCDs fluorescent lamps or sodium lamps are used. The image is transformed then to grey scale image and also histogram equalization would be completed. The extracted features are then used for classification purposes. The neural network would be classified on the premise of the trained set of images. The grouping is predicated on the width of the fringes, area of the fringes and ratio of the interference fringes obtained. By using neural network classification method the area containing defects and the types of defects occurred can be identified [9]. By using this process the mean square error can be reduced. The defect detection based on interference pattern detecting scheme and neural network classification method is found to be very robust and reliable.

Xiaolong Bai proposed a method for detecting defects in automated chips based on template images [10]. Two steps are involved in defect detection process. The primary phase is to gather salient sections of the trial images. The next phase is to relate the variation among the salient sections in the trial images and the consistent areas within the fault free trial images, Phase Only Fourier Transform is intended for saliency detection [11]. The inspections of dies are carried out one by one. For the analysis of salient regions, the captured images are organized in an array and the defect free regions are removed by utilizing the self-similarities among the array of multiple images. Salient regions are easily obtained from the test image array. The defect detection can be done by using template matching [12][13] based on spatial misalignment-tolerant matric [14]. This technique is a simple and easy method for analyzing defects because the normal regions in the image are expeditiously removed in the primary step and further comparison can be done by using template matching in the second step.

Bin Gao introduced a method for analysing defects in metal surfaces based on waveguide imaging with adaptive sparse representation [15][16]. The technique used here is automatic detection so that there is no need for selecting the frequencies manually for defect detection. The core of the strategy could be an intelligent machine learning algorithmic database based on sparse non-negative matrix factorization [17]. For adaptive learning and control sparsity of the factorization, an inner functionality is comprised in the algorithmic program. The algorithm should provide higher accuracy in defect detection process, Bayesian statistics methodology is used for obtaining this high accuracy [18]. The learning process using sparse representation from underlying data statics doesn't use prior information of the fault bands. The defect detection uses waveguide imaging system. For analysis the anomalous patterns in waveguide images, sparse representation is used. The sparse representation method detects the defects automatically in sparse-frequency domain [19]. The mining of the spectrum marks related to the fault is significantly very economical by applying optimal sparsity, which gives higher detection performance in metal surfaces.

The defects in mandarin fruits could be detected by using fuzzy image thresholding and defect classification by using linear classifier model [20]. The feature extraction for classification purpose is done by applying Binary Wavelet Transform (BWT) [21]. The block diagram of pattern detection and classification algorithm is represented in the Figure 2.Image enhancement and segmentation were used for pattern recognition. An efficient methodology was applied for image thresholding [22], preferably fuzzy set theory. The details about greyness ambiguities present in the image is provided by the measure of fuzziness. A combination of fuzzy image thresholding, BWT feature values and linear classifier model were used for external fault recognition and classification using pattern recognition method [23]. The faulty spaces are isolated by segmentation using fuzzy image thresholding. The combination of fuzzy thresholding and BWT was a binary scaled image. The background of this binary image and non-feature components enclosed in the image are suppressed and it shows only the complete outlook. The feature values are calculated from the diagonal details plotted in scatter plot. The linear classifier model is trained by using pattern recognition model. In this defect detection and classification scheme, target adaptation scheme is applied for training process. The target adaptation scheme was almost equal to perception algorithm to fetch the output of classifier closer to the predefined goal. Here the classifier fails to classify accurately, so the training procedure is reiterated by using the feature values in a two class discriminant scrutiny.

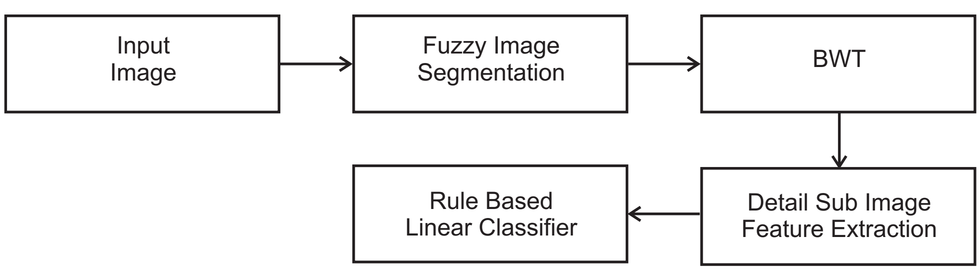

Figure 2: Block diagram of pattern detection and classification algorithm

The bearing surfaces may have some defects which can be analyzed by collecting CCD images and applying image processing based on machine vision technique [24]. The bearing locations/regions were detected by applying least squares fitting and annulus scan, this is the primary step. In the second step, circular images are transformed into rectangular images and the quality of this image is improved using filtering and segmentation. In preprocessing, image enhancement, low pass filtering, sharpening and morphological processing were applied for improving the quality of the acquired image. Also contrast stretching and median filtering were applied in the preprocessing step. Image segmentation uses Otsu's method.

Particle swarm optimization algorithm [25] is employed for defect detection in the surface of solar panel [26].This algorithm as the main part of the proposed methodology, which is preferred to obtain the edges of the image. The different steps in image processing is shown in Figure 3.The cracks and bus bars are analysed using edge detection technique [27]. The classification depends on location of bus bars in the solar cell panel. After edge detection, the image containing cracks and bus bars were analysed and the grouping of pixels based on similar features and different grey values were done. By this manner it could be able to acquire desired informations like cracks, that they have dark grey pixels. The bus bars and cracks were identified by counting the number of dark grey pixels [28]. There were two types of classification used in the system, first one was classification of cracks and second one was normal and defective product classification. The fuzzy logic classification methodology was used for classification of defect in solar cell panel. A PLC (Programmable Logic Controller) was used to separate the defective products, it would reject the product which contains defect. This technique gives good defect detection result.

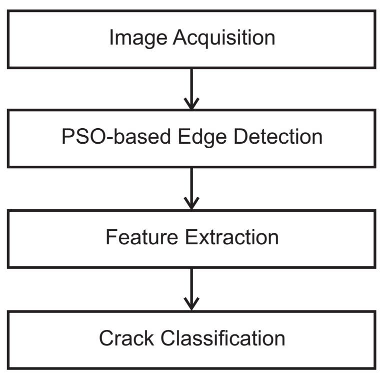

Figure 3: Steps in image processing

Gagen Kishore Nand presented a method based on entropy segmentation for defect detection of steel surfaces [29]. Here, in the preprocessing step illumination compensation could be done by applying inverse illumination to discard irregularity of light intensity presented in the image. After that the defected regions were detected by using local entropy of the image. He also suggested a dynamic updation concept which was useful to identify the background of the image. This methodology also provides an efficient way to classify the faults based on defective and non-defective regions. The defective regions from the entropy images were extracted by using background subtraction methodology. This entropy image was obtained from the comparison between the entropy of the image and the entropy of background. In order to obtain the segmented image, histogram based thresholding method was applied [30]. The histogram based methodology successfully determine the faults in steel surface like water droplet, blister and scratch.

The method of circular region projection histogram (CRPH) method and sparse representation for analyzing imperfections in bottle cap surfaces [31]. In this method, the center of the image was set primarily. The next step was to achieve appropriate radius circle range as the template region of interesting (ROI) on the standard cap surface. The ROI was projected as histograms on completely different directions that were rotated round the center of the image. The histograms were the arrays that generate the particular distribution by calculating the values of the pixel creation that plunge into each bin. These sorts of arrays are deliberated as atoms which generate the template dictionary. Then the trial image is obtained and associated ROI was extracted. The 1D array like sample projected histograms are obtained by projecting the ROI at vertical and horizontal directions. In the final step, the sparse representation method was used to detect the defect by comparing the fragments within the template dictionary to the histogram sample. It is found that sparse representation algorithm is effective for defect detection in bottle caps.

Texture analysis is one of the popular method for surface fault recognition in industries [32]. The fault recognition on the surface of hot rolled steel sheets using texture feature extraction using a three level 2-D Haar wavelet transform [33] and artificial neural network classifier. In the image analysis process, Haar basis function was used for studying small complicated details in the image. The captured image was treated with Haar wavelet packet decomposition at every scale produces a large set of coefficient matrixes. The next level decomposition coefficients are obtained by using matrix with high energy value. For each coefficient matrix frobenius norm was calculated, which represents the energy. So that the channel with highest energy value and dominant frequency were used. Therefore this method of defect detection was much more robust and efficient. An ANN classifier with 2-layer feed forward back proportion was used for image classification purpose. It is configured with 15 input nodes corresponding to 15 input features with hidden layers were used. The output node was used for the classification of feature vectors in defective or defect free classes. In the training process, the value of 1 was assigned to samples with defects and 0 is assigned to samples without defects. The response was compared with the desired target and a classification matrix was created, which helps to provide the information about the performance of the classifier, which was expressed in terms of percentage. This method was suitable for checking surface defects of low resolution and non-uniform lighting images.

An automated method used for crack detection system for analyzing cracks in steel slabs [34][35] which occur during casting process of steel production tonnage. The defects are analyzed by using 3D images of steel slab surfaces. It can be done by using morphological image processing and statistical classification method. In the preprocessing step the slab regions were identified, then compensating for slope, handling occluded data and removing of noise are carried out. Segmentation technique was used for extracting the crack length in the steel slab surface and eliminates the pseudo defect areas similar to defect. No cracks were incorrectly perceived in regions where manual review absolutely dominated out the presence of flaws. The accuracy is low because some cracked regions were completely missed.

A high speed segmentation system integrates wavelet transform [36] and Chan and Verse (CV) model was proposed for crack detection in industrial CT images [37][38].The rough edges were detected by applying 3D wavelet transform, and then region growing was used to obtain cracked regions. The edges of cracked body were captured based on resulting volume data and 3D CV model. In this method, wavelet modulus-maxima was used to locate the rough regions. It lessens the volume of C-V model processed data. It also affords primary contour surface which would speed up the convergence of CV model [39].A hybrid approach consists of CV model and wavelet transform was used for quick segmentation [40]. In the primary step 3Dwavelet transform is used to obtain the irregular sections. Then 3D CV model was used for segmentation of cracked bodies. Theimplementation process of the technique is shown in the Figure 4.

Fuzzy C-mean clustering was applied for detecting defects in potato [41]. The defected areas are detected using Euclidean distance. The various types of defects in potato like rotten, cracks or greening are analysed using this method. The segmentation is based on the image pixel values. Fuzzy C-means clustering and modified fuzzy C-means algorithms are used for detecting defects in potato. The modification in fuzzy C-means algorithm is used to reduce algorithm complexity and make it suitable for real time application. The values of the pixels in the image are compared to check whether or not the pixel belongs to specific cluster [42], it has the values between 0 and 1. The strength of the values of the pixel determines the position in the cluster. The overall pixel values in all clusters is equal to one. If the membership value of a specific cluster is high, the pixel has more possibility to fall into that cluster.

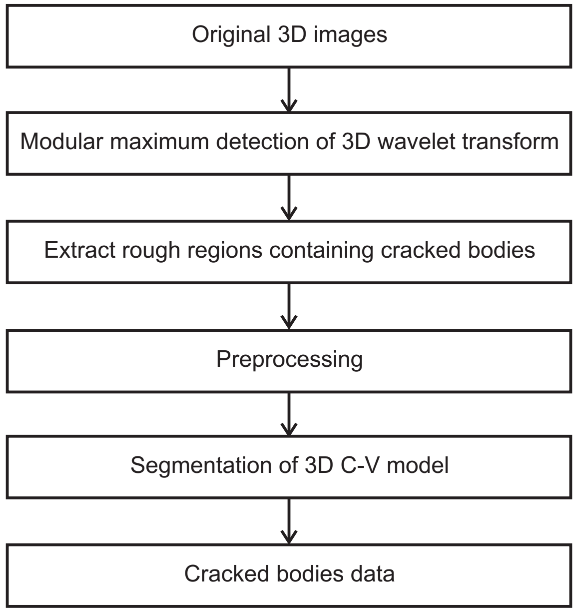

Figure 4: Implementation process of the technique

Table 1
A comparison of various defect detection techniques

Sl.No.	*Author and Year*	*Method/Techniques*	*Purpose*	*Interpretation*
1.	M. A. Hassan and N. M. Hilman 2015	Contrast adjusted Otsu's method	Defect detection in titanium coated aluminum surfaces	Purely histogram based algorithm
2.	Tung-Yen Li and Jang-Zern Tsai, 2013	Optical interference pattern sensing method and neural network classification method	Defect detection in TFT LCDs	This method is found to be very robust and reliable.
3.	Xiaolong Bai and Yuming Fang, 2014	Phase-only Fourier transform (POFT) and Template matching	Detecting defects in electronic chips or dies	This method is a simple and easy method for analyzing defects
4.	W.L. Woo and G.Y. Tian, 2015	Bayesian statistics methodology and adaptive sparse representation method	Defect detection in metal surfaces	This method is more economical and gives higher detection performance in metal surfaces.
5.	Anandhanarayanan Kamalakannan, 2012	Fuzzy image thresholding and linear classifier model	Defects in mandarin fruits	Parameters that must be selected prior to the running of algorithm. Lack of an automated feature selection
6.	DENG Sier and CAI Weiwei 2010	Otsu's thresholding method	Defect detection in bearing surfaces	Purely histogram based algorithm, Fail to properly select a threshold when it is located near a local top on the histogram.

Sl.No.	*Author and Year*	*Method/Techniques*	*Purpose*	*Interpretation*
7.	Amir Hossein Aghamohammad and Anton Satria Prabuwono 2011	Particle Swarm Optimization algorithm	Crack recognition in the surfaces of solar cell panel	It is simply to fall in to local optimum in high dimensional area and incorporates a low convergence rate within the repetitive method.
8.	Gagan Kishore Nand and Noopur 2014	Entropy segmentation	Fault recognition of steel surfaces	This method successfully identifies the faults in steel surfaces like water droplet, blister and scratch.
9.	Wenju Zhou and Minrui Fei 2013	Circular region projection histogram and an algorithm based on sparse representation	Detecting faults in bottle cap surfaces	This algorithm is effective for defect detection in bottle caps
10.	A.Sada Siva Sarma and R. Janani 2013	Texture feature extraction using a three level 2-D Haar wavelet transform and artificial neural network classifier	Fault recognition on the surface of hot rolled steel sheets	This method is suitable for checking surface defects of low resolution and non-uniform lighting images.
11.	Anders Landstrom and Matthew J. Thurley 2012	Morphological image processing and statistical classification method	Analyzing cracks in steel slabs	recognition accurateness of this method is low because some cracked regions are completely missed
12.	Linghui LIU, Li ZENG 2011	Wavelet transform C-V model	Fault recognition in 3D Industrial CT Images	Not appropriate for fast applications. Cannot achieve good segmentation result for complex image with some in-homogeneity
13.	Er. Amrinder Singh Brar and Kawaljeet Singh 2016	Fuzzy C-mean clustering	Potato defect detection	Very effective in analyzing defected areas

4. CONCLUSION

In this paper, a survey on various surface defect detection techniques based on image processing methods is now evaluated. The digital image processing techniques are very helpful for analyzing the defects of assorted surfaces by applying various methods in image processing. Each method has its own merits and demerits. From this review it can be understood that some methods have fast speed, but lacks proper accuracy, where as some other methods have high accuracy but restricted by complex computations, which leads to lower speed. For real time processing, high speed and high accuracy are essential at the same time. This review shows that each method is suitable for detection of some specific defects. So it may be concluded that there is no general technique has yet been proposed for detecting all different types of surface defects at the same time, so that a technique based on various image processing steps would be indispensable for industrial applications.

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