An Effective Surface Defect Detection Method Using Adaptive Thresholding Fused With PSO Algorithm

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***Abstract* - In Image processing and computer vision, the optimization technique aims at producing improved end result from a set of possible inputs. It is considered to be an exceptional method for the detection of defects from coated surfaces. In the presence of on-site inspections, it is practically impossible to detect surface defects such as small cracks on the titanium-coated surfaces of components. In this type of overlooking surface cracks, a new procedure must be discovered and it can effectively assist and improve the detection rates. We recommend titanium-coated surface crack detection system. The proposed method is depends upon the spatially clustered pixels with same grey levels. For image segmentation an Optimized Adaptive Thresholding (OAT) approach is proposed, in which Particle Swarm Optimization (PSO) is used along with adaptive thresholding. The LDP(Local Directional Pattern) approach is utilized for measuring the image edges gradient values in distinct ways and determine the pixel values in a various directions. LDP algorithm is usually applied to spot the image edge. If no edges are detected, then the nearby pixels are checked and joint to a region class using region growing algorithm. Finally the performance of the proposed method can be evaluated in terms of parameter calculations to achieve the high accuracy, specificity and sensitivity of the crack image.**

Keywords: - Titanium Coated surface, Crack Detection, Optimized Adaptive Thresholding, Local Directional Pattern, Region Growing Algorithm.

I. INTRODUCTION

Titanium-coated surfaces has many applications such as medical implants and equipment, aerospace peripherals, cutting appliance, plastic molding tools, punching and forming. These surfaces comprise tiny defects such as very minute cracks. So there is a need for analysing the defects as early as possible. The earlier detection of defects helps to take necessary precautions in order to avoid future damage. The main objective is to provide a better thresholding technique to improve the segmentation accuracy. Titanium-coated surface images were obtained with the help of high-resolution scanning. The sufficiency of defect detection techniques to detect the defects of metal coating surfaces which will help to improve the quality of coated surfaces. This research focuses on providing a defect detection technique to detect the defects of surface coatings using image processing.

The major advantage of the image based analysis of the defect detection is that by using the image processing technique it provides accurate result compared to the conventional manual methods [1]. There is increase in significance using the non-destructive inspection in detecting the image based crack. Because of the random shape and irregular size of cracks and various noises are some of the difficulties evolve in the image based detection [2] [3]. The corner cracks among the defective regions are spotted using Texture and morphological features. Even if the above specified methods carried out high detection rates, these are incredibly restricted to a few explicit work piece or defects [4]. The research in vision based defects detection suggests a technique for casting defects detection using image segmentation [5] [6].

There are numerous image processing approaches are established for crack detection, which depends upon on algorithms were used. By using shape information the crack region can be found by the binary of the grey image with one single threshold [7]. In intelligent transportation systems (ITS) also suggested to decrease the traffic issues like accidents and traffic jams. Most of the ITS outlined by implementing information technology (IT) that have also been discovering important developments in past few years [8]. Motivated by recent developments and an improving availability of UAVs (Unmanned Aerial Vehicle) a growing number of applications have been developed over the last years, ranging from inspections of transmission lines, monitoring of fractionation towers in refineries, among others. However, we should take away irrelevant information associated notice correct segmentation result before diagnose[9]. Cracks on the concrete surface were one of the primitive implications of degradation of structure which is hard for the maintenance as well the continuous exposure would leads to the severe damage to the environment. So, automatic image-based crack detection was recommended as a replacement. Literature presented the different techniques to automatically found the crack and its depth using image processing techniques. In that research, a detailed survey was conducted to identify the research challenges and the achievements till in that field [10][11]. Cracks were showing structural issues in developments result of timber beams; however their recognizable proof in notably roof developments was tough problem. In this way that paper shows a calculation for the computerized recognition of cracks in timber bars tested by LiDAR information. In that calculation allows the ID, investigation and perception of cracks and their geometrical characteristics [12] [13].

II. PROPOSED METHODOLOGY

Analysis of defects on titanium coated surfaces is the one of the most difficult tasks. The sketch cracks are manually prepared in the case of manual inspection and irregularities conditions are mentioned. In the case of qualitative analysis manual approach is according with the specialized knowledge. The image processing techniques are major thing in our approach which automatically identifies the crack. This paper tells the highly efficient crack detection system which is recommended for detecting defect on coated surface. An Optimized Adaptive Thresholding (OAT) approach is feed for image segmentation of cracks by completely taking under consideration the spatial distribution, intensities, geometric and texture features. Gradient values from the edges of an image and the pixels characteristic values from various directions, the LDP technique issued. The approach is generally enforced to recognize particular edges from an image. For crack detection region growing algorithm is used. Finally, the parameter estimation of the proposed method through sensitivity, specificity, accuracy, precision and F-measure are used for the effective performance.

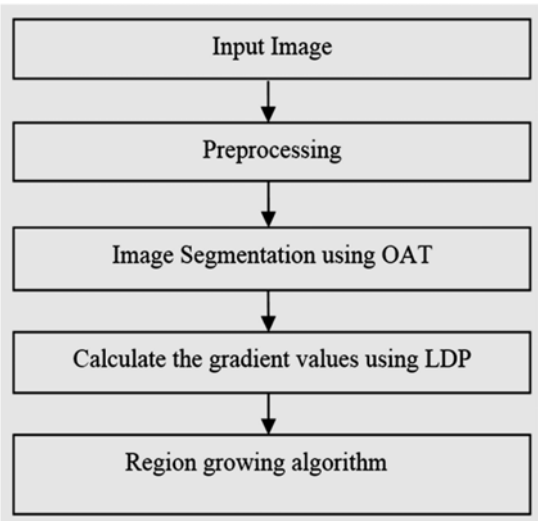

Figure 1: Proposed titanium-coated surface crack detection system

In our proposed work the input image is given to the pre-processing system for collecting the image structure. The pre-processed images apply the OAT algorithm for segmentation. Calculate the gradient values of the segmented imaged using LDP. Finally detect the crack in segmentation image using the region growing algorithm. The above figure shows the proposed flow diagram of titanium-coated surfaces Crack Detection System. The architecture of crack detection technique is used by image processing technique and a benefit in this technique is to provide the accurate result and it is compared to traditional manual methods.

A. Pre-Processing

In the lowest level of operations on images are occurred in terms of image pre-processing. In this process the image information content cannot be increased, but the entropy of information is decreased. To enhance the image data, that stifles undesirable mutilations and analyze the image pre-processing phase with aid of image histogram equalization. Pre-processing is essential for image enhancement. In general, two image enhancement methods are used, spatial domain operation and frequency domain operation. Spatial domain operation is split up into three parts based on particular needs. They are point processing, histogram based techniques and mask processing. The recommended method adopts spatial domain operation (directly work on image pixels) as mask processing for crack detection operation and histogram based techniques for visualization enhancement [14]. Both processes are described below in detail.

A1. Histogram Equalization

For enhance contrast the histogram equalization is utilized to adjust the image intensities .The discrete function between the histogram of a digital image and total possible intensity levels, M in the range of *[0, M-1]*can be defined as the following equation(1):

$$H(I_k) = \frac{n_k}{Total\ number\ of\ pixels} \tag{1}$$

where, I_k denotes the original image intensity level, n_k denotes number of pixels in the image. To change the contrast of the image, it spreads the intensity values by Histogram equalization. The main purpose of histogram equalization is to arrange the gray level in the available dynamic range. The main aim of histogram equalization is to extent the contrast of a given image equally throughout the all available dynamic range [15].

A2. Adaptive Median Filter

The purpose of median filter is to reduce noise in the image and for our proposed work this filter is used for image smoothing to improve the efficiency of algorithm. The median filter manages the pulse noise in higher density. When managing the non-pulse noise level it can preserve more details of an image. The noise of an image can be degrading the quality of an image. This filter is otherwise known as the middle value of the pixels in the neighborhood. The performance of median filter is especially higher for removing impulse noise than alternative filter. By using adaptive filter; which pixels in an image have been affected by impulse noise in spatial processing can be determined. The main purpose of the median filter is to reduce distortion.

$$k_1 = Med - Min, K_2 = Max - Med \quad (2)$$
$$L_1 = M_{xy} - Min, L_2 = Max - M_{xy} \quad (3)$$

The adaptive median filtering works by the following steps:

Step 1:To calculate the parameters K_1, K_2 by using the equation(2)
Step 2:If K_1>0 &&K_2>0
Step 3: Calculate L_1,L_2 by using equation (3)
Step 4: If L_1>0&&L_2>0
Step 5: Output=M_{xy}
Step 6: Else
Step 7: Med is output
Step 8: Else
Step 9: Enlarge the window
Step 10: If window<=Max
Step 11: Repeat steps 1 to step 9
Step 12: Else, Output=M_{xy}

where, M_{xy} describes size of the neighborhood, *Min* describes the lowest grey level points in M_{xy}, *Max* is the highest grey level points in M_{xy}, *Med* is the medium levels of grey in M_{xy},M_{xy} is the grey level at coordinates *(x,y)*, *Max*is highest accepted size of M_{xy}. *Med* is not an impulse means go to the next level(*Min< Med< Max*) ,otherwise *Med* is an impulse involves the size of the window is increased. The M_{xy} is not an impulse, the distortion was reduced [16].

B. Optimized Thresholding Technique

In the second phase illustrated by Optimized Adaptive Thresholding (OAT),this method is specified to image segmentation. Adaptive threshold input is gray scale image. In the implementation part, output representing the binary image as edge information. To calculate threshold value of a binary image using the pixel, the pixel value is below to the threshold value the image is set to background; otherwise it set to a foreground. To obtain an optimal threshold value for the adaptive threshold method, this can be viewed as an optimization problem. For this reason, PSO is recommended to use to get an optimal adaptive threshold value. In the adaptive threshold approach using different type threshold value in a different regions. This is known as local or dynamic thresholding. In the proposed method edges are extracted initially by using adaptive variation threshold. The connectivity of the edges is improved and then obtained using Particle Swarm Optimization algorithm (PSO). The threshold value is measured for every pixel in the image.

The image thresholding technique can be classified as global and local techniques. The conversion of grey level image into binary image using the intensity value is called as global thresholding technique. Image intensity value is applied to the whole image is known as local thresholding. The image's grey level histogram information is depends upon threshold value selection. Image thresholding method is focused to classify the pixel of an image into classes, they are background and foreground [17].

B1. Spatial distribution Feature

Spatial aggregation is applied to find out the cracks must be searched in a group of pixels or regions. Cracks pixels with same grey-levels instead of isolated points, it is urged to detect the inferred crack regions instantaneously by perceiving spatial clusters. To investigate the error occurred through spatial distribution features can be estimated, camera pose. By using the simulation to provide a rigorous analysis of the relationship between the spatial distribution and set of features in the image of camera pose [18].

B2. Geometric Feature

Geometric features may be presented by segments, perimeters and areas of some figures formed by the detected points. The Comparison of penny-molded surfaces, there are various clear geometric characteristics of crack arrangements, for instance, uncovering lineament, higher length, and bigger perspective proportion, etc. as appeared in pixels. To differentiate cracks and textures the geometric feature is another significant approach [19].

C. Particle Swarm Optimization (PSO)

Particle swarm optimization (PSO) is surrounded to envision the manners of birds in look for nourishment on a cornfield or fish school. The technique can competently discover best or close to best solutions in excessive search spaces. There are two types of sorts of variants are utilized with PSO, (i) Individual best (ii) Global best.

"Individual best": It is the individual best selection algorithm by evaluating each individual position of the

particle to its own best position $pbest$, only. The data about the other particles is not employed in this $pbest$.

"Global best": It is the worldwide best selection algorithm, that acquires the global information by making the movement of the particles constitutes the position of the optimal particle from the entire swarm. In addition, every particle exploits its experience with previous incidents in terms of its own best solution. All individual molecule i has a subjectively starting location $x_i = (x_i^1, x_i^2, \dots, x_i^d)$ where x_i^d being its location in the d[th] dimension, velocity, $w_i = w_i^1, w_i^2, \dots, w_i^d$ where v_i^d being the velocity rate in the d[th] dimension, $pb_i = (pb_i^1, pb_i^2, \dots, pb_i^d)$ where pb_i^d is the perfect position in the d[th] dimension, and $gb = (gb^1, gb^2, \dots, gb^d)$ where gb^d is the best value for the global location of the d[th] dimension in the D-dimensional search space. Every molecule can move toward its own best location in all generation. The moving procedure of swarm molecule in the search space is illustrated as the following equations:

$$W_i^d = W_i^d + k_1.ra_1.(pb_i^d - x_i^d) + k_2.ra_2.(gb^d - x_i^d) \quad (4)$$

$$x_i^d = x_i^d + \delta W_i^d \quad (5)$$

From the equations (4) and (5):

k_1, k_2-Coefficients with the range of 2.0

ra_1, ra_2 - Independent random values developed in the limit between 0 and 1.

W_i^d - Velocity of i[th] particle.

x_i^d, pb_i^d - defines the current position i and the optimal fitness value of the molecule at the present iteration

gb^d - Optimum global values in the swarm.

In order to obtain an optimal threshold value for the adaptive threshold method this can be viewed as an optimization problem. Hence, PSO is proposed to use along with adaptive threshold [20][21].

D. Local Directional Pattern (LDP)

By thresholding a *3*3* neighborhood of every pixel with the center value, LDP Operator marks pixel of an image. For labelling the result, binary number is represented as the corresponding decimal number. LDP operator utilizes the edge estimation of pixel's neighbor and encodes the image surface. LDP operator assigns the binary code in the size of 8 bits for all pixels of an input image. The kirsch edge detector is used to assessing the response values of pixels for respective edge. In image, the innermost (central) pixel is given, then the edge response from image of eight directional values are p_i= *(i-0, 1, ..., 7)* calculated. Edge or corner express better response values from specific directions so most respective directions of *K* number should be considered. To generate the LDP code selects a high response values from the K number. Although top-*k* directional bit response (b_t) are having the value as 1 then the remaining *(8-k)* bits having the value as 0. At last the code for LDP is expressed via following (6):

$$LDP_k = \sum_{i=0}^{7} b_i(p_i - p_k) * 2^i, b_i(x) \begin{cases} 1, x \geq 0 \\ 0, x \leq 0 \end{cases} \quad (6)$$

From above equation (6) P_k denotes the k^{th} most important directional response, LDP (Local Directional Pattern) approach is used for measure gradient estimation of the edges for an image indistinct directions. This calculation is typically exercised to recognize the edges for an image [22].

E. Region Growing Algorithm

Region based methods mainly rely on the assumption that the neighboring pixels inside one region have the same value. The common technique is to compare one pixel from the region with its neighbor's pixel. If a similarity criterion is satisfied, then the pixel can be fixed belong to the cluster as one or more of its neighbors. The selection of the similarity criterion is the effective one and the result is influenced by noise in all instances. For the improved image segmentation, region growing is the uncomplicated method. It is also named as a pixel-based image segmentation method. This method is used to segment and evaluates the initial "seed points" neighboring pixels and also to detects the near points of the pixel. The procedure is repeated, in the similar way of general data clustering schemes. Finally crack detection can be performed with the assist of this region growing algorithm [23].

III. RESULTS AND DISCUSSION

An evaluation metric is a measure, which helps to analyze how effectively the attributes of two schemas are matched and to justify the proposed system's developments. Evaluation metrics normally encompass with set of measures to be followed a general method for evaluation. The following figure 2 shows the crack detection output for input images. The white portion shows cracked regions.

Figure 2. Crack Detection output for input images.

A. Parameter Calculation

The parameter estimation of the crack detection approach is evaluated by the following parameters: sensitivity, specificity, accuracy, precision and F-measure, using true positive (TP), true negative (TN), false positive (FP) and false negative (FN) values.

(a) Sensitivity or Recall

The percentage of positives can be effectively recognized by measure for affectability. It identifies with the capacity of test to recognize positive outcomes.

Sensitivity=TP/(TP+FN)

(b) Specificity

The ratio of negatives which are effectively recognized is the measure of the specificity. It identifies with the capacity of test to recognize negative outcomes.

Specificity=TN/(TN+FP)

(c) Accuracy:

Accuracy is defined as percentage between the number of TP,TN and the total number of data, it can be express in the following equation,

Accuracy=(TN+TP)/((TN+TP+FN+FP))

(d) Precision

For the crack detection process, the Precision is the fraction of derived to find the crack of table instances.

P=|(relevantmatch)⋂(derivedmatch)|/|(relevantmatch)|

(e) F-Measures

The F-measure can be determined by the ratio of precision's harmonic mean value (P) and recall (R)

F=2PR/(P+R)

TABLE I: CRACK DETECTION BASED EVALUATION MEASURES OBTAINED USING OPTIMIZED ADAPTIVE THRESHOLDING METHOD

Input Images	Sensitivity	Specificity	Accuracy	Precision	F-Measure
1	0.849506	0.818718	0.900845	0.8313	0.840304
2	0.839009	0.816799	0.898998	0.839938	0.839473
3	0.841495	0.800075	0.901364	0.839814	0.840654
4	0.839583	0.828927	0.899716	0.839984	0.839783
5	0.840097	0.83	0.900189	0.84	0.840048

The performance of our proposed crack detection work is evaluated and which is shown in the above Table 1.The sensitivity, specificity and accuracy measure for our proposed method achieves high measures. When we compare these evaluation measures for the existing Adaptive Thresholding and Watershed algorithm, gives poor result. In the overall measures for sensitivity, specificity and accuracy for our proposed system OAT achieves an average of 0.841938, 0.818902 and 0.900222 respectively.

B. Comparative Analysis

The below table 2 shows the comparison between existing and proposed method for the sensitivity measures. The graphical representation for the table 2 is shown in the following figure 3.

TABLE II. COMPARISON OF PROPOSED AND EXISTING SENSITIVITY MEASURES

Input Images	Proposed OAT	Existing AT	Existing Watershed
1	0.849506	0.786125	0.801957
2	0.839009	0.786576	0.799335
3	0.841495	0.784225	0.802729
4	0.839583	0.785115	0.799817
5	0.840097	0.755163	0.791273

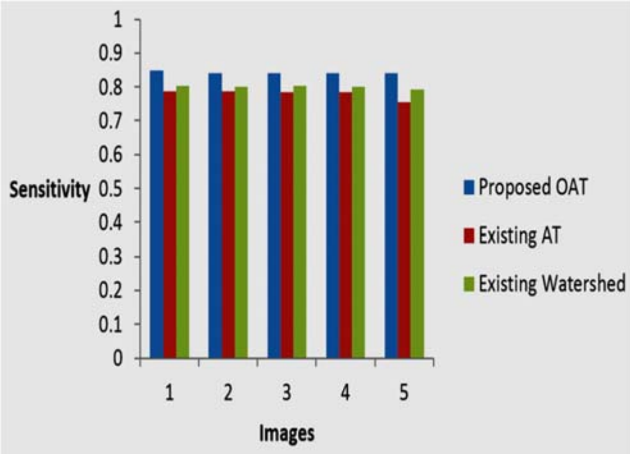

Figure 3: Graphical Comparison of Sensitivity measures

The existing approaches yield the poor result. The below table 3 shows the comparison between existing and proposed method for the specificity measures. The graphical representation for the table 3 is shown in the following figure 4.

TABLE III. COMPARISON OF PROPOSED AND EXISTING SPECIFICITY MEASURES

Input Images	Proposed OAT	Existing AT	Existing Watershed
1	0.818718	0.782202	0.771101
2	0.816799	0.800495	0.790198
3	0.800075	0.792643	0.782569
4	0.828927	0.790901	0.786695
5	0.83	0.811842	0.793092

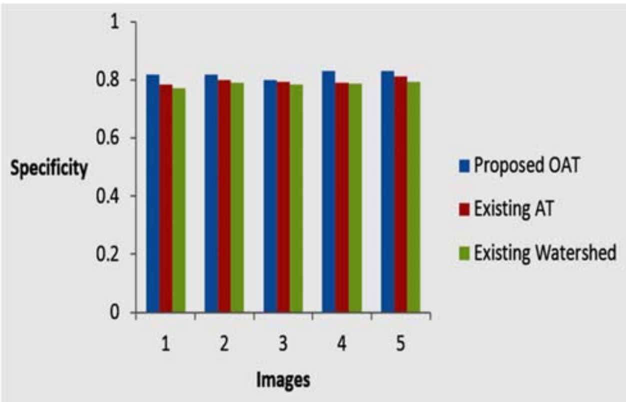

Figure 4. Graphical Comparison of specificity measures

For the categorization of proposed crack detection system makes use of optimal adaptive thresholding technique. In our proposed methodology the highly efficient accuracy is achieved while compare with an existing approaches as Adaptive thresholding technique and watershed algorithm. The comparison results are illustrates in the following table 4 and the graphical representation of an accuracy measure for table 4 is shown in the following figure 5.

TABLE IV. COMPARISON OF PROPOSED AND EXISTING ACCURACY MEASURES

Input Images	Proposed OAT	Existing AT	Existing Watershed
1	0.900845	0.866078	0.881957
2	0.898998	0.866871	0.879335
3	0.901364	0.864583	0.882729
4	0.899716	0.865056	0.879817
5	0.900189	0.835225	0.871273

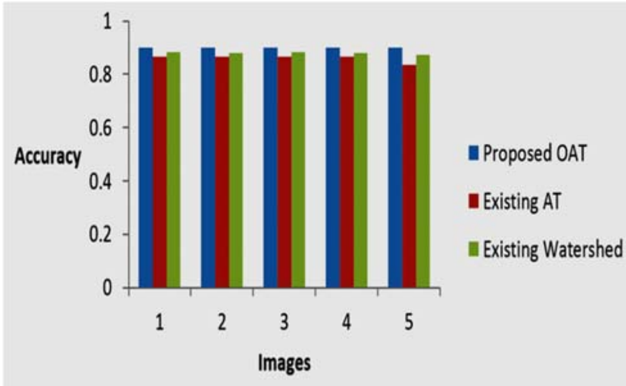

Figure 5: Graphical Comparison of accuracy measures.

IV. CONCLUSION

The proposed Optimized Adaptive Thresholding procedure is the best one which is reasonable for image segmentation by thoroughly contemplating the spatial dissemination, geometric and surface choices of cracks. LDP algorithm is used to ascertain the angle estimations of image edges and locate the trademark estimations of the pixels every which way. This algorithmic control is usually connected to decide the particular edges in the specific image. Finally the parameter estimation of the proposed technique is evaluated by means of sensitivity, specificity, accuracy, precision and F-measure for a spread of various cracks. It is found that the proposed method gives better accuracy compared to existing adaptive thresholding method and watershed method for crack detection.

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