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An Image Processing Approach for Detection of Surface Defects in Laser Hardfaced Stellite-6 Surfaces

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ABSTRACT

This study is intended to propose a new method for explicit analysis of surface defects using Computer Aided Deduction (CAD) system. In this investigation an intelligent scheme is proposed to perform the filtering process in the preprocessing stage by using Proposed Hybrid Gaussian Filter (PHGF). Manual quality control is always associated with a certain degree of variation in both throughput and accuracy an automated vision system can improve both of these significantly and this study aims to develop such a computer aided system for the specific application for surface defect detection in the laser hardfaced surface of Stellite-6. In this work the microstructure images of Stellite-6 Laser Hardfaced samples have been investigated. In this phase, Scanned Electron Microscopic (SEM) image is acquired and noises from those images are removed using Proposed Hybrid Gaussian Filter (PHGF). Which performs the three-step ranking operation from different spatial directions on the image data that offers higher Peak Signal to Noise Ratio (PSNR) value of 50.007dB and lower the Mean Square Error (MSE) value of 11.796. The performance results show that the Proposed Hybrid Gaussian Filter (PHGF) outcomes better results compare to Mean filter, Median filter, Wiener filter and Gaussian filter, in terms of Mean Square Error (MSE), Mean Absolute Error (MAE), Peak Signal to Noise Ratio (PSNR), Entropy-1, Entropy-2 and Image Enhancement Factor (IEF). This analysis helps to select the filter and best combination of process parameters along with the less surface defects.

Keywords: Routing, non-repudiation, Byzantine failure, MANET, Security, Authentication, Integrity, Non-

I. INTRODUCTION

The aim of this study is to develop Computer Aided Detection (CAD) system for the detection of surface defects present in the laser hardfaced surfaces of Stellite-6 using Heuristic Algorithms. Auditing the quality of products is more critical task in the modern industrial manufacturing with the global developments in the manufacturing industry. Nondestructive visual inspection techniques are in high demand for defect detection and localization. The process of manual inspection is very risky, labor intensive and tends to be erroneous. Since it purely depends on the psychology and experience of the human observer and is often influenced by his prior knowledge about the object under inspection. As visual monitoring systems require same type of images over and over again to recognize the anomalies, an automated surface inspection technique is the only immediate alternative to human inspector in order to detect the abnormalities which deviate from the actual pattern. The surface defects generally result from textural irregularities on the outer surface. Hence, irregularities on surface are the main concern for visual surface inspection techniques. These methodologies have innumerous applications on various surfaces like wood, steel, wafer, ceramics, etc., yet they have extensive applications in industries. Before making them usable in industries they should be examined for flaws. The early detection is the most effective way to reduce serious hazards in the finished products. But it is not possible to detect the defects accurately in the metal surface by using human vision technology. So there is a need for automated solution to detect the defects in the metal surface. The evolution of CAD system has made a giant leap in the effective detection. Furthermore, it can help to get better sensitivity, cost effectiveness and less time-consumption. The association of CAD (Computer Aided Deduction) system is highly application dependent. Some systems are stand-alone applications which solve a specific measurement or detection problem, while others constitute a sub-system of a larger design etc. Computer vision offers solutions to formidable data acquisition and exploitation challenges.

Figure 1. Scanned Electron Microcopy (SEM)

II. SURFACE DEFECT DETECTION IN METALS USING IMAGE PROCESSING TECHNIQUES

The five stages of image processing technique are Image Acquisition, Image Enhancement, Image Segmentation, Feature extraction and Classification. The laser hardfacing, experimental runs were carried out on 304 Stainless-Steel plate using cobalt based (Stellite-6) hardfacing powder. The upper limit was coded as + 2 whereas the lower limit -2 by using the input parameters and their working range. The design matrix was developed and the experiments were conducted as per the design matrix consisting 30 set of experiments. After hardfacing the deposit was cut into small samples by using Electrical Discharge Machining (EDM) for scanned electron microcopy (SEM) images and these images are used for detection of defects using CAD system.

2.1 Image Acquisition

A Scanned Electron Microscope (SEM) image of the Laser hardfaced samples is captured and stored in a data base. Image capture devices is used to view and reproduce images of the sample, these devices include scanners and microscopes. SEM images are being converted to gray scale image and then processed for further steps. Performing image acquisition in image processing is always the first step in the work flow sequence because, without an image, no processing is possible.

2.2 Image Enhancement

This mainly refers to initial processing of SEM image. The microscopic image captured are transferred into computer, these are converted to digital image. Digital images are digits which are readable by computer and are converted to tiny dots or picture elements representing the real objects. In some cases, pre-processing is done to improve the image quality by removing the undesired distortions referred as noise and to enhance the details. In this work image enhancement / filtering is done using various filters such as Mean, Median, Wiener, Gaussian and PHGF.

2.3 Image Segmentation

Image segmentation is a process of cutting, adding and feature analysis of microscopic images aimed at dividing an image into regions that have a strong co-relation with objects or area of interest using the principal of matrix analysis. The main objective is to partition an image into mutually exclusive and exhausted region, hence each Region of Interest (ROI) is spatially contiguous and the pixels within the regions are homogeneous with respect to a predefined criterion. In the proposed system, the segmentation is performed using Kernel Fuzzy C Means (KFCM) and Correlation Super Pixel Segmentation (CSPS).

2.4 Feature extraction

Feature extraction is a key step in most pattern analysis tasks. Discrimination, Reliability, Independence and optimality are major factors to be considered in feature extraction. In this phase, Component Analysis method is employed and the significant features of the image such as color moment, color auto correlogram, Edge detection, shape detection and Histogram are quantified.

2.5 Classification

The extracted features are interpreted automatically using knowledge about the analyzed image in order to evaluate its quality. In this work Support Vector Machine (SVM) and Support Vector Machine Kernel

Trigger (SVMKT) programming classifier is proposed and implemented.

Figure 2. Laser Hardfaced samples

III. PERFORMANCE EVALUATION FOR VARIOUS FILTERS

The validation of enhancement is subjective as the visual assessment is enough to evaluate the improved performance. However, in this work Mean Square Error (MSE), Mean Absolute Error (MAE), Peak Signal to Noise Ratio (PSNR), Entropy-1, Entropy-2 and Image Enhancement Factor (IEF) are used as a performance metric. The selection of best filter is achieved by adding Salt and pepper noise density to that SEM images and thereby evacuating it for utilizing suitable filters. In this investigation mean, median, wiener, Gaussian and the suggested PHGF were employed and based upon the performance metrics the best filter is figured out.

3.1 Mean Square Error (MSE)

MSE value must be minimum for a good filtering output. Analysis of MSE produces the error value by summing up the squared pixel value of all the pixel images and it is divided by the total pixel count. It is evaluated by the following formula.

$$MSE = \frac{1}{mn}\sum_{i-0}^{m-1}\sum_{j-0}^{n-1}[I(i,j) - K(i,j)]^2 \quad (1)$$

Where, m=Number of rows; n=Number of columns; I=Input image; K= Reconstructed image.

3.2 Mean Absolute Error (MAE)

MAE is used to measure the average magnitude of the error. It outcomes as the accuracy of the observation. MAE has to be minimum for the better filter output.

$$MAE = \frac{1}{mn}\sum_{i-0}^{m-1}\sum_{j-0}^{n-1}[|I(i,j) - K(i,j)|] \quad (2)$$

Where, m=Number of rows; n=Number of columns; I=Input image; K=Reconstructed image.

3.3 Peak Signal to Noise Ratio (PSNR)

Peak Signal to Noise Ratio outcomes the relationship between the signal and noise pixels of the image. It is inversely proportional to the MSE value and directly proportional to the logarithm of data pixel value. For the optimum filtering output the PSNR value needs to be higher. The PSNR (in dB) is characterized as.

$$PSNR = 20\log_{10}(MAX) - 10\log_{10}(MSE) \quad (3)$$

3.4 Entropy-1

Entropy-1 is the negative summation of the product of pixel points and the logarithm. It is calculated using the following formula.

$$Entropy - 1 = \sum_{i=0}^{n-1}[p(i)\log_2(p(i))] \quad (4)$$

3.5 Entropy-2

It is the absolute expected value of the data which is calculated by second order product values.

$$Entropy - 2 = \sum_{i=0}^{n-1}[p(i)^2.\log_2(p(i)^2)] \quad (5)$$

Where, p = histogram of the image; n = number of element in the histogram.

3.6 Image Enhancement Factor (IEF)

Image enhancement factor validates the enhanced factor of the images by comparing each and every pixel points which are modified after denoising. For better filters the IEF factor should be maximum. IEF is calculated using the following formula.

$$IEF = \frac{\sum_{i=0}^{m-1}\sum_{j=0}^{n-1}[N(i,j)-O(i,j)]^2}{\sum_{i=0}^{m-1}\sum_{j=0}^{n-1}[D(i,j)-O(i,j)]^2} \quad (6)$$

m= Number of rows, n = Number of columns, O = Original image, N=Noisy image,
D= Denoisy image

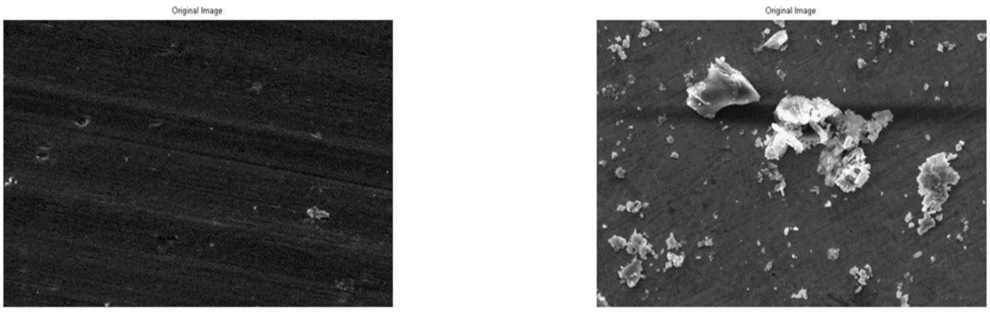

Figure 3. Scanned Electron Microscope Images for Evaluation of Filters

IV. PERFORMANCE EVALUATION OF THE FILTERS:

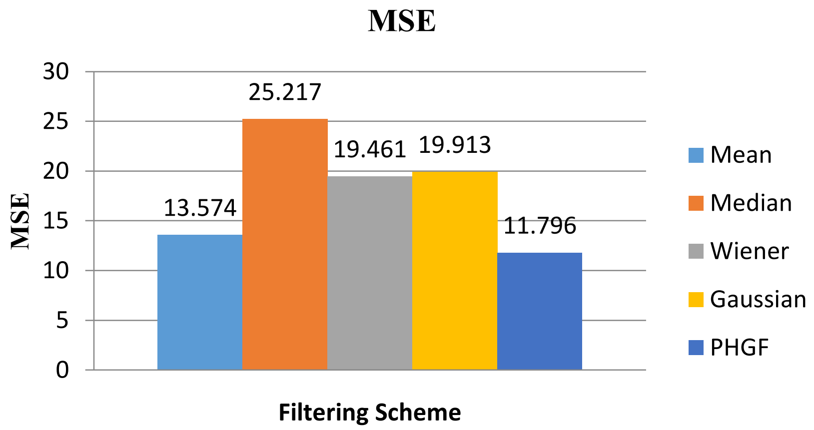

Figure 4. Average Mean Square Error of various filters for laser hardfaced images

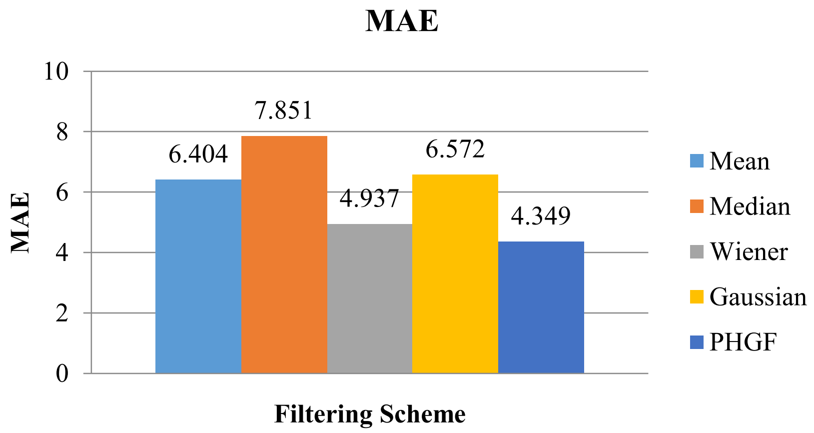

Figure 5. Average Mean Absolute Error of various filters for laser hardfaced images

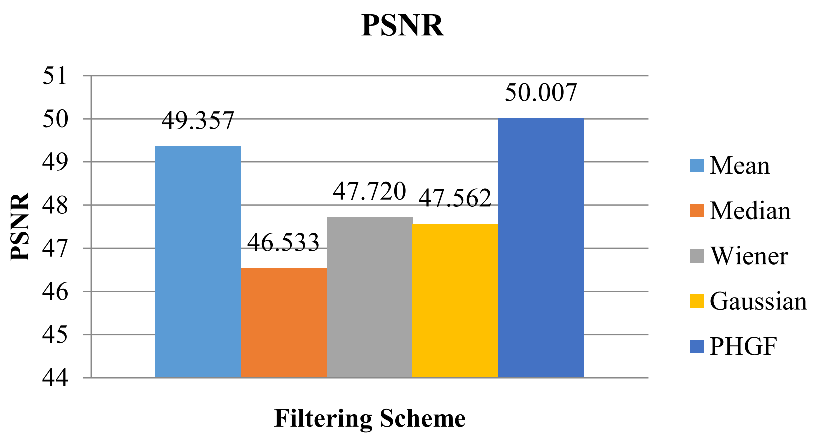

Figure 6. Average PSNR of various filters for laser hardfaced images

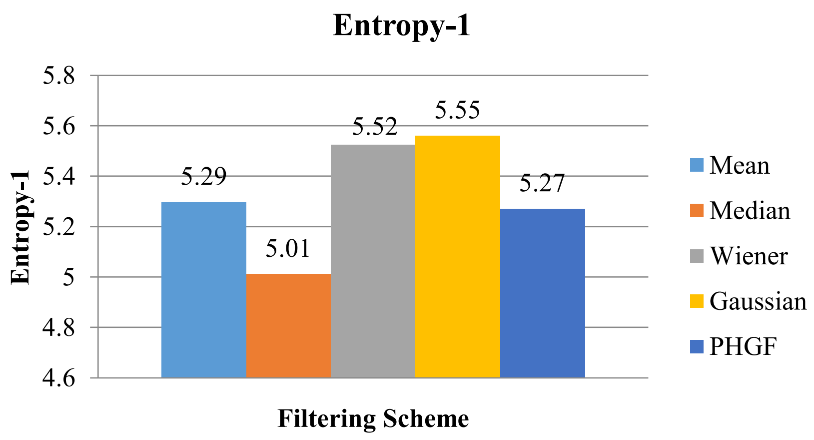

Figure 7. Average Entropy-1 of various filters for laser hardfaced images

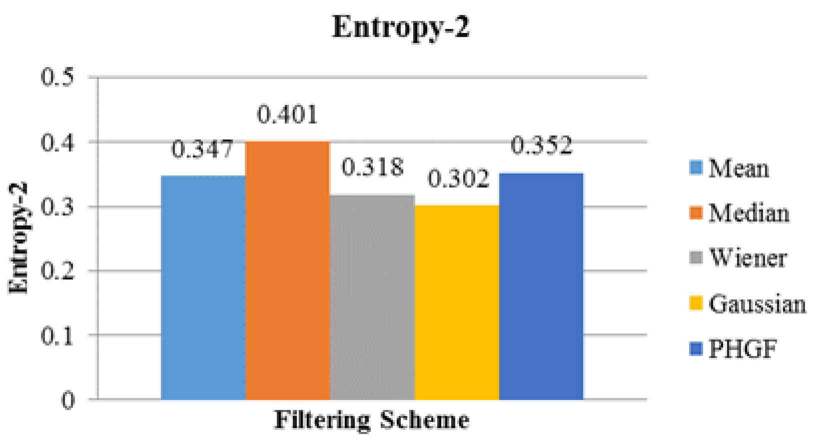

Figure 8. Average Entropy-2 of various filters for laser hardfaced images

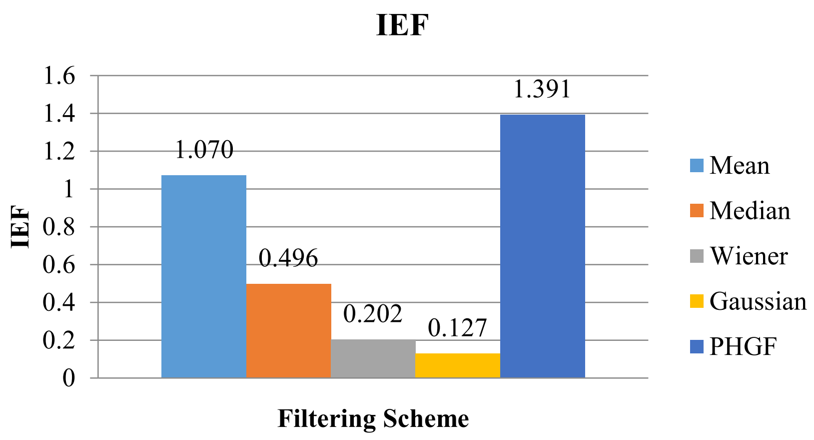

Figure 9. Average IEF of various filters for laser hardfaced images

In Figure: 4 depicts the Average performance of filters in terms of Mean Square Error (MSE). The average Mean Square Error (MSE) levels of filters are from 11.796 to 25.217. In this comparison the proposed PHGF generates the lowest Mean Square Error (MSE) value of 11.796. Lowest Mean Square Error (MSE) ensures the better filtering noise. Mean filter produces next better level of Mean Square Error (MSE) value with the average of 13. 574. In Figure:5 depicts the average performance of filters are in terms of Mean Absolute Error (MAE). The average MAE levels of filters are from 4.349 to 7.851, in this comparison, the PHGF consequences the lowest level of MAE value and that is 4.349 Lowest MAE indicates the better filtering noise. Wiener filter produces next better level of MAE value with the average of 4. 937. In Figure: 6 The average performance of filters is depicted in terms of Peak Signal to Noise Ratio (PSNR). These average levels of filters are from 46.533 dB to 50.007 dB, in this comparison, the proposed PHGF ensures the highest level of PSNR value and that is 50. 007, The higher the PSNR value authenticates the better noise filtering. In Figure: 7 shows the Entropy-1 of various filters. In this comparison PHGF consequences the average level of Entropy-1 value and that is 5.27. In Figure: 8 shows the Entropy-2 of various filters, it depicts the Average performance of filters in terms of Entropy-2. These average values of filters are lies from 0.302 to 0.401. In this comparison, PHGF achieves the average level of Entropy-2 value as 0.352. The average PSNR value authenticates the better noise filtering. In Figure: 9 average level Image Enhancement Factor (IEF) for images is demonstrated for all existing filter approach and PHGF. The Estimated IEF values are lies between 0.127 and 1.391. Among these filters, Proposed Hybrid Gaussian Filter (PHGF) produces higher IEF value as 1.391, hence we use PHGF for image enhancement and further the image segmentation, Feature extraction and Classification are carried out and the defect ratio is calculated.

V. DEFECT RATIO

Percentage of defect present in the Stellite-6 Laser hardfaced Surface can be calculated from the values of true positive, true negative, false positive, false negative, total number of pixel point in the image and number of pixel points in the classified output.

$$Percentage\ of\ defects\ =\frac{(TP\ +\ FN)}{\left[\frac{(TP+FP+TN+FN)\ *\ NCP}{IR}\right]} \qquad (7)$$

Where,

TP = True positive
TN = True negative
FP = False Positive
FN = False Negative
NCP = Number of classified pixels
IR = Image Resolution (width x height)

SAMPLE No	DEFECT RATIO	SAMPLE No	DEFECT RATIO
1	0.463223	16	0.141434
2	0.379865	17	0.393553
3	0.417204	18	0.383015
4	0.318325	19	0.351067
5	0.377758	20	0.266534
6	0.330189	21	0.13555
7	0.237146	22	0.020574
8	0.120001	23	0.427852
9	0.245343	24	0.306537
10	0.204594	25	0.01432
11	0.273521	26	0.102101
12	0.156528	27	0.089544
13	0.220133	28	0.109278
14	0.211727	29	0.10661
15	0.184878	30	0.086569

Table 1. Defect ratio for various laser hardfaced samples

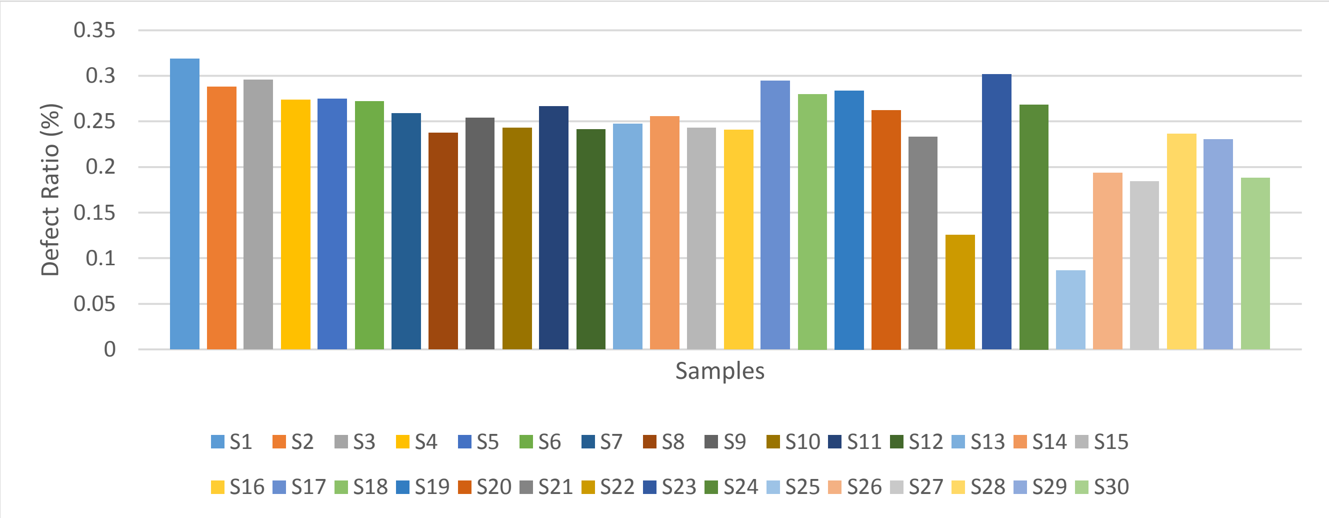

Figure 10. Defect ratio of the Stellite - 6 Laser hardfaced samples

From Figure: 10 It is evident that the surface defects present in the hardfaced surface vary for different samples. Sample number 1 and 23 shows more surface defects when it is hardfaced with stellite-6. Sample numbers 25 and 22 shows less defects. Further, this analysis helps to select the best combination of process parameters along with the less surface defects.

VI. CONCLUSION

In this work, an intelligent scheme is proposed to perform the filtering process in the preprocessing stage by using Proposed hybrid Gaussian filter (PHGF). The microstructure images of Stellite-6 Laser Hardfaced samples have been investigated. The performance results show that the proposed PHGF filter outcomes better results compare to Mean filter, Median filter, Wiener filter and Gaussian filter, in terms of Mean Square Error(MSE), Mean Absolute Error (MAE), Peak Signal to Noise Ratio(PSNR), Entropy-1, Entropy-2, Image Enhancement Factor (IEF). In this phase the Scanned Electron Microscopic (SEM) image is acquired and noises from those images are removed using Proposed Hybrid Gaussian Filter (PHMF) which performs the three-step ranking operation from different spatial directions on the image data that offers higher PSNR value of 50.007 dB and lower the MSE value of 11.796. This analysis helps to select the filter and the best combination of process parameters along with the minimum surface defects.

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