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SURFACE DEFECTS DETECTION OF SILVER IMPREGNATED GRAPHITE CONTACT OF RAILWAY SIGNALLING RELAY USING IMAGE QUALITY ASSESSMENT

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ABSTRACT

In recent days, quality control of different industries is performed using image processing. Deformities recognition, a significant part of image processing, which provides different graded image by analyzing the distorted image with referred image, is an imperative approach for industrial purpose. This image based grading could evaluate the quality of the product. Here, this image processing is used to study and measure the failure analysis of metal to carbon relay, a significant component of Indian railway signalling system. These signaling relays consist of silver Impregnated Graphite (SIG) and silver contact which compose and split as per signaling logic to operate different signaling components. A skinny sheet of Oxide, sulphides forged on the surface of the SIG contact, which originates high resistance on the relay. Facet of the SIG contact has been damaged. The reliability of the metal-carbon relay is poor. Rail security and rapidity has interrupted by extraordinarily high contact resistance. In this work failure study of SIG contact has done using image quality analysis.

KEYWORDS

Signalling Relay, Image Processing, Reliability, Image quality Analysis.

1. INTRODUCTION

Metal to carbon relays is used in signaling system in Indian railway to operate various signaling components viz. Track circuits /points / signals etc. These relays have mainly two types of contact namely, silver Impregnated Graphite (SIG) and silver contact, which keeps close and open continuously as per signaling logic. Due to substantial stress, environmental impacts guide to the irregularities on the signalling relay of the silver impregnated graphite surface. The surface texture of metal to carbon relay contact is an important feature, for quality assessment of deformed surface. A thin layer of Oxide, Sulphides is formed on the surface of the SIG contact, which causes high resistance on the relay. Failure of these relays cause interruption in train movement and delays the time schedule. There are many causes of relay defects viz. high contact resistance, sulphation of spring/connector, coil defects, entree of ants inside the relay, breakage of armature etc. Hence, the reliability of these relays is very poor (Khagra, 2013).

Image samples of defected relays are collected in this work. Image-based grading has been applied on these images to analyse the deformation of the relays. Image quality estimation is most predominant features for various type of image processing application.

Human Vision System (HVS) is one of the most complicated methods with psychological activities, in image processing. HVS extract structural information from the viewing scene (Wang and Bovik, 2004). Image quality describes by HVS according to the sharpness of the image. In another approach, pixel by pixel difference method, a reference image and defective images are compared pixel by pixel, in the direction of evaluate

the quality of the image. MSE and Peak signal to noise ratio algorithms are the popular examples of the pixel by pixel difference method, have been adopted to appraise the quality from earlier.

In this regard, a study proposed SSIM index model based on error sensitivity model. The structural similarity has applied to JPEG compressed image to find structural distortion. This approaches significantly different from traditional SSIM indexing algorithm. No reference model appropriate for this approach (Wang and Bovik, 2004).

In another work, in a previous research (FR-IQA), numerous algorithms have been used in their work Structural similarity index(SSIM), Multi-scale similarity index measure(MS-SSIM), Visual information fidelity(VIF), Most apparent distortion(MAD), Feature similarity measure(FSIM), Feature similarity measure for colour images(FSIMC), Dynamic range independent measure (DRIM) and Tone mapped images quality Index (TMQI).

This work is essential for multimedia application (Mohammadi and Moghadam, 2015). Without concentrating one particular feature of reference image and distorted image. Based on a recent study has done a comparative study of objective image quality algorithms and quality index with different types of data sets (Ruikar and Sinha, 2014). MSE, PSNR, SSIM has been applied on these data sets, which takes less time to figure out the quality information with respect to other algorithms. Previous research has analysed objective type full reference image quality metrics. PSNR and SSIM algorithms have been applied on various degraded images. They have found a correlation between them, sensitivity changes according to the intensity of degradation (Hore and Ziou, 2010).

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Another type is Correlation measurement with the reference image and defective image (Wang et al., 2002). Defects has been identified by this method. Image quality assessment is mainly of two type- subjective quality assessment and objective quality image assessment. Objective quality assessment is commonly used in image processing applications. In this proposed work we applied image processing to exhibit quality and degradation measure of the signaling system.

A recent study proposed a metric based analysis of distortion process. In the proposed model of Full reference image quality assessment, the degradation process is linearly mapped from an original pixel to corresponding distorted pixel (Ma and Jiang, 2017). To analysis the mapping weights they have utilized linear regression analysis. In another work, a research has applied image quality assessment through statistical approach to estimate the unpredictability of the IQA objective method. He has done a case study on noise affected images (De Angelis et al., 2007).

Based on a previous research on real time defect detection methodologies and proposed a system to monitoring deformation on the cast extrusion manufacturing (Iyer and Subbaih, 2014). Defects originate from various stages of manufacturing industries (Tsai and Tseng, 2006). Failure study and proper classification of failure degree using failure image is another challenging job in this proposed work.

In this proposed work defected image samples have been collected and pre-processed for further quality assessment with respect to PSNR, MSE and SSIM. This paper is organized as follows. Section II describes the Image quality assessment methods and types. Section III describes the mathematical formulation of the proposed system. Section IV describes the flowchart and Algorithm. Conclusion is explained briefly in Section.

1.1 Image quality Assessment

Quality measurement of a photograph is an essential aspect for image processing technique as discussed earlier. In recent years numbers of approaches have developed to estimate the degree of excellence of the image. Quality of the portrait is a characteristic. Degradation of a photograph can be estimated by comparing with the reference perfect photograph. Quality deterioration of a photograph happened due to frequency distortion, noise, blurring, fading etc. which makes the entire image distorted.

As discussed earlier quality assessment of an image is of two types- subjective and objective. In subjective quality assessment method by human appraise the image quality through mean opinion score (MOS) method. Human Visual System (HVS) extricate structural information from the observing territory. So, Image distortion estimation through structural distortion should be a good practice. In the objective method standard of the image estimated through different algorithms. Depending on the presence of reference image, objective quality assessment is categorized into three types- full reference, reduced reference and no reference. In full reference, allusion image and distorted image required for the detailed analysis. In reduced reference, image is partly available, and no reference image is available for assessment, blindly estimated.

1.2 Full-Reference Model

In objective image quality assessment is done by difference measuring between original image and distorted image. Image quality describes by the mathematical model, this method is fast, stable and easy to quantify. The most widely used full reference quality metric is mean squared error (MSE), calculated by averaging the squared intensity difference of reference and distorted image pixels, along with associated variety of peak signal- to-noise ratio (PSNR). Statistical characteristics of image error has explored through PSNR and MSE.

1.3 Reduce-Reference Model

In this model partial information of the reference picture is used which is not directly related to degradation. Mutilated picture quality quantifies this mode. In this procedure the reference picture is simply partially open, as a course of action of isolated segments made available as side information to evaluate the way of the contorted picture.

1.4 No-Reference Model

No reference model has no information of the reference image. This is also called "blind model" method. These model work as human visual framework which does not has a source to estimate.

2. MATHEMATICAL MODELLING

Image quality Assessment found on Structural distortion proposed by Zhou wang [2,3]. This

$$Q = \frac{4\sigma_{I_{ref}I_{dis}}\overline{I_{ref}I_{dis}}}{(\sigma_{I_{ref}}^2 + \sigma_{I_{dis}}^2)(\overline{I_{ref}}^2 + \overline{I_{dis}}^2)} \quad (1)$$

Where $\overline{I_{ref}} = \frac{1}{N} \sum_{i=1}^N I_{refi}$, $\overline{I_{dis}} = \frac{1}{N} \sum_{i=1}^N I_{disi}$

$$\sigma_{I_{ref}}^2 = \frac{1}{N-1} \sum_{i=1}^N (I_{refi} - \overline{I_{ref}})^2$$

$$\sigma_{I_{dis}}^2 = \frac{1}{N-1} \sum_{i=1}^N (I_{disi} - \overline{I_{dis}})^2$$

$$\sigma_{I_{ref}I_{dis}} = \frac{1}{N-1} \sum_{i=1}^N (I_{refi} - \overline{I_{ref}})(I_{disi} - \overline{I_{dis}})$$

Quality Index model of any distortion based on three different factors: loss of correlation, mean distortion, and variance distortion.

MSE defined as:

$$MSE = \frac{1}{M \times N} \sum_{i=1}^M \sum_{j=1}^N (I_{ref}(ij) - I_{dis}(ij))^2 \quad (2)$$

Where I_{ref} is the Reference image and I_{dis} is the distorted image, $M \times N$ are the width and height of the image. Compression ratio increases when MSE value increases. When pixel by pixel matching of images become perfect, MSE value becomes zero.

Peak Signal to Noise Ratio: Is a ratio between maximum possible power of a signal and the power of corrupting noise that affects the fidelity of its representation.

$$PSNR = \frac{\log_{10} L^2}{MSE} \quad (3)$$

In the above equation L is the dynamic range of the pixel values. Maximum dynamic range is 255 of 8 bit depth Sample.

Structural Similarity Index (SSIM)

This is a measuring loss of the image structure. In SSIM, measuring picture quality which has been hypothesized the distortion come from variation in lighting, contrast and brightness. Information is given about three aspects of information loss, all are complementary with each other luminous distortion, contrast distortion and correlation distortion. SSIM is given by the equation

$$SSIM = \frac{(2\overline{I_{ref}I_{dis}} + c_1)(2\sigma_{I_{ref}I_{dis}} + c_2)}{(\overline{I_{ref}}^2 + \overline{I_{dis}}^2 + c_1)(\sigma_{I_{ref}}^2 + \sigma_{I_{dis}}^2 + c_2)} \quad (4)$$

3. ALGORITHM

Input: Reference Image (I_{ref}), Sample Images ($I_{dis1}, I_{dis2}, I_{dis3}, I_{dis4}, I_{dis5}, I_{dis6}, I_{dis7}, I_{dis8}$), Maximum Dynamic Range of Pixel value ($L = 255$), Positive stability constant ($C1, C2$)

Output: Quality Index (Q), Mean Square error (MSE), Peak signal to Noise Ratio (PSNR), Structural Similarity Index Measure (SSIM)
Begin Algorithm:

Step 1: convert RGB Image to gray scale Image.

Step 2: For computation of Quality Index $I_{ref} = \{I_{refi} | i = 1, 2, \dots, N\}$ and $I_{dis1} | i = 1, 2, \dots, N\}$, similarly $I_{dis2}, I_{dis3}, I_{dis4}, I_{dis5}, I_{dis6}, I_{dis7}, I_{dis8}$ has been taken. From Equation No (1)

$$Q = \frac{4\sigma_{I_{ref}I_{dis}}\overline{I_{ref}I_{dis}}}{(\sigma_{I_{ref}}^2 + \sigma_{I_{dis}}^2)(\overline{I_{ref}}^2 + \overline{I_{dis}}^2)}$$

Step 3: Computing the mean value of I_{ref} and I_{dis} in the denominator of step 2

Step 4: Computing the standard deviation of I_{ref} and I_{dis} in the denominator of step 2

Step 5: Computing the Co-Variance of I_{ref} and I_{dis} in numerator of step 2

Step 6: Computing Mean Square Error of I_{ref} and I_{dis} as below Equation No (2)

$$MSE = \sum_{i=1}^M \sum_{j=1}^N (I_{ref}(ij) - I_{dis}(ij))^2$$

Step 7: Computing peak signal to noise ratio of I_{ref} and I_{dis} , MSE value calculated from step 5 from Equation No (3)

$$PSNR = 10 \log_{10} L^2 / MSE$$

Step 8: Computing structural similarity Index measure (SSIM) of I_{ref} and I_{dis} as below, Equation No (4)

$$SSIM = \frac{(2I_{ref}I_{dis} + c1)(2\sigma_{I_{ref}I_{dis}} + c2)}{(I_{ref}^2 + I_{dis}^2 + c1)(\sigma_{I_{ref}}^2 + \sigma_{I_{dis}}^2 + c2)}$$

4. RESULT

Signalling relay, QN1 series line relays has used with sixteen no of contacts. This is divided into four vertical columns (A.B.C.D). In this work column A has taken for the experiment. In this work, One QN1 relay is unused and other one is defected. Silver impregnated graphite (SIG) relay contacts have collected from these relays. Size of 7x5 mm. In this proposed work A, B and C columns have been used, twenty samples of used relays have collected.

Table 1: Image of samples		
SAMPLE NUMBER	IMAGE OF THE SAMPLES	DISTORTED AREA OF EACH SAMPLE
Original/Reference Image		No distortion
Sample Image 1
Sample Image 2
Sample Image 3
Sample Image 4
Sample Image 5
Sample Image 6
Sample Image 7
Sample Image 8
Sample Image 9
Sample Image 10

Figure 1: Gray scale Images of Reference and Distorted

Table 2: Numbers of knocking per samples	
Sample No	No of Knocking
1	2260
2	3580
3	15770
4	22390
5	18768
6	32856
7	15689
8	22,780
9	82545
10	90622
11	86344
12	46880
13	68655
14	25899
16	26782
17	54689
18	14866
19	22832
20	46872
21	45322
22	68435
23	72845

Figure 2: Different Knocking Samples

Full reference image quality assessment viz. Peak signal to noise ratio (PSNR), Mean Square Error(MSE), Quality Assessment and Structural Similarity Index(SSIM) etc. have been applied on the sample images. Degradation level varies according to numbers of knocking per samples.

Figure 3: Quality Index, MSE, PSNR vs distorted samples

Table 3: Quality assessment of samples

Sample No	Quality Index	MSE	PSNR	SSIM
1	0.4194	23.5453	34.4118	0.1924
2	0.9932	36.8356	32.4681	0.1213
3	0.0725	33.3283	32.9027	0.0725
4	0.5390	49.0325	31.2260	0.1562
5	0.2051	11.1938	37.6410	0.1299
6	0.2179	9.6135	38.3020	0.0883
7	0.9555	99.3932	28.1572	0.2671
8	0.9154	38.3539	32.2927	0.1184
9	0.2706	7.4038	39.4362	0.1109
10	0.9763	26.3232	33.9274	0.1110
11	0.4537	15.5716	36.2075	0.0457
12	0.2239	7.2043	39.5549	0.1160
13	0.9456	60.4209	30.3189	0.1016
14	0.4082	15.0906	36.3437	0.1186
15	0.7997	28.2655	33.6182	0.0838
16	0.5701	20.7130	34.9684	0.0523
17	0.2400	3.0070	43.3495	0.3432
18	0.4686	6.0856	40.2878	0.4686
19	0.2051	11.1938	37.6410	0.1299
20	0.2179	9.6134	38.3021	0.0883

Figure 4: SSIM of distorted samples

5. DISCUSSION

Signaling relays life span 1,000,000. Degradation level varies according to numbers of knocking per samples and that particular area might have corrosion in presence of oxygen and due to knocking, deformation happened rapidly. Visual image quality of a digital image identifies the formation and nature of the perceived degradation. In this proposed work an efficient approach for defect detection has been used for analysis of successive failure pattern of Carbon to carbon relay surface due to impact and as well as find out other chemical and environmental aberration of the contact surface. Peak signal to noise ratio (PSNR) and Mean square error (MSE) algorithm have used to measure pixel by pixel difference. To measure structural difference Structural similarity index (SSIM) has used. Here, defective region has been accurately identified but not classified. The characteristics of the defects can be classified in the further studies.

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