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PSNR & Eigen value based rust defect recognition & evaluation of steel coating conditions.

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Abstract: PSNR is one of the most often and universally used method for measuring quality of image. In this paper we propose a methodology for assessment of coating condition of bridge images. The defect recognition algorithm includes conversion of captured images into grey level; these grey level images are grouped into defective & non defective group. Further that is processed to plot correspondence map. The correspondence map is measure of matching image. Straight line with 45^0 in correspondence map indicates no defect in scene image. In contrast if correspondence map produces nonlinear image it indicates defect (rust) in scene image. The nonlinear shape of grey level distribution in correspondence map can be analyzed by calculating Eigen values. Two similar images will produce smaller Eigen value (approximately zero), whereas it will be distinctly large for dissimilar images. The PSNR determines proportion of rust in scene image with relation to reference image.

Keywords: Rust detection, covariance matrix, Eigen values, correspondence map, PSNR, MSE.

I. INTRODUCTION

Bridges are valuable assets of nation. Steel bridges are widely used due to aspects like, easy construction, less time consuming, & cost effective. Apart from this qualities bridge failures have been observed in this century. For example the I-35W Mississippi River Bridge was collapsed on August 1, 2007, resulting in a loss in human lives and properties. Rust, cracks, fatigues are commonly observed characters for failure of steel structures.

In order to ensure the safety of steel bridges, bridge condition should be monitored and assessed in routine inspections. The quality of coating is one of the indexes to judge the condition of steel bridges. Corrosion is an effective chemical process which affects structural integrity & durability of steel structure. Steel structures are designed with many small structural components & fasteners. E.g. bracing & rivets, which are more difficult to protect against corrosion. The application of protective coating is a common preventive measure to protect steel from corrosion. But due to humidity & other water leakages the applied protective coating lasts within a short period, hence causes the problems of rusting. Here is the technique which analyses coating condition of steel structure & detects rust.

II. DEVELOPMENT OF AUTOMATED RUST DEFECT RECOGNITION & EVALUATION METHOD

Automated rust defect recognition & evaluation method includes following stages:

1. Capturing of bridge images & pre-processing. 2. Plotting of correspondence map. 3. Calculation of covariance matrix 4. Eigen value, MSE, PSNR calculations. 4. Data analysis.

A. Capturing bridge images & pre-processing.

Defect detection technique in constructional steel used here starts with capturing defective & non defective image for database. These images are captured using consumer digital camera; two groups are done non defective & defective. Bridge coating images were taken at a distance of around 3 feet (0.92 m) from the steel beam surfaces to acquire clear coating images. From the acquired digital images defective & non defective groups are made for further analysis.

Figure1. Steel coating image without rust defects (Reference image)

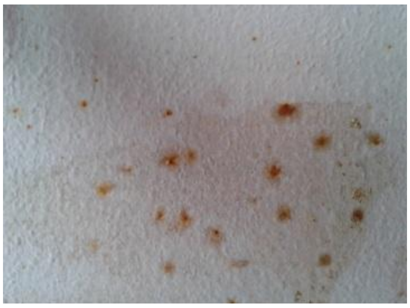

Figure1. Steel coating image with rust defects (Scene image)

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These captured images are grouped into defective & non defective group. Further they are converted into grey levels.

B. Plotting of grey level correspondence map.

Let R(x,y) & S(x,y) be grey levels of respective reference image & scene image at pixel coordinate (x,y) The pair-wise gray values at coincident pixel locations in the two compared images are used as the coordinates to plot the correspondence map, where the *x*-axis is the gray level for the reference image *R*, and the *y*-axis is the gray level for the scene image S.

If two compared images are same then correspondence map will be a diagonal straight line.

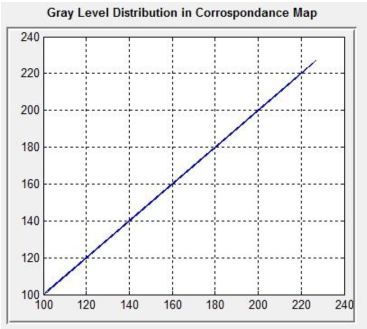

Figure3. Grey level correspondence map of identical images

In contrast if two compared images do not matches i.e. scene image contains rust defect, then correspondence map will be nonlinear shape.

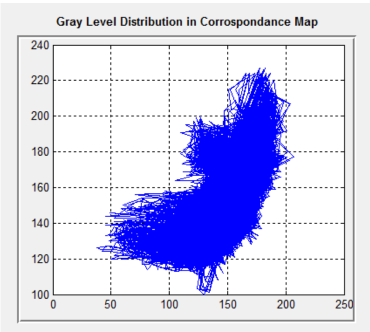

Figure3. Grey level correspondence map of dissimilar images

C. Calculation of covariance matrix:

If the two compared images are non-identical the correspondence map shows an irregular shape which derived from satirical & geometrical properties of Eigen values of covariance matrix of data points in correspondence map.

The covariance matrix M of Reference image R(x, y) & Scene image S(x, y) both of size m×n in grey level correspondence map is given by,

$$M = \begin{bmatrix} m_{11} & m_{12} \\ m_{21} & m_{22} \end{bmatrix} \quad (1)$$

Where

$$m_{11} = \left[\frac{1}{m \times n} \sum_{x=0}^{m-1} \sum_{y=0}^{n-1} S^2(x,y)\right] - (\bar{S})^2 \quad (2)$$

$$m_{22} = \left[\frac{1}{m \times n} \sum_{x=0}^{m-1} \sum_{y=0}^{n-1} R(x,y)\right] - (\bar{R})^2 \quad (3)$$

$$m_{12} = m_{21} = \left[\frac{1}{m \times n} \sum_{x=0}^{m-1} \sum_{y=0}^{n-1} S(x,y).R(x,y)\right] - (\bar{S}.\bar{R}) \quad (4)$$

$\bar{R}$ & $\bar{S}$ are the mean grey values of R(x,y) & S(x,y)

$$\bar{R} = \frac{1}{m \times n} \sum_{x=0}^{m-1} \sum_{y=0}^{n-1} R(x,y) \quad (5)$$

$$\bar{S} = \frac{1}{m \times n} \sum_{x=0}^{m-1} \sum_{y=0}^{n-1} S(x,y) \quad (6)$$

The covariance matrix M is calculated directly from grey level images R(x,y) & S(x,y) . The defective & non-defective images can be differentiated by determining eigen values & correspondence map. For a given non defective (reference) image R(x,y) & defective (scene) image S(x,y) a grey level distribution map can be plotted with coordinates [R(x,y),S(x,y)] for each image pixel. If the two compared images are perfectly identical then the grey level distribution map shows diagonal line. & If the two compared images are different, the grey level distribution map shows nonlinear shape. The eigenvalue measures the shape of grey level distribution.

D. Calculations of eigenvalues, MSE, PSNR:

The two eigenvalues for correspondence matrix can be calculated as,

$$\lambda_L = \frac{1}{2}\left[m_{11} + m_{22} + \sqrt{(m_{11} - m_{22})^2 + 4m_{12}^2}\right] \quad (7)$$

$$\lambda_s = \frac{1}{2}\left[m_{11} + m_{22} - \sqrt{(m_{11} - m_{22})^2 + 4m_{12}^2}\right] \quad (8)$$

$$\lambda_S \leq \lambda_L \quad (9)$$

The eigenvalues extracts the information about the grey-level in correspondence map. λ_L i.e. Larger eigenvalues represents variance of data along major-axis of shape. Where as λ_S represents variance of data along minor axis. When two compared images are identical the correspondence map is straight line & $\lambda_S = 0$ as variance along minor axis of line zero. λ_S Shows distinctly large value, if grey level correspondence map is an irregular shape. Thus smaller eigenvalue is used measure similarity between two images.

Pick Signal to Noise Ratio (PSNR) is the quality measure between reference & scene image. It is the ratio between maximum possible power and corrupting noise that affect the representation of image. It is basically used to measure quality of reconstructed image. Here we are using PSNR to compare the reference & scene image. High value of PSNR indicates great matching between reference & scene image. PSNR id defined via Mean Square Error (MSE)

The PSNR can be calculated by first computing mean-squared error using the following equation.

$$MSE = \frac{1}{MN} \sum_{m=1}^{m} . \sum_{n=1}^{n} [[R(m,n) - S(m,n)]^2 \quad (10)$$

$$\text{PSNR} = 10\log_{10}\left[\frac{(255)^2}{MSE}\right] \quad (11)$$

III. RESULTS & DISCUSSION

In test 1 two identical images are processed, the defect recognition algorithm shows correspondence map as a straight line. With smaller eigenvalue as 0 & larger Eigen value 111.973. In contrast the test results show irregular

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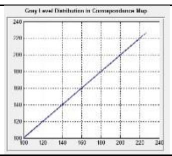
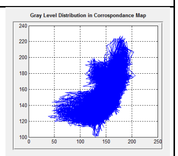
shape in correspondence map & smaller Eigen value 541.607. Thus smaller Eigen value is used to recognize similarity between two images.

TABLE I. Results of automated defect recognition algorithm

Items	Test1	Test2
Reference image		
Image under test		
Correspondence Map		
λ_S	0	541.607
λ_L	111.973	497.73
PSNR	100	13.67
Conclusion	Non defective image (no rust)	Defective image

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