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° 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:

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 grey level for the reference image R, and the y-axis is the grey level for the scene image S.

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

![Grey Level Distribution in Correspondence Map](image)

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.

![Grey Level Distribution in Correspondence Map](image)

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,

\[
M = \begin{bmatrix}
    m_{11} & m_{12} \\
m_{21} & m_{22}
\end{bmatrix}
\]

Where

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

\[
m_{22} = \frac{1}{m \times n} \sum_{x=0}^{m-1} \sum_{y=0}^{n-1} S(x,y) - \bar{S}^2
\]

(1)

(2)

The two eigenvalues for correspondence matrix can be calculated as,

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

\[
\lambda_S = \frac{1}{2} m_{11} + m_{22} - \sqrt{(m_{11} - m_{22})^2 + 4m_{12}^2}
\]

(3)

(4)

\[
\lambda_L \leq \lambda_S
\]

(5)

The eigenvalues extracts the information about the grey-level in correspondence map. \( \lambda_L \) i.e. Larger eigenvalues represents variance of data along major-axis of shape. Where as \( \lambda_S \) 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. \( \lambda_S \) 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)

\[
MSE = \frac{1}{MN} \sum_{m=1}^{M} \sum_{n=1}^{N} \left[ |R(m,n) - S(m,n)| \right]^2
\]

(6)

\[
PSNR = 10 \log_{10} \left[ \frac{255^2}{MSE} \right]
\]

(7)

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
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

<table>
<thead>
<tr>
<th>Items</th>
<th>Test1</th>
<th>Test2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reference image</td>
<td><img src="image" alt="Reference image" /></td>
<td><img src="image" alt="Reference image" /></td>
</tr>
<tr>
<td>Image under test</td>
<td><img src="image" alt="Image under test" /></td>
<td><img src="image" alt="Image under test" /></td>
</tr>
<tr>
<td>Correspondence Map</td>
<td><img src="image" alt="Correspondence Map" /></td>
<td><img src="image" alt="Correspondence Map" /></td>
</tr>
<tr>
<td>( \lambda_S )</td>
<td>0</td>
<td>541.607</td>
</tr>
<tr>
<td>( \lambda_L )</td>
<td>111.973</td>
<td>497.73</td>
</tr>
<tr>
<td>PSNR</td>
<td>100</td>
<td>13.67</td>
</tr>
<tr>
<td>Conclusion</td>
<td>Non defective image (no rust)</td>
<td>Defective image</td>
</tr>
</tbody>
</table>

REFERENCES