Automated Defect Recognition Using Spline Interpolation

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Abstract - Existing infrastructure systems are aged and deteriorated rapidly, state agencies started searching for more advanced way to maintain their valuable assets to the acceptable level. One of them is the application of digital image processing. This problem proposes a digital image processing method to assess a steel bridge coating surface. The image processing method was developed based on B-Spline interpolation and can be used to recognizing the existence of bridge coating rust defects. An automated defect recognition method can make a decision whether a given digitized image contains defects by image comparison.

***Key Words*:**B-Spline interpolation, Digital Image Processing, Automated defect recognition method, Image comparision

1.INTRODUCTION

Recently, in the civil engineering domain, digital image processing methods have been developed to the areas of pavement conditions, underground pipeline inspection, and steel bridge coating assessment (H.D. Cheng et al. 1999, S.K. Sinha et al. 2003, S. Lee al. 2005). These distinct advantages have bought attention to state agencies to minimize the short coming of existing inspection practices. The conditions of steel bridge painting surfaces can be evaluated accurately and quickly by applying digital image processing. Also, Machine vision-dependent inspections can provide more consistent inspection results than human visual inspections. Because conventional inspection heavily relies on individual's abilities, inspection results are error-prone and may have wide variations between inspectors. The result can be different depending on personal preferences, work experiences and the work load of the inspectors. It is pretty important to develop reliable infrastructure condition assessment for better maintenance of the assets. In case of bridge coating, bridge managers can more realistically develop long term coat effective maintenance programs if they have dependable coating condition data. Also, they can make decisions as to whether a bridge shall be painted again immediately or later..

This problem concerns with rust defects on steel bridge. Rust defects are one of the most commonly observed defects on coating surfaces and are to be taken care of appropriately since they can severely affect the structural integrity of bridges and generate unpleasant appearance to passing drivers. A rust defect assessment methods need to be developed to maintain good quality steel bridge painting. For more objective rust defect recognition, digital image recognition methods have been developed for the past few years and they can expect to replace or complement conventional painting inspection methods.

2. DEVELOPMENT OF AUTOMATED DEFECT RECOGNITION METHOD

The methodology for the development of defect recognition method can be classified into two stages: (1) image acquisition, (2) image processing. The detailed description of each stage is given as follows:

- **Image Acquisition:** In the image acquisition stage, steel bridge coating images have to be taken first. Every digital image is acquired by fixing the digital camera in front of the steel bridges. The color of the bridge is generally blue or reddish brown, which are commonly used for painting the steel bridges.
- **Image Processing:** In this image processing stage, original color images are converted to grey-scale images. A color image is consisted of three primary colors: Red, Green and Blue. A color can be generated by numerical proportion of the three components. Each primary color axis has 256 (2^8) levels of color shade, which means a total of 2^{24} colors, can be generated technically from the color space. The origin of the cube corresponds to black and can be designed as (0, 0, 0). The point with (1, 1, 1) indicates white. Three primary colors of red, green and blue are located on each primary axis. If an image has a combination value of (255, 0, 0), it means pure red. Grey-level images are represented by only 8 bits. A value is assign to each pixel according to light intensities ranging from 0 to 255. The value of 0 means black and the value of 1 means white. There are lots of sophisticated gray levels between white and black. Therefore, image sizes can be significantly reduced by converting to grayscale images, while improving computing efficiently.

  B-Spline is a combination of flexible bands that passes through the number of points that are called control points and create smooth curve. These functions enable the creation and management of complex shapes and surfaces using a number of points. B-Spline of degree n is a piecewise polynomial function of degree n-1 in a variable x. It is defined over 1 + n locations t_j, called knots of break points, which must be in non descending order $t_j \leq t_{j+1.}$ The B-Spline contributes only on the range between the first and last of these knots and its zero elsewhere. For each finite interval where it is nonzero, a B-spline is a polynomial if degree n – 1. A B-Spline is a continuous function at all knots. When all the knots belonging to the B-Spline are distinct, its derivatives are also continuous up to the derivative of degree n – 1.If the knots are coincident at the given value x, the continuity of derivative order is reduced by 1 for each additional coincident knots.

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One distinguishes internal knots and end points. Internal knots cover the x domain. Since a single B-Spline is an already extends over 1 + n knots, It follows that the internal knots need to be extended with n – 1 end points on each side, to give full support to the first and last B-Spline which affect the internal knot intervals. The value of the endpoints do not matter, usually the first and last internal knot is just repeated.

The usefulness of B-Spline lies in the fact that any Spline function of order n on a given set of knots can be expressed As a linear combination of B-splines:

$$S_{n,t}(x) = \sum_i \alpha_i \beta_{i,n}(x).$$

B-Splines play the role of basis functions for the spline function space, hence the name. This property follows from the fact that all pieces have the same continuity properties, within their individual range of support, at all knots.

Expression for the polynomial pieces can be derived by means of the Cox-de Boor recursion formula.

$$\beta_{i,0}(x) = \begin{cases} 1 \; if \; t_i \leq x < t_{i+1} \\ 0 \quad\quad otherwise \end{cases}$$

$$\beta_{i,k}(x) = \frac{x - t_i}{t_{i+k} - t_i}\beta_{i,k-1}(x) + \frac{t_{i+k+1} - x}{t_{i+k+1} - t_{i+1}}\beta_{i+1,k-1}(x)$$

That is $\beta_{j,0}(x)$is piecewise constant one or zero indicating which knot span x is in (zero if knot span j is repeated).

The recursion equation is in two parts:

$$\frac{x - t_i}{t_{i+k} - t_i}$$

ramps from zero to one as x goes from t_i to t_{i+k} and $\frac{t_{i+k+1} - x}{t_{i+k+1} - t_{i+1}}$

Ramps from one to zero as x goes from t_{i+1} to t_{i+k+1}. The corresponding Bs are zero outside those respective ranges. Here by Spline smoothing input image can be used to extract the shape of information about the grey level distribution in the pair wise comparison. B-Splines are usually defined as being left-continuous. De Boor gives fortant routines for least squares fitting to experimental data.

3. ALGORITHM OF AUTOMATED DEFECT RECOGNITION

- Input the image
- Convert the image to grayscale
- Apply B-spline smoothing to the image
- Intensity adjustment
- Histogram equalization
- Display histogram graph

4. EXPERIMENTAL RESULT (DEFECT RECOGNITION)

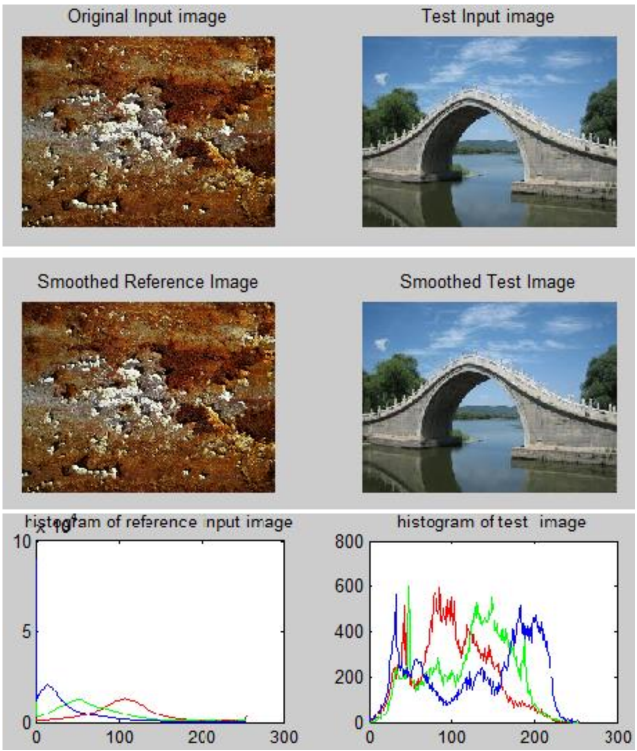

Fig. Image comparision when compared image mismatches original image

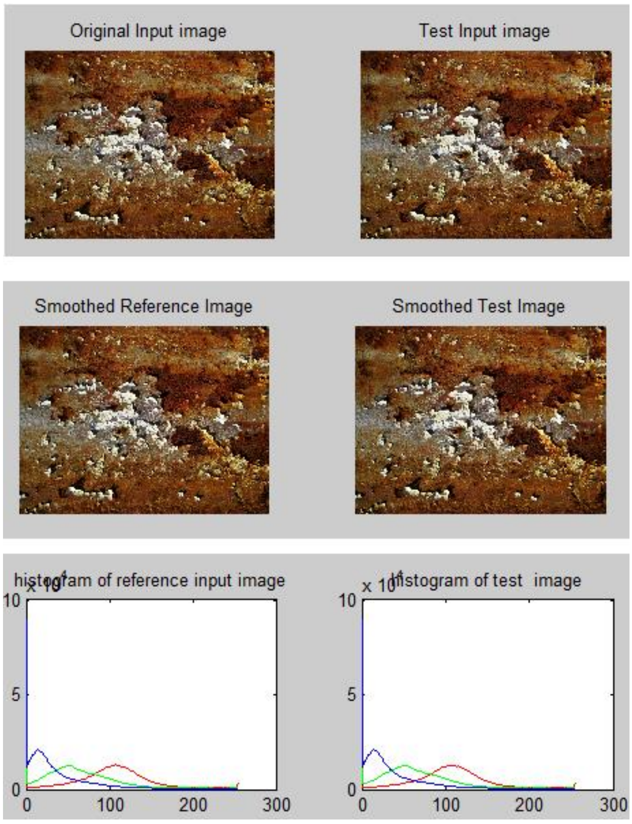

Fig. Image comparision when compared image matches original image

3. CONCLUSION

Bridge coating images were processed and spline smoothing is applied on the images. Two kinds of pair-wise comparisions were perfomed: non-defective image with the defective image and defective image with the defective image. 105 data points were obtained from the comparision with defective image. Also 225 data points were achieved from the comparision of a non-defective image with the defective image.

The result of the comparisions are also shown using the histograms graph. Too much of variation were visible in the histogram graph of comparision of non-defective image with the defective image. On the other hand, the histogram graph of the comparision of defective image with defective image matched exactly.

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The heading should be treated as a 3rd level heading and should not be assigned a number.

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