Title	Improved image analysis based corrosion assessment using preprocessing techniques
Author(s)	Pakrashi, Vikram; Schoefs, Franck; Memet, Jean Bernard; O'Connor, Alan J.
Publication date	2008-01
Original citation	Pakrashi, V., Schoefs, F., Memet, J. B. & O'Connor, A. (2008). Improved image analysis based corrosion assessment using preprocessing techniques. MEDACHS 08 (Marine Environment Damage to Atlantic Coast Structures and Buildings: Methods of Assessment and Repair) 1st International Conference, Construction Heritage in Coastal and Marine Environments: Damage, Diagnostic, Maintenance and Repair. Lisbon, Portugal 28-30 Jan 2008.
Type of publication	Conference item
Item downloaded from	http://hdl.handle.net/10468/2620

Improved Image Analysis Based Corrosion Assessment using Preprocessing Techniques

Vikram Pakrashi[1], Franck Schoefs[2], Jean Bernard Memet[3] and Alan O' Connor[4]

[1] Postdoctoral Research Fellow, Department of Civil, Structural and Environmental Engineering, Trinity College Dublin, Ireland, pakrashv@tcd.ie
[2] Lecturer, Institute in Civil and Mechanical Engineering, Nantes Atlantic University, Nantes, France, franck.schoefs@univ-nantes.fr
[3] A-Corros expertise, Corrosion and conservation of Cultural heritage, Arles, France, jbmemet@yahoo.fr
[4] Lecturer, Department of Civil, Structural and Environmental Engineering, Trinity College Dublin, Ireland, alan.oconnor@tcd.ie

Abstract

The importance of non-destructive techniques (NDT) in structural health monitoring programmes is being critically felt in the recent times. The quality of the measured data, often affected by various environmental conditions can be a guiding factor in terms usefulness and prediction efficiencies of the various detection and monitoring methods used in this regard. Often, a preprocessing of the acquired data in relation to the affecting environmental parameters can improve the information quality and lead towards a significantly more efficient and correct prediction process. The improvement can be directly related to the final decision making policy about a structure or a network of structures and is compatible with general probabilistic frameworks of such assessment and decision making programmes. This paper considers a preprocessing technique employed for an image analysis based structural health monitoring methodology to identify sub-marine pitting corrosion in the presence of variable luminosity, contrast and noise affecting the quality of images. A preprocessing of the gray-level threshold of the various images is observed to bring about a significant improvement in terms of damage detection as compared to an automatically computed gray-level threshold. The case dependent adjustments of the threshold enable to obtain the best possible information from an existing image. The corresponding improvements are observed in a qualitative manner in the present study.

Keywords: Image Processing, Probability of Detection, Probability of False Alarm,Non-Destructive Techniques.

1. Introduction

Non-Destructive-Testing (NDT) and evaluation for structures and infrastructure networks have become extremely important and topical in the recent times (Yong *et al.* 2003). NDT based assessments guarantee no significant mechanical interference with the structural response. Information obtained from NDT can be used on a wide range of applications in the field of engineering involving (but not limited to) structural health monitoring, decision making, optimisation of repair work and 'do-nothing' options for an individual infrastructure system or a network of systems. Recent European Union (EU) projects (SAMARIS 2005, Rudlin and Dover 1996) have emphasized the importance of maintenance and management of infrastructure networks on a large scale from a national and international point of view. Since NDT based assessments directly affect the decision making process of infrastructure owners, managers and engineers and significantly affect national and international trade, evaluation and improvement of the techniques are considered to be critical.

A typical and important example of such assessment can be related to offshore structures, specifically a metallic pile wharf. Being in a marine environment, the piles undergo corrosion and can lead to serious structural degradation from the safety and serviceability viewpoints over the course of time. Regular monitoring and evaluation of these structures related to corrosion is extremely important. Manual inspection techniques using divers for this purpose suffer from subjectivity and lack of expertise. There are associated time and financial constraints as well. As a result, subjective techniques (potentially unmanned) which provide data for experts off site for further processing are deemed useful. Since corrosion on a steel pile is usually associated with a significant change of colour (Tsushima *et al.* 1997) of the affected location, image processing based techniques can be successfully used (Tsushima *et al.* 1997, Pakrashi *et al.* 2007) for the detection and quantification of the corroded region. Such image processing technique based information also forms a basis of probabilistically identifying the efficiency of the technique itself through the use of Receiver Operating Characteristics (ROC) (Schoefs *et al.* 2007) which plots the Probability of Detection (PoD) versus the Probability of False Alarm (PFA). The POD is defined as the probability of correcting identifying a damage when it exists, while the PFA is defined as the probability of identifying a damage when there is not any.

A special problem arising with the case of image processing based corrosion detection process is that the data (which are essentially videotapes or photographs obtained by a diver) are of varying qualities and tend to deteriorate with time. Due to the variability of natural conditions the chief variables affecting the image quality are luminosity, contrast and noise. The quality of assessment can significantly vary based on the conditions of these variables. Although, it is not possible to improve the quality of data, it is often possible to modify the images as pre-processing to qualitatively obtain the best results possible. This paper considers the detection of corrosion in an aluminium plate through image processing and synthetically introduces varying image qualities. A possible pre-processing technique from a qualitative point of view is proposed in this regard to improve the probabilities of detection. The pre-processing allows improving certain cases of deteriorated image conditions without having to resort to improvement in the methodology or the measurement, thus improving the quality of the assessment technique.

2. Image Processing Based Detection

2.1 Problem Description

An aluminium plate affected by pitting corrosion due to its residence in brackish sub-marine conditions over a period of twenty years is considered for the detection. The photograph of the corroded plate is available and is used as a basis for detection of corrosion. The detection is based on the fact that the corroded regions are in contrast with the general background of the plate. So the objective of an image processing based detection technique depends of its efficiency to separate the foreground consisting of corroded regions, from the background. Since the corroded regions are spatially distributed over the plate, a successful separation of the background from the foreground is considered non-trivial.

2.2 Detection Scheme

The image processing based detection scheme usually starts with obtaining a photograph or a video of the damaged region and its subsequent conversion to computer readable digital version. The photograph or the video needs to be benchmarked in terms of a known measured length in horizontal and vertical direction for future reference with pixel numbers. The digitised image is essentially a rectangular grid of pixels where each pixel is characterised by its hue-saturation value. The digitised coloured image is converted into a binary image and the edges of the black and white images are identified. Based on the definition of the minimum size of damage and on the number of successfully identified closed geometries, a prediction of damage regions within the image can be obtained. For a successful detection, the statistical properties of the closed regions in terms of pixels can be related to actual value by referencing the length benchmarking. Figure 1 provides a schematic for such detection process.

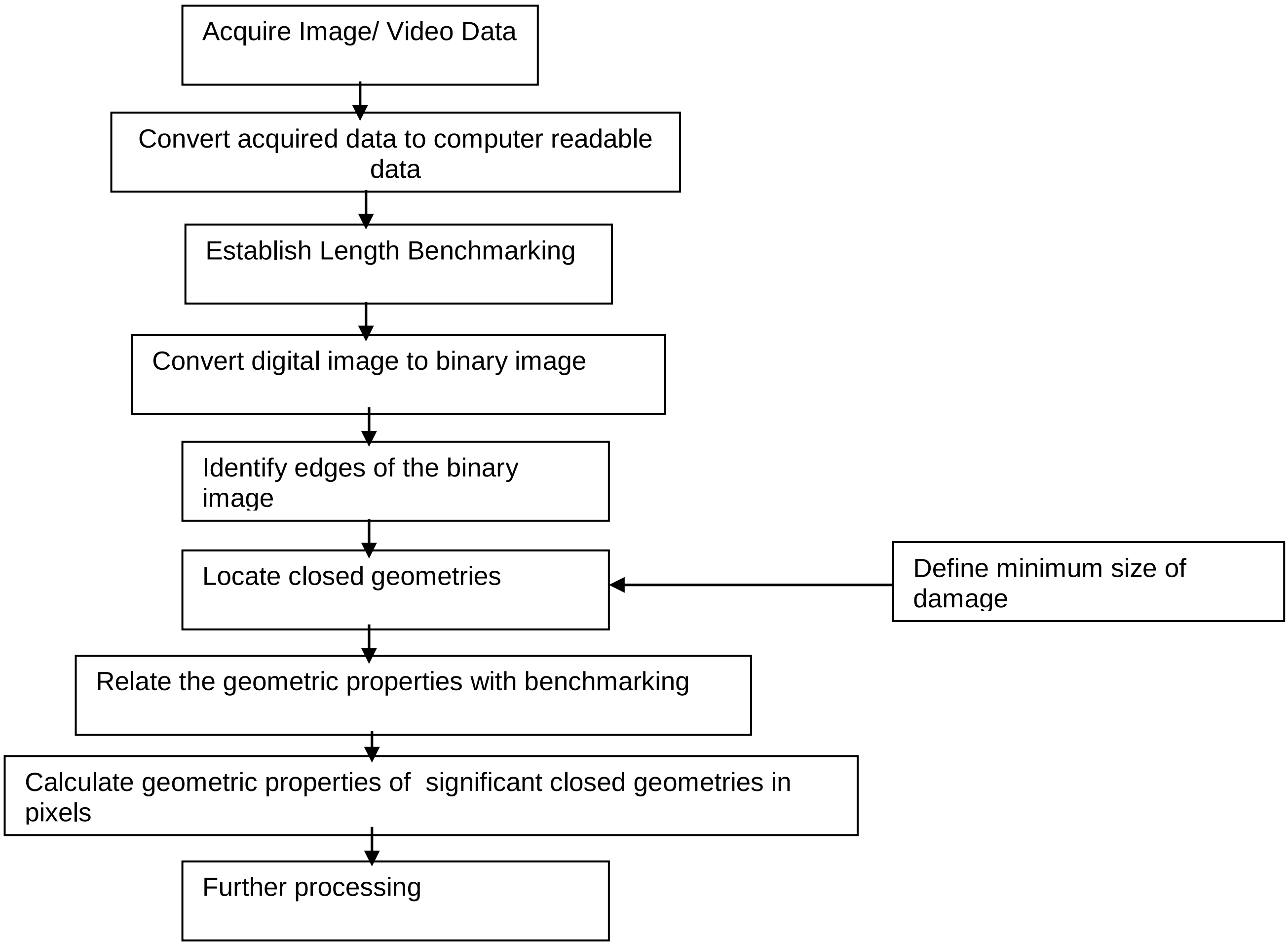

Figure 1. Schematic of Image Based Detection Scheme

2.3 Possibility of Improvement

It is observed from section 2.2 that the separation of the background from the corroded foreground of the image forms the basis of the detection. The background, in this context can be described by the gray-level threshold of the image available for analysis. The gray-level threshold is obtained by minimizing the interclass variances of the black and white pixels using Otsu's method employing MATLAB 7.0 image processing toolbox (MATLAB 2006). Pixels below the threshold assume a value zero and turn black, while the pixels above the threshold turn white. As a result, the coloured original digital image is converted into a simpler black and white binary image. Since the feature of interest, the corroded regions are in contrast with their surroundings in the image this conversion is helpful for identifying the corroded regions.

However, the automatically computed gray-level threshold does not guarantee an optimized solution for appropriate detection of corroded region in the image. This is because of the fact that the identification of corroded regions or the regions of interest is essentially a local and image specific phenomenon on the two-dimensional photographic plane and thus the simultaneous maximisations of the interclass variances in the sub-regions of interest are not always possible. To improve the detection process, image specific adjustments of the threshold are proposed to be carried out to obtain the best possible information from the post-processing of the existing image. Incorporation of a correction to the automatically computed gray-level threshold through heuristic search to find the best value of the threshold maximising the visual information of the picture in terms of corrosion identification is thus proposed qualitatively.

3. Results

A photograph of a corroded aluminium plate used previously for image processing based detection of corrosion (Pakrashi *et al.* 2007) has been used in the present study. Figure 2 shows a digital photograph of the corroded aluminium plate. The luminosity, the contrast and the noise of the photograph have been synthetically changed to obtain different image qualities. These variations are similar to what can be expected under field conditions. Three different levels (high, normal and low) of each of such affecting factors have been chosen. The noise is characterised as additive Gaussian noise and has been described by the parameters of its normal distribution. The luminosity is changed by changing the amount of 'whites' in each pixel while the contrast change is characterized by tuning the differences between the adjacent colours in each pixel. These changes can be performed easily through commercial photo editors, where the luminosity and contrasts are usually marked from a scale of zero to hundred.

For each of the combination of luminosity, contrast and noise, the image processing based detection of corrosion is carried out for automatically computed gray-level threshold and for heuristically fit gray-level threshold. Figure 3 illustrates the adjustments of the gray-level threshold required for various images corresponding to various environmental conditions. The non-adjusted threshold values refer to that obtained from Otsu's method, while the adjusted values correspond to the values obtained from heuristic thresholding. It is observed, that for certain combinations of luminosity, contrast and noise the heuristically set thresholding is significantly different from that obtained by automatic thresholding.

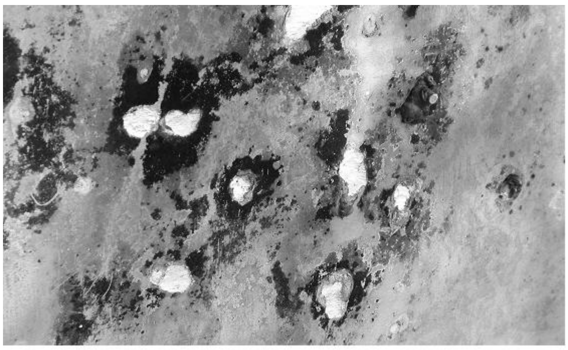

Figure 2. Photograph of the Corroded Plate

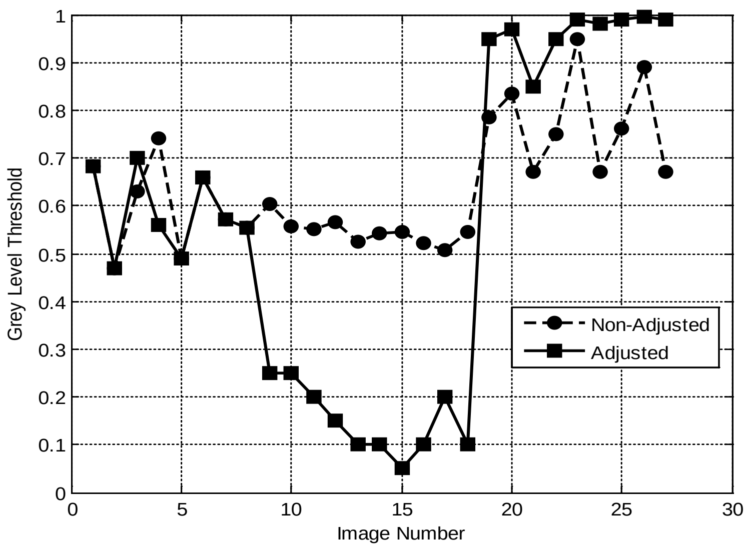

Figure 3. Image Adjustment by heuristically adjusting the Gray-level Threshold.

	Quality Indicator			Level of Identification	
Image Number	**Luminosity**	**Contrast**	**Noise**	**Without Threshold Adjustment**	**With Threshold Adjustment**
1	Normal	Normal	Normal	Somewhat	Somewhat
2	Normal	Normal	Low	Somewhat	Somewhat
3	Normal	Normal	High	Somewhat	Somewhat
4	Normal	Low	Normal	Good	Good
5	Normal	Low	Low	Somewhat	Somewhat
6	Normal	Low	High	None	None
7	Normal	High	Normal	Good	Good
8	Normal	High	Low	Good	Good
9	Normal	High	High	Somewhat	Good
10	Low	Normal	Normal	None	Good
11	Low	Normal	Low	None	Good
12	Low	Normal	High	None	Somewhat
13	Low	Low	Normal	None	Good
14	Low	Low	Low	None	Good
15	Low	Low	High	None	Poor
16	Low	High	Normal	None	Good
17	Low	High	Low	Somewhat	Good
18	Low	High	High	None	Somewhat
19	High	Normal	Normal	Somewhat	Good
20	High	Normal	Low	Somewhat	Good
21	High	Normal	High	None	Somewhat
22	High	Low	Normal	None	Somewhat
23	High	Low	Low	Somewhat	Good
24	High	Low	High	None	None
25	High	High	Normal	None	None
26	High	High	Low	Somewhat	Fairly Good
27	High	High	High	None	None

Table 1. Qualitative Improvement by Adjusting Gray-level Threshold

The qualitative improvement of the various conditions is observed for each of the image. The qualitative level of improvement due to heuristic adjustment of gray-level threshold has been presented in Table 1. The improvement has been in terms of the probability of detection of the actual corroded area. The level of detection is described in a qualitative sense for each of the combinations of luminosity, contrast and noise for automatically obtained and heuristically fitted gray-level threshold. The conditions where significant improvement is obtained by the proposed preprocessing are marked in gray. About 64% of the cases are observed to improve in terms of corrosion detection by following the proposed pre-processing of image data. Thus, preprocessing techniques can be found to be useful in improving NDT based identification and assessment even when no new data is available and improvement in the measurement technique is not possible.

4. Conclusions

The importance of pre-processing techniques for the purpose of improvement in NDT based assessment schemes is discussed in this paper. A typical application problem related to corrosion identification using image processing based methods is taken up as an illustrative example in this regard. Various environmental factors, like luminosity, contrast and noise can alter and deteriorate the quality of the optical data for an image processing based information. It is observed that the separation of the corroded regions from the background of an image is non-trivial for a wide range of qualities of the image. The automatically computed gray level threshold for image processing is found qualitatively to be inferior to a heuristically fitted gray level threshold for the purpose of separating the corroded regions from the image background.

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