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DETECTION OF PITTING CORROSION IN STEEL USING IMAGE PROCESSING

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Abstract: This paper presents an image processing based detection method for detecting pitting corrosion in steel structures. High Dynamic Range (HDR) imaging has been carried out in this regard to demonstrate the effectiveness of such relatively inexpensive techniques that are of immense benefit to Non – Destructive – Tesing (NDT) community. The pitting corrosion of a steel sample in marine environment is successfully detected in this paper using the proposed methodology. It is observed, that the proposed method has a definite potential to be applied to a wider range of applications.

1 INTRODUCTION

The use of Non Destructive Testing (NDT) in the field Structural Health Monitoring (SHM) has become significantly popular for infrastructure maintenance management. With ageing infrastructure elements all around the world and increasingly global constraints on available budget for the maintenance of such infrastructure (SAMARIS, 2005) the importance of NDT is even more topical. Detection of damage in structures is one of the most important aspects in this regard.

A typical three step methodology for damage detection lies in the efficient identification of the presence, the location and the severity of the damage. This information can then be fed into various assessment models, including probabilistic ones and could be used for future decisions on the remaining lifespan and possible rehabilitation options (Rouhan and Schoefs, 2003). The rehabilitations options often include the prioritisation of the structure in terms of the amount of investment and the time of investment. The 'do – nothing' option, where the benefit of leaving the structure without rehabilitation till its performance becomes unacceptable is also highly dependent on the efficiency of NDT techniques. It is apparent, the transfer of benefits due to improved NDT methods to the end user and the bridge owners and managers is exceptional.

Of the many different types of damages that significantly affect structures, pitting corrosion holds a very special place. This type of corrosion is essentially manifest as isolated corroded damage units within metal and is typically characterised by their rapid change in depth over a relatively short geometric spread. Pitting corrosion is also, very typically, associated with considerable change in colour due to the chemical reactions that bring about the corrosion (Tsushima et. al 1997). These corrosions affect a very wide range of civil engineering structures, including pile wharfs, bridges and pipes to name a few. In associated fields, pitting corrosion has plagued a range of applications as wide as from aviation (Qingyuan et. al, 2006) to the printing industry (Sailer, 2007).

The detection of pitting corrosion is thus a commercially important and challenging problem. A number of methods, like Ultrasonic Spectroscopy, Digital Radiography, Infrared Imaging, Eddy Current Mapping, Time Domain Reflctometry and many others have been successfully used to identify pitting corrosion in various systems and under various conditions (Bardal and Drugli, 2004; Liu et.al, 1999). However, detection from the typical discolouration due to the presence of pitting corrosion seems to chiefly limited to comparatively subjective visual identifications methods. A visual identification method, even when applied by experts can provide very limited data on the nature and the spread of damage. The importance and the potential of image processing based methods for such detection seems to have been somehow relatively overlooked.

The importance of using information based on images are manifold. Obtaining visual data is relatively simple, inexpensive and often requires relatively less training. The existing documentation of such data from earlier inspections are also in relative abundance than its more sophisticated counterparts. Consequently, the exploitation of image based data can be considered to be a very practical way of dealing with pitting corrosion in a considerably wide field of application. A significant number of pitting corrosion surveys are carried out using photographic and video data. Very often, typically in the case of pitting corrosion in marine environment, the data is collected by divers and are assessed by experts from the photographs and videos. The quality of the photographic data significantly affects the Receiver Operating Characteristics (ROC) of the NDT method and affects the quality of the decision (Pakrashi et.al, 2008). The use of image processing based information for the identification of pitting corrosion is still relatively few.

It is observed, that there is a specific need to exploit the visual data in a somewhat inexpensive and simple fashion while maximising the information obtained with confidence regarding pitting corrosion detection. This paper demonstrates the use of High Dynamic Range (HDR) imaging for this purpose and successfully applies the technique to a corroded steel plate specimen submerged in marine environment. The findings indicate that such technique holds great possibility in maximising visual information while encroaching minimum into traning, cost or other related resources. The possibilities of the method being applied to a wider range of applications are also clearly observed.

2 HIGH DYNAMIC RANGE (HDR) IMAGING

For the present paper, we consider the case of pitting corrosion in a specimen of steel corroded within the marine environment. A definite discolouration within a closed geometry of relatively limited size characterises the damage. Instead of taking a single, arbitrary photograph, High Dynamic Range (HDR) imaging is proposed for the identification of pitting corrosion through visual inspection.

The dynamic range of a scene is the ratio between the brightest and darkest parts of the scene, whereas for a display the dynamic range is the ratio between the maximum and minimum intensities emitted from the displayed image. Dynamic range is measured as the ratio of the maximum and the minimum luminance values of a scene or an image.

In real world every scene has a significant amount of brightness variation. The human eye is capable of handling a dynamic range of 100000:1. In simpler words, the human eye can accommodate the dynamic range between the shadowy interior of a room to the sunlit views outside the window. In contrast, a typical video camera, or a digital still camera, provides only about 8 bits (256 levels) of brightness information at each pixel. Consequently, almost all images captured by a conventional imaging system is either too dark in some areas and possibly too bright in others. Images of significantly compromised quality are what we are often left with for interpretation and detection. The low range of brightness information of the existing images poses a severe limitation on what computational vision can accomplish. A very simple modification, HDR imaging, can be made to any conventional imaging system to dramatically increase this range.

An HDR image is such an image whose dynamic range exceeds the dynamic range of the capturing or the display device and in turn provides detailed information on every pixel of the image. The HDR images can be created by sequentially capturing multiple exposures of the same scene using a standard digital camera. By using multiple exposures each image in the sequence will have some pixels of the image properly exposed, and other pixels will be either under or overexposed. For example, a high exposure image will be overexposed in the bright scene areas but will capture the dark regions well. In contrast, a low exposure image will have proper exposure in bright regions but will end up being too dark in the dark areas. The complementary nature of these images allows one to combine them into a single high dynamic range image. Such an approach has been employed in.

3 RESULTS

Three images of a steel specimen undergoing pitting corrosion in the marine environment are captured with a standard commercially available digital camera. The threes images are such that, one is normally exposed, the second one is overexposed and the third one is underexposed. These three photographs are combined together to generate the HDR image. Figure 1 shows the HDR image along with the three parent images that were used to create it. It is important to note here that a higher number of images, above and below the normal exposure can be used to obtain a better tonal variation on the final image. However, this requirement varies from case to case and for the current condition, three images serve the purpose of illustrating the efficiency of the method very successfully.

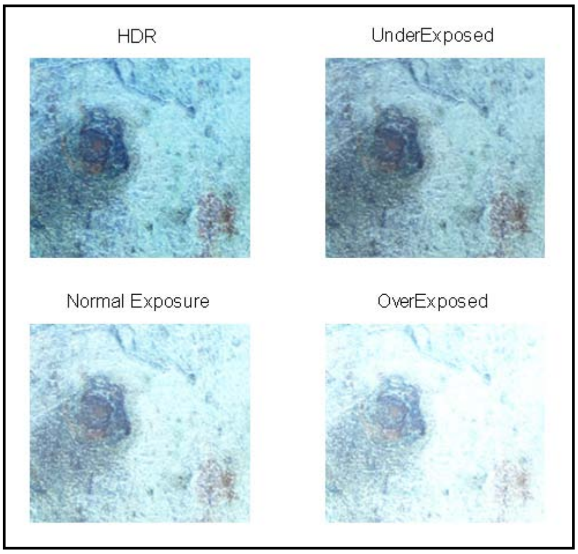

Figure 1. HDR image obtained from parent images.

The HDR has a wider dynamic range than any other image by a camera. As a result, the variation of the Red (R), Green (G) and Blue (B) pixel values are more sensitive in an HDR image than other images. Additionally, the RGB by itself is expected to change within the damaged region due to its typical discolouration. To explore these aspects a pixel profile plot along a linear section of the photograph is taken. The line is so chosen that it crosses both the damaged and undamaged surfaces. Figure 2 shows the line along which the profile plot is considered.

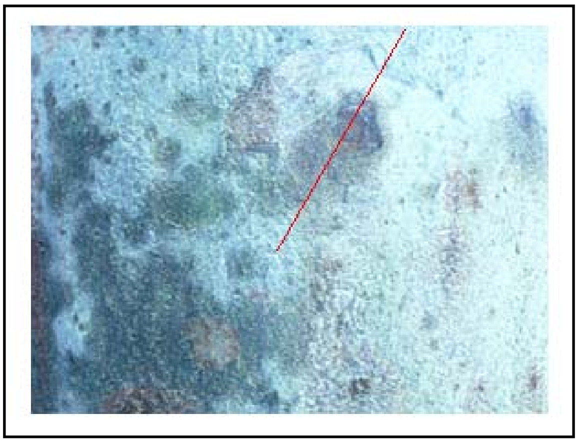

Figure 2. Profile plot along a line over the damaged and undamaged regions.

Figure 3 presents the variation of RGB values along the line for which the profile plot is generated for an image with normal exposure and is compared with the HDR image. The shaded region indicates the location of the damage, as is apparent by the sudden spatial change of the RGB values.

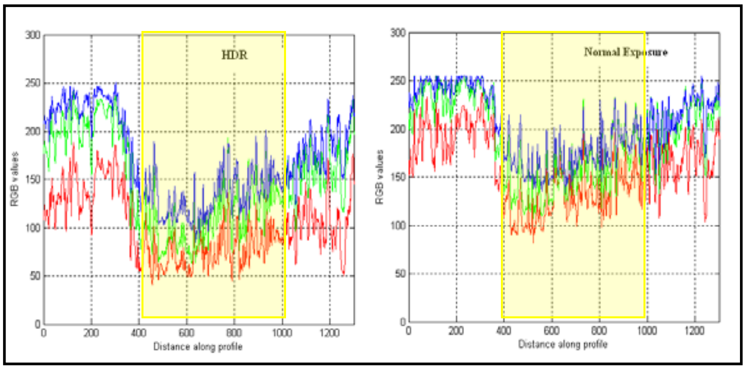

Figure 3. RGB values along the line for which the profile plot is considered.

It is important to note that in both images the extent of the damage is relatively easily captured quite efficiently, but the HDR image shows a significantly bigger variation of the RGB values with respect to the background values. This indicates that the chances of masking, which is expected when the corrosion colour contrasts with the background more weakly, is significantly less in HDR imaging. Apart from decreasing the chances of damage masking, the HDR image is observed to have a better sensitivity in distinguishing among various contrasts and colours. As a result, a damage indication map could be used using HDR technique when image data from various conditions are available and such a map is expected to be more sensitive than those constructed from the parent images which give rise to the HDR image.

4 CONCLUSIONS

The importance of image processing based detection of pitting corrosion is emphasized in this paper. A steel specimen, undergoing pitting corrosion and submerged in the marine environment is considered in this regard. HDR imaging is proposed as a simple and inexpensive way to significantly increase the available visual information. The HDR imaging was successfully used to detect the pitting corrosion and was demonstrated to be superior to single images. The possibility of the use of HDR in a wider field of application is immediately observed.

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