COST TU1402: Quantifying the Value of Structural Health Monitoring

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Interpretation of Receiver Operating Characteristic Scatter Plots for Assessing Damage Forms Using Image Processing Techniques

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Introduction

The monitoring of underwater structures is often beset by limited access, high costs and inherent safety issues. The camera, in conjunction with powerful image processing techniques, is increasingly being recognised as a convenient, low-cost, and versatile NDT tool capable of extracting quantitative information from visual data.

Image processing techniques can detect and quantify a wide range of visible damage forms. These damage forms may be conveniently categorised according to their effective dimensionality. For instance, cracks may be considered as a 1-dimensional damage form due to their linear fine-structured nature, planar damages such as surface corrosion can be considered as a 2-dimensional damage form, while damages that are described by their geometric shape can be considered as a 3-dimensional damage form. These damage forms often appear on marine structures due to the harsh and corrosive marine conditions. Examples of these damage forms are shown in Fig. 1.

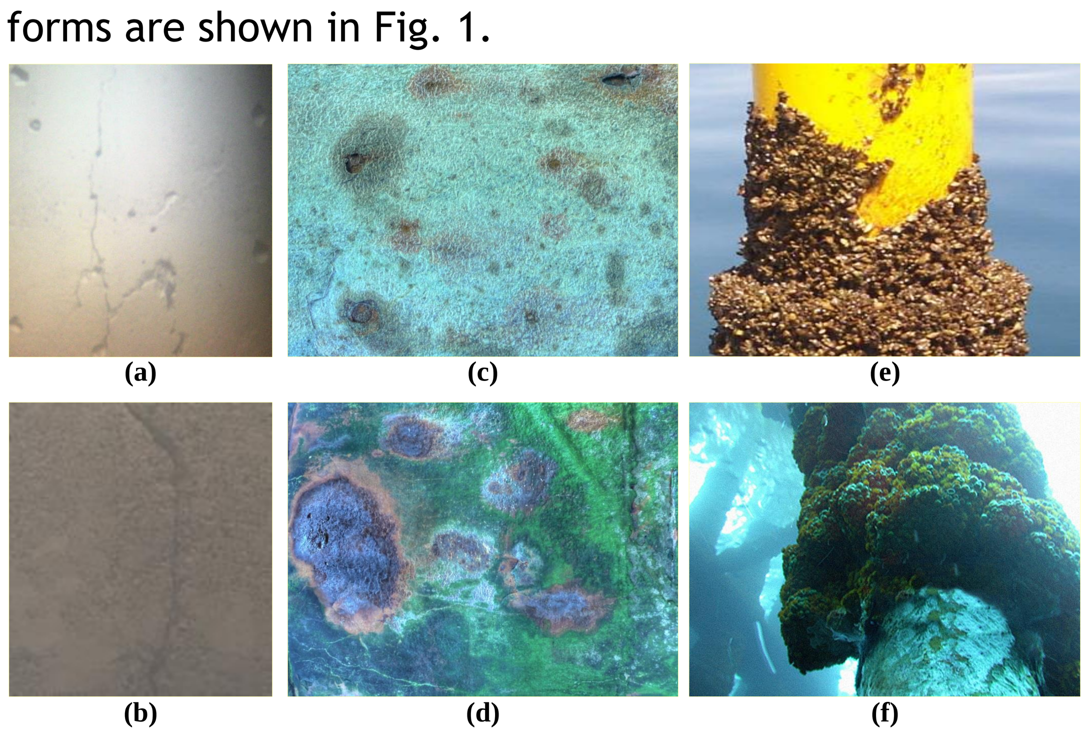


Fig. 1. Examples of damage: **(a-b)** *Cracks,* **(c-d)** *2D Surface Damage,* **(e-f)** *3D Damage*

The image processing algorithms in each damage category naturally follow different methodologies as they typically aim to determine the crack width/length, the area occupied by surface damage, or the volume of 3D damage respectively. It is of great practical importance for inspectors to have a sense of the effectiveness of image processing techniques when applied in an underwater setting so they can decide if image based methods are appropriate for their needs.

Objectives

To date, there has been very little work carried out exploring the use of image based techniques for the purpose of detecting and quantifying structural damage, particularly affecting the submerged part of marine structures. This research aims to advance this emerging field through the development and performance characterisation of image methods. A three pronged strategy is adopted to this end (Fig. 2). It involves:

1) Developing algorithms which are able to handle the challenging underwater visibility conditions

2) Developing a protocol for acquiring imagery in an underwater setting

3) Creating an underwater image repository. This repository features a range of damage forms under varying environmental conditions.

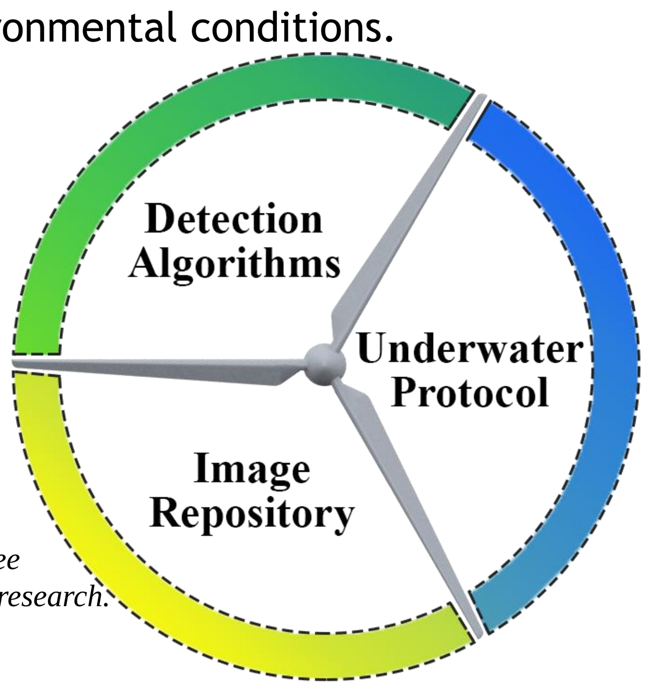


Fig. 2. The three strands of this research.

This body of work ties together the first and third strands as the performance of damage detection algorithms for 1D, 2D and 3D damage forms are evaluated using the controlled image repository.

Methodology

The imagery used in this study was generated by taking photographs of specimens in a controlled underwater environment. A stereo system was used for capturing 3D information as shown in Fig. 3.

Fig. 3. Experiment set-up and camera equipment

The specimens feature simulated damage. This 'damage' is artificially created such that its dimensions are precisely known. For the 3D damage category, regular objects of known dimensions are used. The specimens cover a wide range of geometric and photometric properties. They are photographed under varying visibility conditions, as controlled by adjusting the turbidity and lighting. A full breakdown of the parameters for each category is shown in Fig. 4.

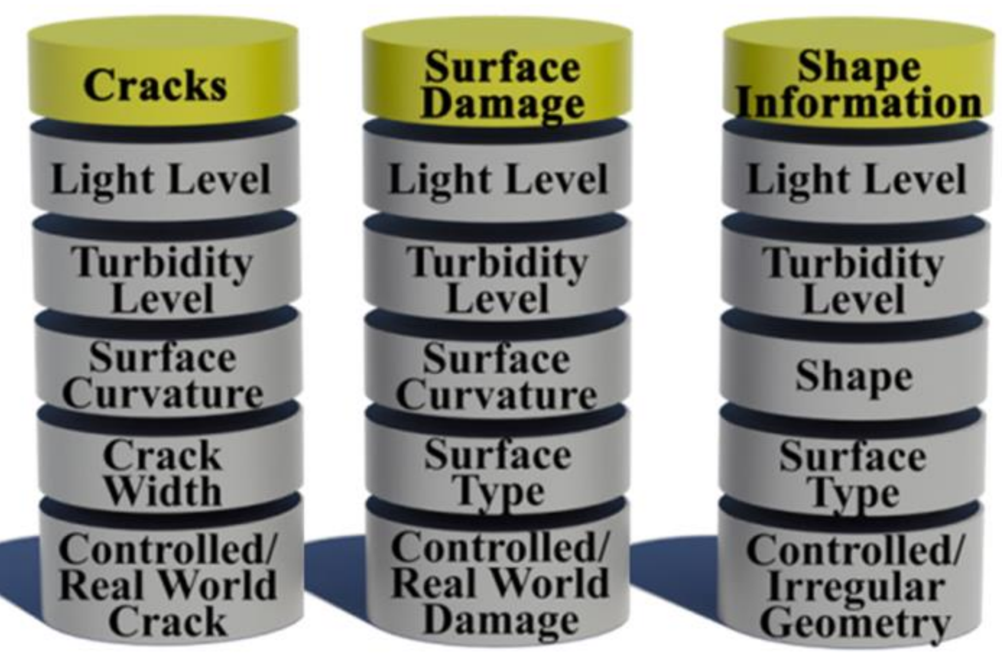


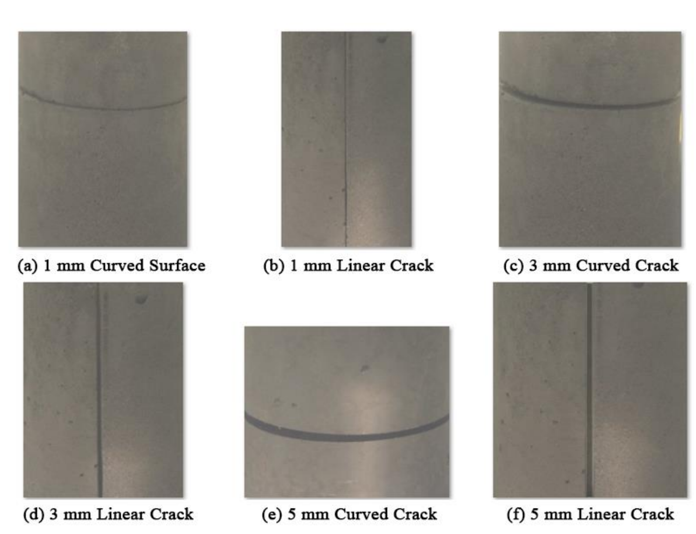
Fig. 4. Attributes of the specimens for each damage category {1D, 2D, 3D}.

Once the image processing techniques are applied to the specimens, the detected damaged regions are compared against the control images which are assumed to show the true damage extent. Receiver Operating Characteristic (ROC) analysis is then used to evaluate the performance of each technique

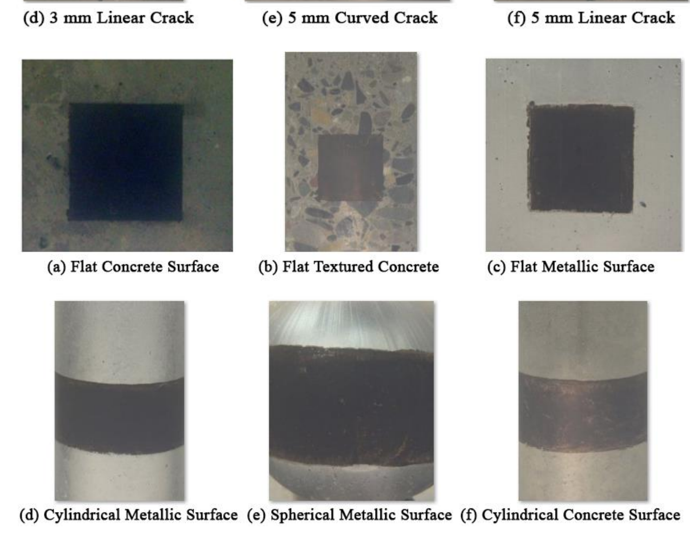
Analysed Imagery

A sample of the controlled imagery from each category is shown below:

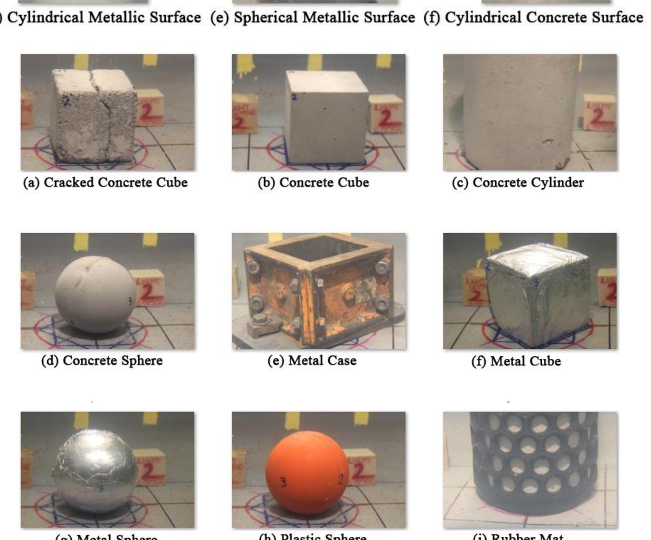
Cracks



Surface Damage

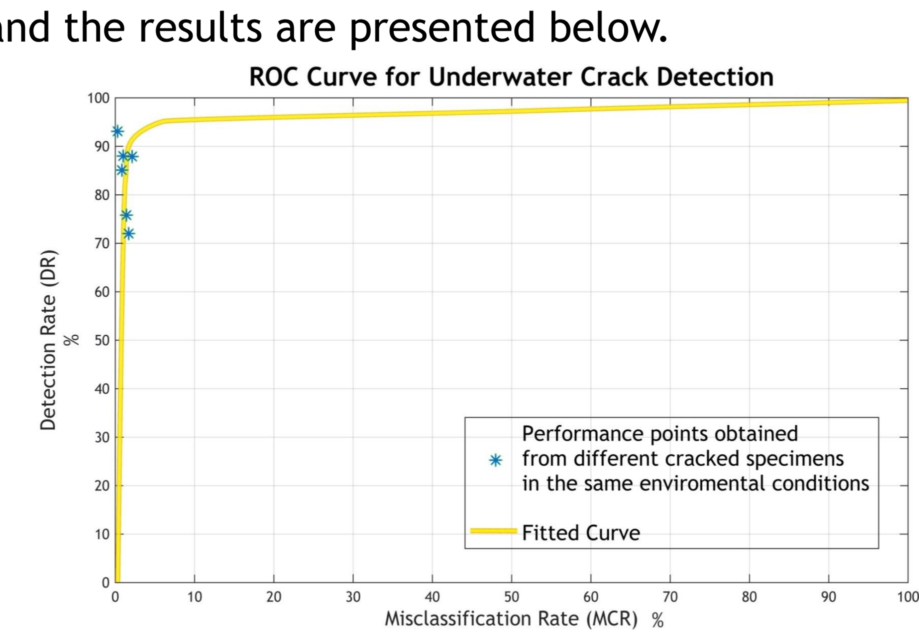


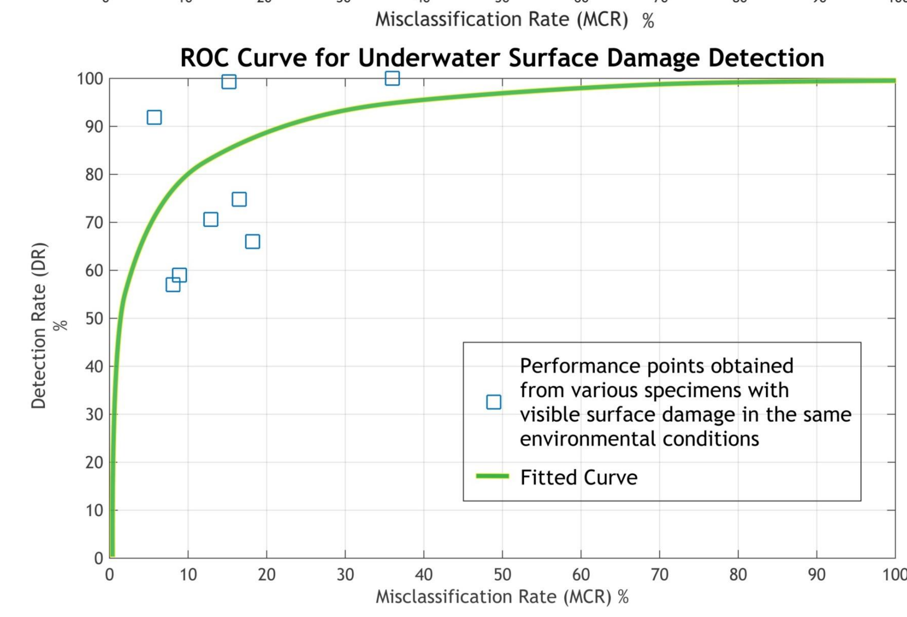
Shape Information

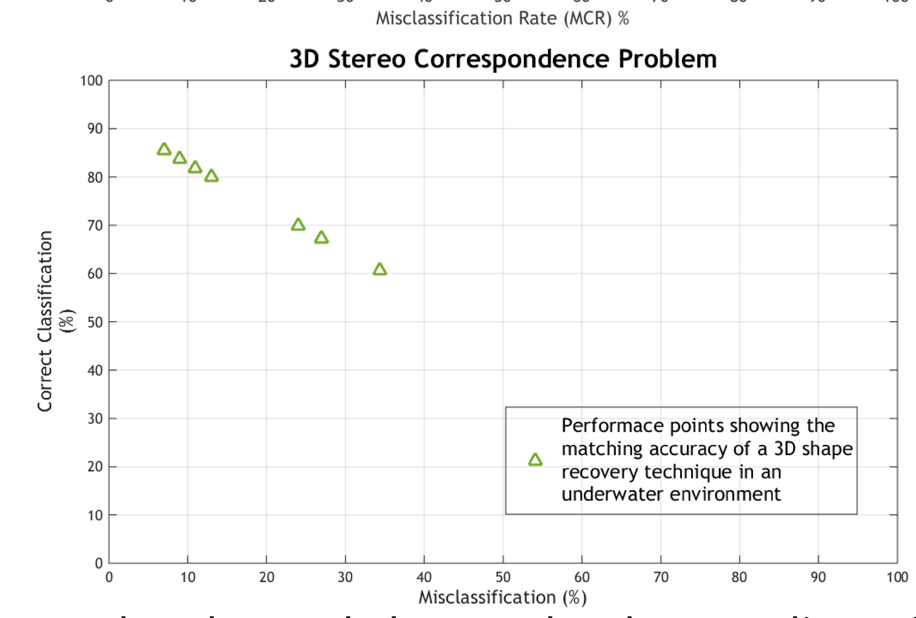


Results

A percolation based crack detection technique, a surface damage detection technique, and a stereo matching algorithm have been applied to controlled imagery in the repository under the same environmental conditions and the results are presented below.







It may be observed that as the damage dimensionality increases, so too does the variability/scatter in the detection results. This could be explained by the increasing complexity of higher dimensional damage forms which are difficult to interpret from an image analysis perspective.

Conclusions

Adopting image processing techniques can vastly improve the condition of monitoring, reduce the operational complexities and partially offset the financial burden of regular inspections. Image processing methods provide a source of quantitative information which lends itself to many applications in SHM, however, it is important that we have a sense of how accurate this information is. By analysing the performance points in the ROC space for a 1D crack detection technique, a 2D surface damage detection technique, and a 3D stereo matching technique, applied under the same environmental conditions, it was found that a trend emerges suggesting that there is greater variability in the results when dealing with higher dimensional damage forms. Characterising the efficiency of image processing techniques in this manner helps inspectors to assess the capabilities, limitations and reliability of image methods prior to undertaking an inspection.

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