Enhancing Visual-based Bridge Condition Assessment for Concrete Crack Evaluation Using Image Processing Techniques

Huiju WI
MPhil Student
Griffith University
Gold Coast, Australia
h.wi@griffith.edu.au

Vu NGUYEN
Dr
Griffith University
Gold Coast, Australia
vu.nguyen@griffith.edu.au

Jaeho LEE
Research Fellow
Griffith University
Gold Coast, Australia
j.lee@griffith.edu.au

Hong GUAN
Associate Professor
Griffith University
Gold Coast, Australia
h.guan@griffith.edu.au

Yew-Chaye LOO
Professor
Griffith University
Gold Coast, Australia
y.loo@griffith.edu.au

Michael BLUMENSTEIN
Professor
Griffith University
Gold Coast, Australia
m.blimenstein@griffith.edu.au

Summary

Condition assessment is one of the most essential practices inbridge asset management to maintain the safety and durability of structures. Routine bridge inspection, a visual-based method, is regularly performed by qualified inspectors to determine the condition of individual bridge elements manually using bridge inspection standards. However, the quality of a visual-based condition assessment relies heavily on the inspector's knowledge and experience. Theresearchpresented here focuses on the development of an enhanced method to minimisethe shortcomings of visual-based inspection. In this paper, we investigate the performance of RBF-kernel support vector machines (SVMs), a supervised machine learning technique, to increase the reliability of visual-based bridge inspection. The resultsof this study can contribute to minimising the shortcomings of current visual-based bridge inspection practices.

Keywords: Bridge management; Condition assessment; Visual-based bridge inspection; Image processing techniques.

1. Introduction

Bridges are essential components of a national transport networkthatrequire timely decision-making for maintenance, repair and rehabilitation (MR&R) operations. To ensure the optimum long-term condition of bridges, it is necessary that the bridge condition ismonitored and recorded constantly. Most bridge agencies have adopted routine bridge inspection for assessingbridge conditions. Routine bridge inspection, a manual visual-based inspection method, is regularly performed by qualified inspectors to determine the current condition of individual bridge elements,according tobridge inspection standards. This inspection method is a convenient way toevaluate the current health status of a structure. However, visual-based condition assessment raises many issues.For example, inspection outcomes arepotentially unreliable and subjective, because theydependentirely on the bridge inspector's knowledge and experience.To overcome the limitations, it is necessary to investigateand develop an enhanced visual-based bridge inspection method to provide consistent and reliable data acquisition to be used as useful information in a Bridge Management System (BMS).Aprevious studyproposedan image processing technique forcrack detection with a rigidrule-based classifier. However, due to the complex nature of the background/concrete surface, a rigid rule-based classification scheme is not sufficiently robust to deal withcrackshavingunconstrained shapes and sizes. To overcome thisshortcoming, amachine learning approach is proposed and investigated here.

2. Visual bridge condition assessment

The purpose of visual-based bridge inspection is to determinethe current condition of bridge components, which is essentialfor the safety of road users and to provide bridge agencies with information for planning the management of bridge components. Visual-based bridge inspection requires the assessment of every visible bridge component by a qualified inspector every 2–3 years based on a standard condition rating. The condition rating classifies the condition state (CS) of bridge components between CS1 and CS4, with

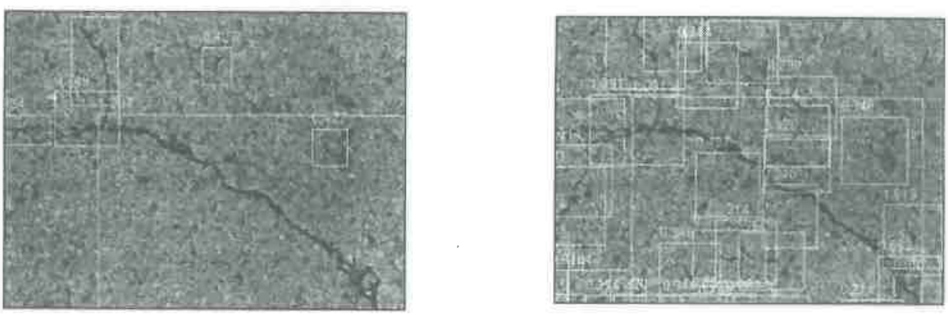
CS4 being very poor condition.Visual bridge inspection standards classify the elements of a bridge as concrete, steel, timber and other materials. These four material types have different deterioration behaviours according to the materials from which they are constructed and their surrounding environment.

3. Methodology

Image processing techniques for concrete crackevaluationare proposed in this paper. The proposed method consists of six steps: (1) raw image acquisition from the bridge elements; (2) an image subtraction pre-processing operation to help reduce unnecessary information such as irregular illumination and shading; (3) conversion of colour images to grey-level intensity images; (4) binarisation as a result of threshold decisions, which isan important process for distinguishing crack candidature from the grey-level intensity image; (5) cluster detection and classification to identify and discard invalid cracks and (6) identification of the maximum crack width to determine the CS based on the standard.In addition to real cracks, thresholding may also produce non-crack clusters of black pixels thatshould be discarded prior to subsequent processes. As non-crack clusters may appear in any shape or size, rigid rule-based and heuristic approaches may not be sufficiently robust to correctly distinguish them from real cracks. In our research we investigate the performance of RBFkernel SVMs, a supervised machine learning technique.

4. Results and discussion

The proposed image processing method istested using animage of a concrete bridge elementwith a resolution of 5616×3744 (21megapixels). An image of a footpath (Element 4C) on bridge #x5xxxisprocessed following the six steps and the result is displayed in Figure 1a. To validate the proposed image processing method, its outcome for this image can be compared with that from the existing method that employs a rigid rule-based classifier (Figure1b).



(a) Machine learning technique (b) Rigid rule-based technique

Fig. 1: Results of image processing technique (Element #4C on Bridge #x5xxx)

In the comparison of the machine learning and rigid rule-based techniques, the machine learning method is more effective in removing invalid cracks from the original images. This implies that the machine learning-based image processing technique can more successfully represent the crack. Based on the results obtained, it can be concluded that the machine learning technique is effective in crack classification.

5. Conclusions

Animprovement of the proposed methodis described in this paper.Upon validation, the proposed SVMmethodcan more effectively discarda largerproportion of non-crack clusters from the imagesthan the previous method.The proposedimage processing approachis believed to be a useful methodology for effective implementation of visual-based bridge inspection. However, based on the outcomes of the present study, further improvementsto the classification processare requiredto handle all valid cracks and case studies will be required.Further work will consider various environmental effects, such as irregular illumination and shading.