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Structural damage detection using 3D laser scanning

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ABSTRACT

Bridges, one of the important transportation infrastructure, are exposed to a wide variety of loadings in their service life, such as traffic, flood, wind, and seismic loads. To evaluate the structural soundness, manual visual inspection is generally adopted for investigating damages on the structural surface. Recently, digital image processing in conjunction with deep learning significantly improve the inspection performance in terms of the accuracy and the computational time. However, only the usage of the two-dimensional (2D) image is difficult to directly quantify the surface damages in the three-dimensional (3D) space. This study proposes a framework for the structural damage detection based on the 3D laser scanning. The point cloud of the bridge is utilized as an input for the proposed approach, in which the surface damages are localized and quantified in the 3D space.

1. INTRODUCTION

Bridges are exposed to a wide variety of loadings in their service life, such as traffic, flood, wind, and seismic loads. (Kim et al., 2017) Because these kinds of loadings can degrade the structural soundness, manual visual inspection is typically adopted for investigating damages on the structural surface. Although the manual inspection is the most common way to evaluate the structural integrity, it is costly, time-consuming, and dangerous for the inspectors. Recently, digital image processing and deep learning are considered as an alternative for robust and automated inspection. (Kim et al., 2019) However, the only use of the 2D image is difficult to perform damage localization as well as quantification in the 3D space.

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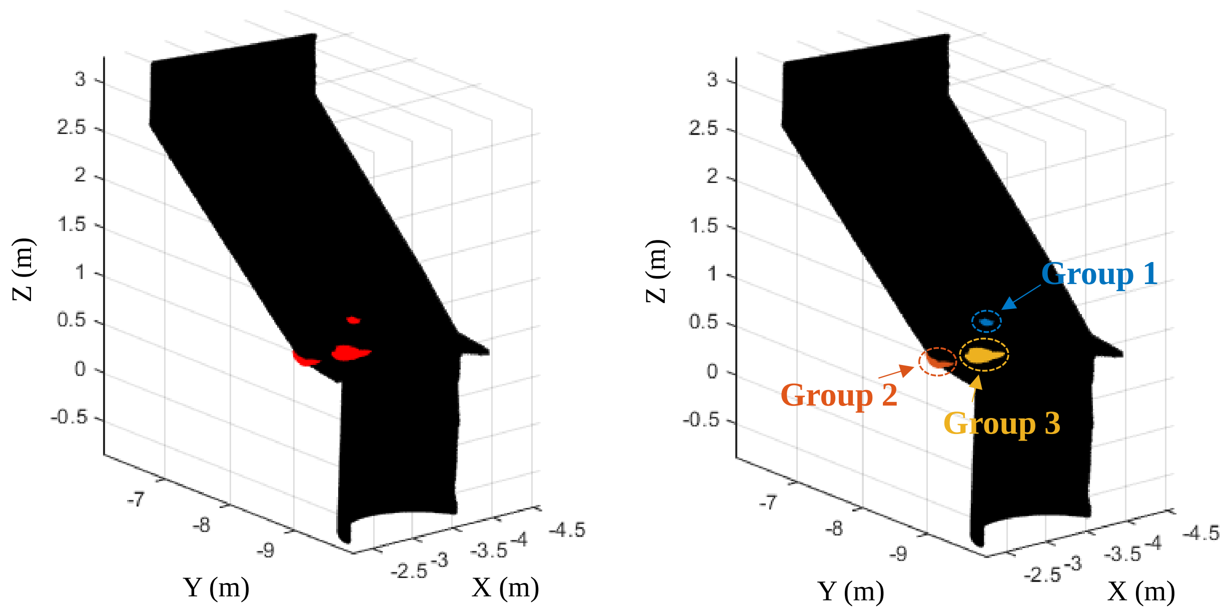
This study proposes a framework for the structural damage detection using the 3D laser scanning. The application of point clouds is more advantageous than that of the 2D image for damage evaluation of civil infrastructure. (Kim et al., 2020) The point cloud of a structural component is measured by the 3D laser scanner, in which the typical surfaces are automatically identified using a tailored surface fitting strategy. The surface damages are then detected and quantified from the proposed framework. The identification performance of the proposed method is experimentally validated on the structural components.

2. PROPOSED FRAMEWORK

The proposed framework is designed to detect the surface damages from the point cloud of a structural component. The irregular shape of damages is expressed as the point cloud in the 3D space using the laser scanning, in which the distribution of points in the 2D cross-section is utilized to identify the surface type. For the automated surface fitting, a set of 3D points with neglecting the scanning axis is used as an input for random sample consensus (RANSAC) (Fischler and Bolles 1981). Here, a random subset of points is selected to fit the mathematical models, of which the inliers and outliers are distinguished based on the minimum distance to the obtained model. This process is repeated until the mathematical model has a high number of inliers. The final outliers are the points on the damage (see Fig. 1(a)), which are grouped by the distance between the points. The three damage groups are localized as shown in Fig. 1(b).



(a) (b)

Fig. 1 Typical damage identification results: (a) damage points and (b) damage groups

The damage quantification is conducted to estimate the damage volume in each group. The damaged areas are first calculated using the obtained model; subsequently, the volume of damages is estimated by summing all the damaged areas along the scanning axis. The damage volume in each group is shown in Fig. 2. Each color represents the corresponding damage location in Fig. 1(b).

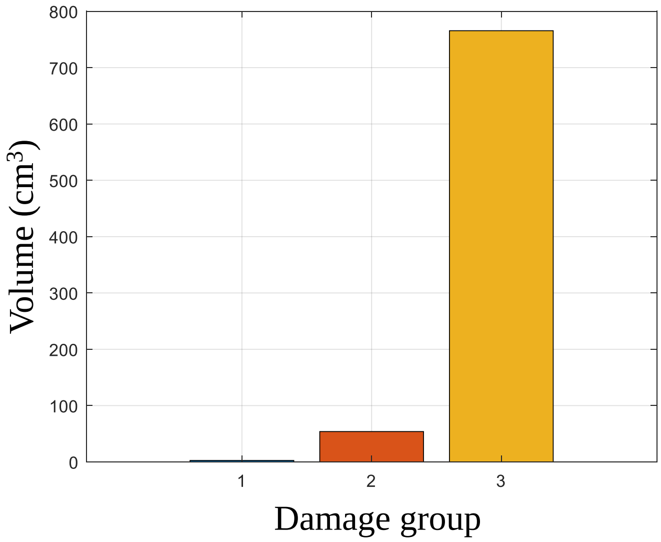


Fig. 2 Typical damage quantification results

3. CONCLUSIONS

Bridges, one of the important transportation infrastructure, are exposed to a wide variety of loadings, such as traffic, flood, wind, and seismic loads. Manual visual inspection is the most common way to investigate damages on the surface, of which the structural soundness can be evaluated based on the obtained information. Digital image processing and deep learning significantly improve the inspection performance in terms of the accuracy and the computational time. However, only the 2D image is difficult to directly use for damage localization and quantification in the 3D space. This study proposes a framework for the structural damage detection using the 3D laser scanning. The point cloud of the bridge is utilized as an input for the proposed approach; subsequently, the surface damages are localized and quantified in the 3D space.

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