Concrete Damage Detection Based on Machine Learning Classification of Terrestrial Laser Scanner Point Clouds

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SUMMARY

Health monitoring of concrete structures, subject to damage and material decay through the years by human activities and natural hazards, is an important requirement for the assessment of the integrity and safety of the structure. Although damage assessment based on imagery is an extensively researched topic, using spatial point clouds to detect damage is still in its infancy. This paper presents a supervised classification approach for high precision damage detection of concrete structures using terrestrial laser scanners. It uses a support vector machine to learn a classifier for predicting damage location based on a feature vector consisting of measured range, incidence angle, local point density, and eigenvalue-based features such as change of curvature, eigenentropy, etc. Either all or only the selected features are provided to the classifier. A systematic point-wise defect classifier is employed to label training data in an unsupervised way and thus avoids the manual work, automatically labels the damaged points in the train data and provides accurate training data. The unsupervised process labels the training points with the use of local surface variation as the most defect-sensitive feature that strongly changes in areas affected by damage. It applies a robust version of Principal Component Analysis (PCA) to distinguish between structural damage and outliers present in the laser scanning data. Afterwards, the derived robust surface variation feature is examined against a defined systematic threshold to automatically label the training points. Once the classifier has been trained, it can be used to predict the location of damaged points in any unseen dataset captured with the minimum required density of 5 mm scanning resolution of point clouds. Unlike the unsupervised classifier used for labelling the training points, which only uses the surface variation, a variety of geometric features were contributed to train the model and predict whether the area is affected by damage or not. This supervised approach is computationally more efficient than the robust PCA, used for data training, and is thus feasible for large point clouds providing a complete picture of the surface health of concrete structures. The applicability of the proposed supervised method has been implemented and evaluated on three real datasets: a concrete heritage site and two civil pedestrian concrete structures. The experiment results obtained by the three datasets demonstrate the validity of the proposed supervised method for accurate predictions of damage as small as 1 cm or less on the surface of concrete structures.