Postprint: Automatic Detection of Slope Deformation Cracks through Fusion of Point Cloud and Digital Image Data

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Abstract

Surface cracks, as one of the precursor characteristics of slope deformation, can provide predictive information for early identification of geological hazards and determination of kinematic instability features. Constrained by terrain conditions, manual inspection suffers from low efficiency, while the use of single-source remote sensing data also struggles to address crack size effects and noise filtering issues against complex backgrounds. To efficiently acquire the distribution locations and geometric information of surface cracks on deforming slopes, point clouds and Digital Orthophoto Maps (DOM) obtained from UAV terrain-following flight were employed as data sources. First, six algorithmic models utilizing point cloud roughness, slope, dispersion, digital image pixel gradient, grayscale values, and RGB (red green blue) values as features were implemented for preliminary identification of slope cracks, with Receiver Operating Characteristic (ROC) curve analysis conducted for different models to determine segmentation thresholds. Second, three filtering algorithms—morphological restoration, and crack direction, length, and frequency indexing based on density-based clustering—were applied to process background noise in the initial extraction results, capable of removing up to 82.7% of noise points while causing minimal crack distortion. Third, binary classification model evaluation metrics were employed to analyze the merits of the six filtered crack extraction results, and an optimal detection model was obtained through data fusion addressing the crack size effect (F1=0.8350). Finally, six quantitative characteristic indicators—quantity, length, width, direction, dispersion, and crack density—were automatically calculated based on crack skeletons and contours. The results demonstrate that multi-dimensional data fusion can resolve the spatial scale effects in surface crack identification, and the filtering approach based on crack unit indexing is applicable for noise removal in large-scale complex surface scenarios.

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Full Text

Title

Automatic Detection of Deformation Cracks in Slopes Fused with Point Cloud and Digital Image

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Abstract

Surface cracks, as one of the precursor characteristics of slope deformation, can provide predictive information for early identification of geological hazards and determination of instability characteristics. However, due to topographic constraints, manual inspection is inefficient, and identification using single-source remote sensing data struggles to address crack scale effects and noise filtering issues in complex backgrounds.

To efficiently acquire the distribution and geometric information of surface cracks on deforming slopes, point clouds and digital orthophoto maps obtained from UAV terrain-following flight are employed as data sources. First, six algorithmic models using point cloud roughness, slope, dispersion, digital image pixel gradient, grayscale value, and RGB (red, green, blue) values as features are implemented for preliminary crack identification, with receiver operating characteristic (ROC) curve analysis applied to determine optimal segmentation thresholds for each model. Second, three filtering algorithms—morphological repair and crack orientation, length, and frequency indexed by density-based clustering—are applied to remove background noise from the initial extraction results, achieving a maximum noise removal rate of 82.7% while minimizing crack distortion. Third, binary classification model evaluation metrics are used to analyze the performance of the six filtered crack extraction results, resulting in an optimal detection model following data fusion (F1=0.8350) that specifically addresses the crack scale effect.

Finally, six quantitative characteristic indicators—quantity, length, width, orientation, dispersion, and crack density—are automatically calculated based on crack skeletons and contours. The results demonstrate that multi-dimensional data fusion can effectively resolve spatial scale effects in surface crack identification, and the filtering approach indexed by crack units is applicable for noise removal in large-scale complex surface scenarios.

Keywords

UAV; geological hazards; slope deformation cracks; automatic extraction; information statistics

Note: Figure translations are in progress. See original paper for figures.