Surface reconstruction as a basis for deformation analysis

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Investigating the applicability of surface models for laser scanner-based deformation analysis

Germany has over 300 dams that require regular stability inspections through geodetic deformation measurements and analysis. This process typically relies on fixed object points, marked by pillars, elevation bolts, or targets placed near and on the dam wall. A two-epoch comparison then reveals any point deformations. For research purposes, area-based deformation analysis of dams are increasingly performed using terrestrial laser scans. This approach allows for the examination of the entire airside surface of the dam, rather than just individual points. Creating 3D models of this surface can be an effective tool for assessing the stability of the dam. Therefore, it is crucial to evaluate which methods are best suited for generating such 3D models to detect potential deformations. Within the study, we investigate different methods for surface reconstruction and develop a working program to use these models for deformation analysis. First, we will investigate the applicability of different reconstruction methods to our data and then analyse the advantages and disadvantages of these methods with respect to deformation analysis.

Keywords: Deformation monitoring, Terrestrial laser scanner, Surface modelling

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Assessing 3D morphological dune changes using medial axes

Representing and characterizing terrain change dynamics from multi-epoch 3D point clouds remains a challenge. In case of 2 epochs, subtracting the corresponding terrain models conveys local erosion and sedimentation patterns, but not landform rotation and translation. Current laser scanning possibilities provide us easily with 10s (drone or airplane based LiDAR) to 1000s (permanent laser scanning) of consecutive epochs of terrain data representing sandy beach-dune systems. Coastal dunes grow or shrink vertically over time, but also migrate and reorient due to eolian or marine forcing. Instead of considering pairwise epoch comparisons, we propose to assess the change of such dynamic 3D objects by simplifying these objects using the so-called medial axis transform (MAT) as shape descriptor. The MAT provides MAT points that are positioned centrally inside (or outside) the surface, here the dune surface as sampled by laser scanning. The MAT points can directly or indirectly, via a local neighborhood analysis, be used to estimate local dune ridge positions. The MAT radius is a parameter directly linked to the local scale of a dune. The MAT analysis also allows to estimate the local orientation and asymmetry of the considered dunes. This MAT methodology will be demonstrated on 2 different case studies. The first case considers 5 epochs of UAV-LiDAR data of an embryo dune field at the Sand Engine, The Netherlands. The second case considers a mature dune system sampled by 3 epochs of airborne LiDAR data, i.e. the Dune du Pila on the French Atlantic coast.

Keywords: 4D, Deformation analysis, Laser scanning, Morpho-dynamic

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Assessing the Potential of Neural Radiance Fields and Gaussian Splatting for Change Detection and Change Quantification

Neural Radiance Fields (NeRFs) and 3D Gaussian Splatting (3DGS) are methods alternative to multi-view-stereo (MVS) reconstruction in processing photogrammetric data. While they have been developed and optimized for creating synthetic 2D views, they are increasingly used for 3D reconstruction in the form of 3D point clouds. However, applications in geosciences are rare, and especially their suitability for change detection and quantification methods has not been assessed. In this contribution, we therefore create point clouds using state-of-the-art MVS on the one hand and NeRFs/3DGS on the other hand and compare the changes extracted from bitemporal differencing of these point clouds. For this differencing, we utilize the Multiscale Model-to-Model Cloud Comparison (M3C2) algorithm. We investigate two different study sites and include a riparian forest area as differences between MVS and NeRF/3DGS are especially pronounced in vegetated areas. For one of the areas, reference values for change are available through accurate laser scanning data. We compare the detected changes qualitatively as well as quantitatively by means of accuracy, precision, and recall. Finally, we provide conclusions for change detection and quantification with photogrammetric data using NeRFs and 3DGS.

Keywords: NeRF, Photogrammetry, Machine Learning, Uncertainty, Change

Ch. Michel, M. Ulrich

Automatic Inspection of Punched Metal Plate Fasteners on Timber-to-Timber Joints with Image-Based 3D Reconstruction

Roof structures of commercial buildings like supermarkets are often constructed with prefabricated timber trusses connected by punched metal plate fasteners. These fasteners are susceptible to failure due to mishandling during assembly or installation, as well as differing moisture content of the timber in use. Currently, a regular inspection of the joints is performed manually, which is time-consuming and prone to errors. We propose a methodology that performs the inspection automatically with high accuracy. This is achieved by performing an image-based 3D reconstruction, which allows determining deformations and distances of the fasteners to the timber surface. A handheld stereo camera that returns RGB and disparity images is used to acquire multiple frames of a joint. The images are acquired from different positions to minimise gaps and noise in the resulting reconstruction. After segmenting the fastener and timber in the images, they are transformed to 3D point clouds. Coarse and fine registrations estimate the poses of the individual measurements resulting in a combined point cloud. To increase the accuracy, we model the fastener and the timber with different mathematical surface representations and estimate their model parameters. Most fasteners are best described by B-spline surfaces, which are able to approximate local deformations and defects. We evaluate the proposed methodology on two fasteners: one in a laboratory context and the other in a real application scenario. The experiments show that the distance of fastener and timber can typically be estimated with a deviation to a reference measurement in the range of 0.5 mm.

Keywords: 3D reconstruction, Stereo camera, B-spline surfaces, Metal plate fasteners