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A multi consumer-grade fixed camera set-up with poorly determined camera geometry for precise change detection [abstract]

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A multi consumer-grade fixed camera set-up with poorly determined camera geometry for precise change detection

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Key words: *Close range photogrammetry, Structure-from-Motion (SfM), camera calibration, 3D reconstruction, surface comparison, displacement monitoring*

Monitoring surface change with low-cost systems is of interest to both, science and industry. The Structure-from-Motion (SfM) workflow (SNAVELY *et al.*, 2006) is a photogrammetric technique which provides a valuable option for a range of monitoring applications. Inexpensive non-metric passive sensors such as single lens reflex (SLR) cameras, fully automated photogrammetric software and capabilities comparable to Terrestrial Laser Scanner (TLS), support the increasing use of this technique. However, some critical factors can affect the quality of the 3D scene generated (MOSBRUCKER *et al.*, 2017) introducing constraints and limitations. Specifically, camera calibration remains a critical control on the accuracy of derived data.

A four-fixed consumer-grade digital camera system has been evaluated, including the impact of poorly determined camera geometry, through both laboratory experiments (LE) and by field verification (FV). For the LE a scaled model of a steep vegetation-free slope was built at Loughborough University (Fig.1a). Critical factors investigated included camera calibration, network configuration and number of images processed. FV was conducted at the Spittles cliffs (Lyme Regis, England) to test the system on a real site and at larger scale (Fig.1b). This unstable cliff, mainly composed of Greensand that rests on Lower Lias clays with interbedded limestone layers (MAY, 2003), represents an ideal site for detecting small geomorphic change.

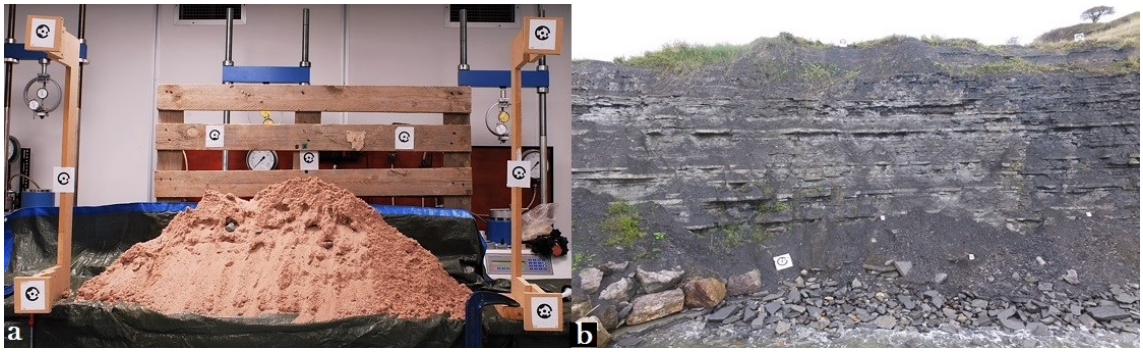


Figure 1: a) Lab experimentation: the slope was composed of sharp sand and was 1.5m long, 0.5m wide, 0.5m high and with a gradient of 60°. b) A section (25x20m) of an unstable sea cliff was selected for field verification.

During the LE, image acquisition was carried out using four DSLR cameras (Nikon D80) with a convergent geometry mounted on tripods placed 2m from the artificial slope. Tests were conducted with both, cameras in fixed and unfixed locations. After a first photo acquisition (Epoch1), a second set of images (Epoch2) was obtained after excavating three small localised holes on the slope surface. The general methodological approach involved using the SfM-MVS workflow to generate dense point clouds corresponding to the different epochs and estimating distances between closest points to obtain local displacements in 3D. Photogrammetric processing was implemented in PhotoModeler (www.photomodeler.com), whilst CloudCompare (www.danielgm.net/cc/) was used for change analysis. Distances were calculated with the multiscale model-to-model cloud comparison (M3C2) algorithm (LAGUE *et al.*, 2013). On both study sites use of only four frames produced high density point clouds and 3D surface change were successfully detected for both LE (Fig.2a) and FV (Fig.2b). On the FV,

displacements due to removal of targets, footprints in loose scree, small collapses, talus erosion and presence of vegetation were identified. Results demonstrate a significant improvement using a fixed camera system when compared to an unfixed configuration. As expected, a pre-calibrated camera model produced the most accurate result. Using this calibration option with a fixed camera configuration and comparing Epoch1 and Epoch2, a standard deviation of 0.9mm and mean distance of 0.02mm was produced. Interestingly, a wrong lens model produced similar results (standard deviation=1.5mm; mean distance=0.02mm), suggesting a significant reduction in systematic errors if fixed cameras are adopted.

The results of this investigation demonstrate the potential of developing an automated near-real time monitoring system that exploits a fixed camera configuration. The next stage of the research project will develop a variable frequency monitoring approach that will be presented.

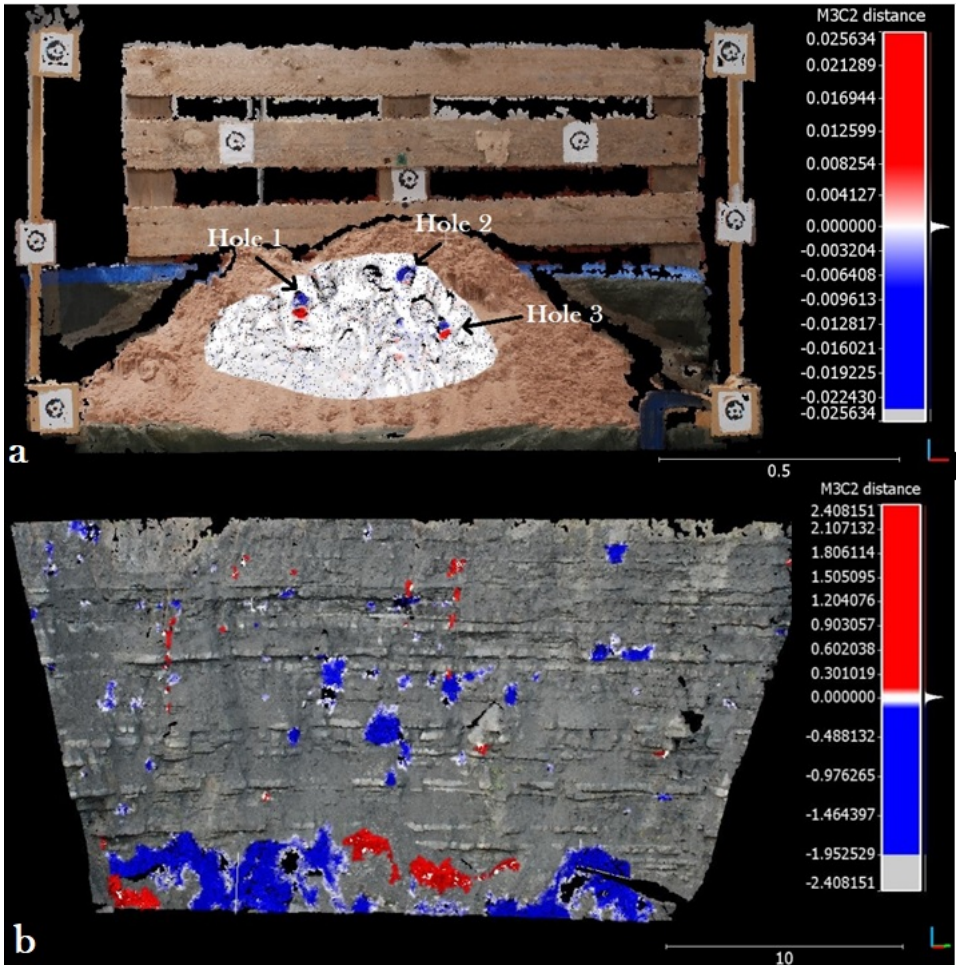


Figure 2. Example of the generated 3D point cloud for both LE (a) and FV (b). Multi-temporal comparisons obtained with the M3C2 algorithm and represented with colour scale histograms, shown capabilities to detect geomorphic changes (Blue – erosion; Red – deposition; White – no change).

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