On the use of low-cost trail cameras for high-resolution monitoring of river bank erosion in cold climates

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Due to global climate change, an increase in extreme weather events, flooding, more timely river break-ups and reduced snow cover is expected in cold climates (COOLEY & PAVELSKY, 2016). Climate change, together with sedimentation on water bodies, might lead to an increased flood risk because of channel changes.

Besides studies on river flow characteristics, spatio-temporally high-resolution observations of bank dynamics during the flow period of open channels are important for hydro-morphological observations and modelling to support flood mitigation at arctic rivers.

We present a novel and cost-effective approach based on stereo photogrammetry using time-lapse images of a river bank captured by low-cost trail cameras to generate spatio-temporal high-resolution 3D models for change detection. The fundamental technique is Structure-from-Motion (SFM), which has already enjoyed great popularity in the geoscientific community for several years (ELTNER & SOFIA, 2020).

Trail cameras are characterised by long operating times with one battery charge and seem to be excellent for long-term monitoring. In a first field campaign, four trail cameras were installed at distances of about 60 metres towards an erosion-prone river bank at Pulmanki River, Finland (see Fig. 1). They were set to time-synchronised serial modes with 2-hour intervals and, with sufficient illumination, reliably captured images between September 2020 and May 2021. Furthermore, we installed six permanent ground control points (GCPs) for georeferencing and scale definition: three on the flanks of the bank and three on the shore towards the cameras.

In the late autumn and winter months, the study area is covered by snow, which is why we split the observation time into two periods. The first period ranges from the day of camera installation to the first heavy snow fall, i.e. 20th September to 16th October 2020. The second period ranges from the day of the areas almost cleared of snow to the day of the data retrieval during a second field campaign, i.e. from 10th April to 16th May 2021.

We propose robust vision methods enabling automated image processing and 3D change detection. This implies the assembly of the individual image data sets, the automatic image measurement of GCPs and the image matching to determine the respective image orientation parameters in a joined reference system via SFM. Dense 3D point clouds are computed for each time stamp via dense matching. However, the low-cost images suffer from low image resolutions and poor image quality, especially in low light conditions, which manifests in image noise, artefacts and aberrations and negatively affects the quality of 3D reconstruction. Therefore, change detection is done by M3C2-PM distance measurement considering precision maps to account for noise in the 3D data (JAMES *et al.*, 2017). The determined changes are further reviewed against local and systematic errors, the latter to be detected by plausibility controls comparing chronological models.

We used this method for the semi-automatic processing of the first observation period and generated 133 high-resolution 3D point clouds with an average inner precision of 2 cm. Only an initial pre-selection of the GCPs based on one image per camera was necessary to provide the basis for subsequent automatic detection. The change mappings reveal quantifiable landslide events even in this first period, which so far would have remained undetected (Fig. 2).

Figure 1: Study area: Pulmanki River, Arola, Finland (69.93°N lat, 28.04°E lon). Red triangles: camera positions.

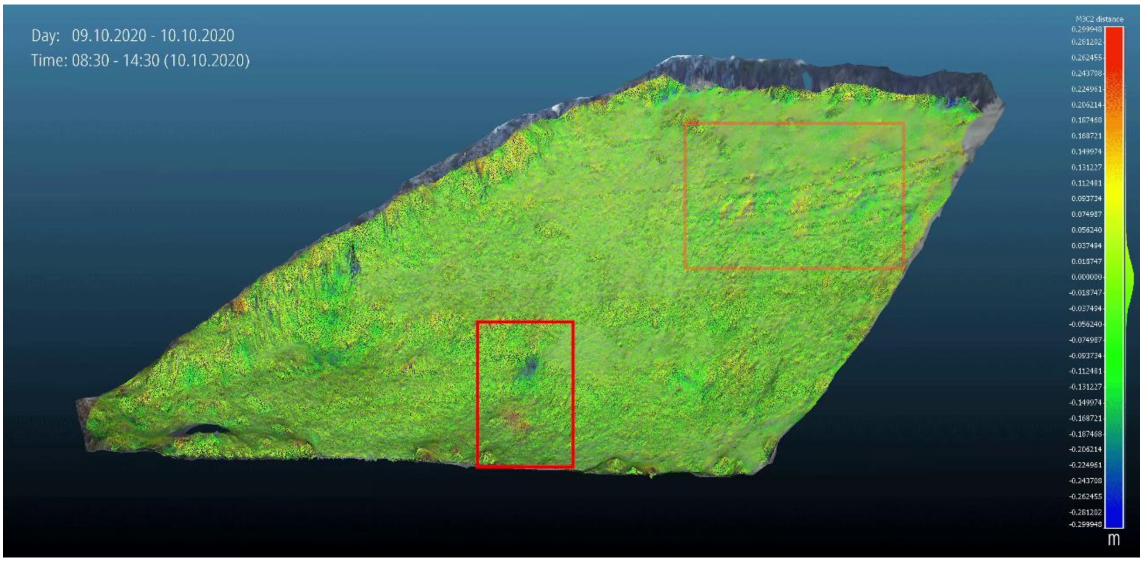

Figure 2: Landslide detection and quantification within the bank area.

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