Assessing UAV survey performance for geomorphological monitoring of mountain rivers

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Motivation

Unmanned aerial vehicles (UAV) offer a low-cost technique to obtain high-precision elevation data, which is attractive for regular watershed monitoring. Besides costs, UAV-based monitoring requires the usage of ground control points (GCP) that reference image pixels to spatial coordinates on a digital surface model (DSM). Despite the advantage of such points, their implementation can be difficult and time consuming, due to poor access, light conditions and canopy present in natural environments. This work aims to suggest a number of GCP in consideration of terrain topography and the desired definition to be obtained in the resulting DSM. We carried UAV flights at various heights over two different areas: a steep-slope area with irregular topography that comprises a narrow road and a mountain creek, and a nearly-flat area that comprises a river channel with its floodplain.

Since 2017, we are surveying the Navisence River in Zinal, Switzerland. We are interested in optimizing the number of GCP for our surveying area.

Area of interest - Technical details

Characteristic	Nearly-flat area	Steep-slope area
Altitude range [m.a.s.l.]	1670 to 1682	1715 to 1913
Surface [ha]	4.34	4.25

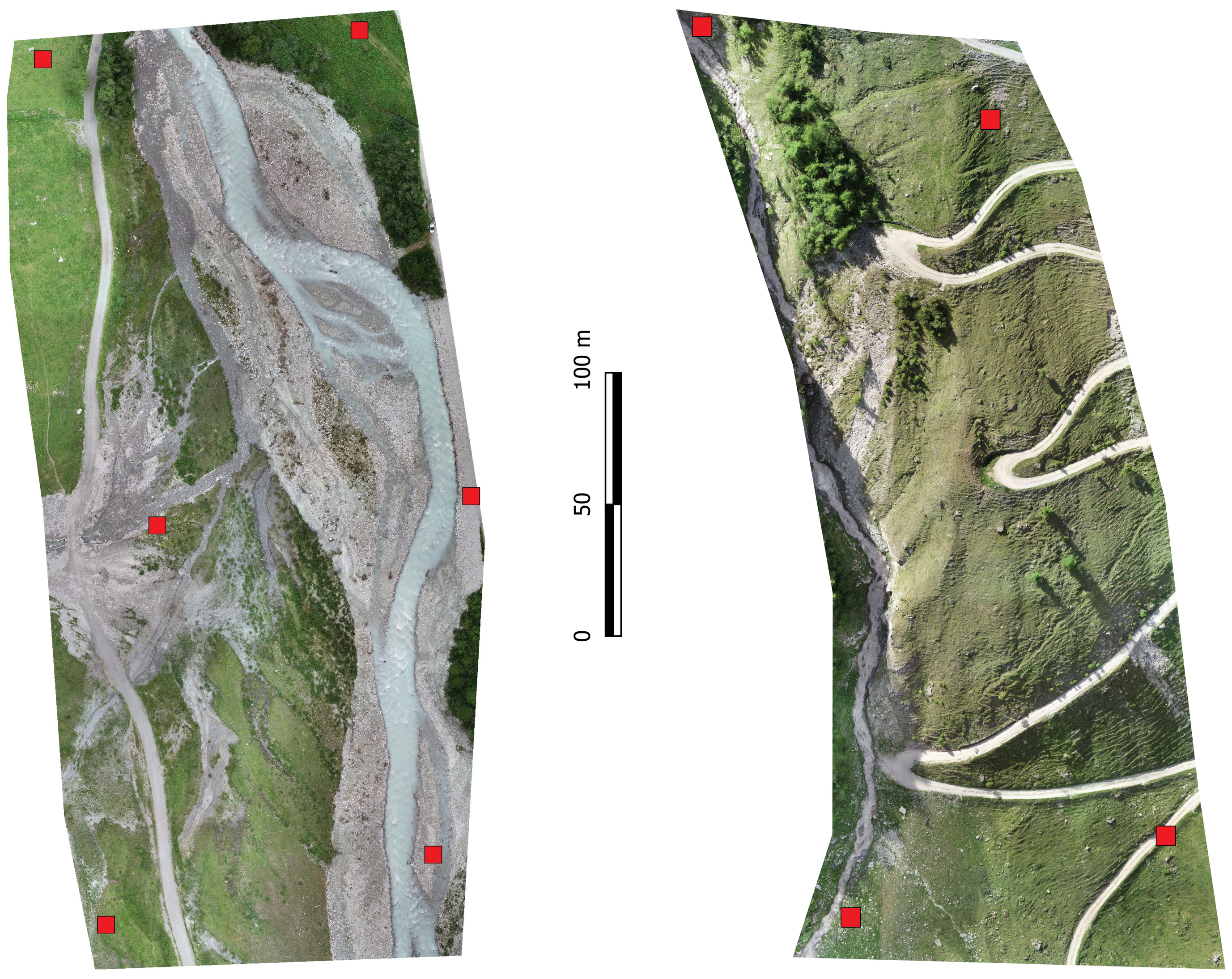

Figure 1: Nearly-flat (left) and steep-slope (right) areas. Red squares: Ground Control Points (GCP) considered for DSM in Fig. 2 and Fig. 3.

Number of GCP	3 to 10
Target size	40 cm red square plate w/ 5 cm-thick white cross
Number of check-points	8
GPS	Leica Zeno 20
Flight height [m]	40, 60, 80, 100, 120, 140
Flight overlap [%]	80
Camera orientation	Nadir
UAV Model	DJI Phantom 4 Pro
Flight planning software	Map Pilot Pro w/ terrain awareness
Processing software	Pix4D Mapper
DSM output resolution	5 cm (> GSD at 140 m) w/ same grid

About the targets

While the DSM roughness is affected by the flight height, its global accuracy is not, as long as the GCP targets are large enough so that the points can be easily defined. Although the width of the cross was larger than the GSD, the cross was too small for the flights carried out at 140 m, which resulted in larger errors on the control points. Thus, these models were not considered in the analysis.

Error map analysis

For each flight height, 4 DSM are obtained using 3, 4, 6 and 10 GCP. These models are calculated for each area, resulting in 48 DSM. As expected, accuracy vary significantly between models. We quantify the model accuracy with control points (CP) spread over the area, of which their coordinates are known. **Surprisingly, models using 4 GCP show much larger errors for the nearly-flat area than for the steep-slope area (see Fig. 2). In particular, on the steep-slope area models with 4 GCP, the errors are smaller but still larger than observed in other models using more GCP.**

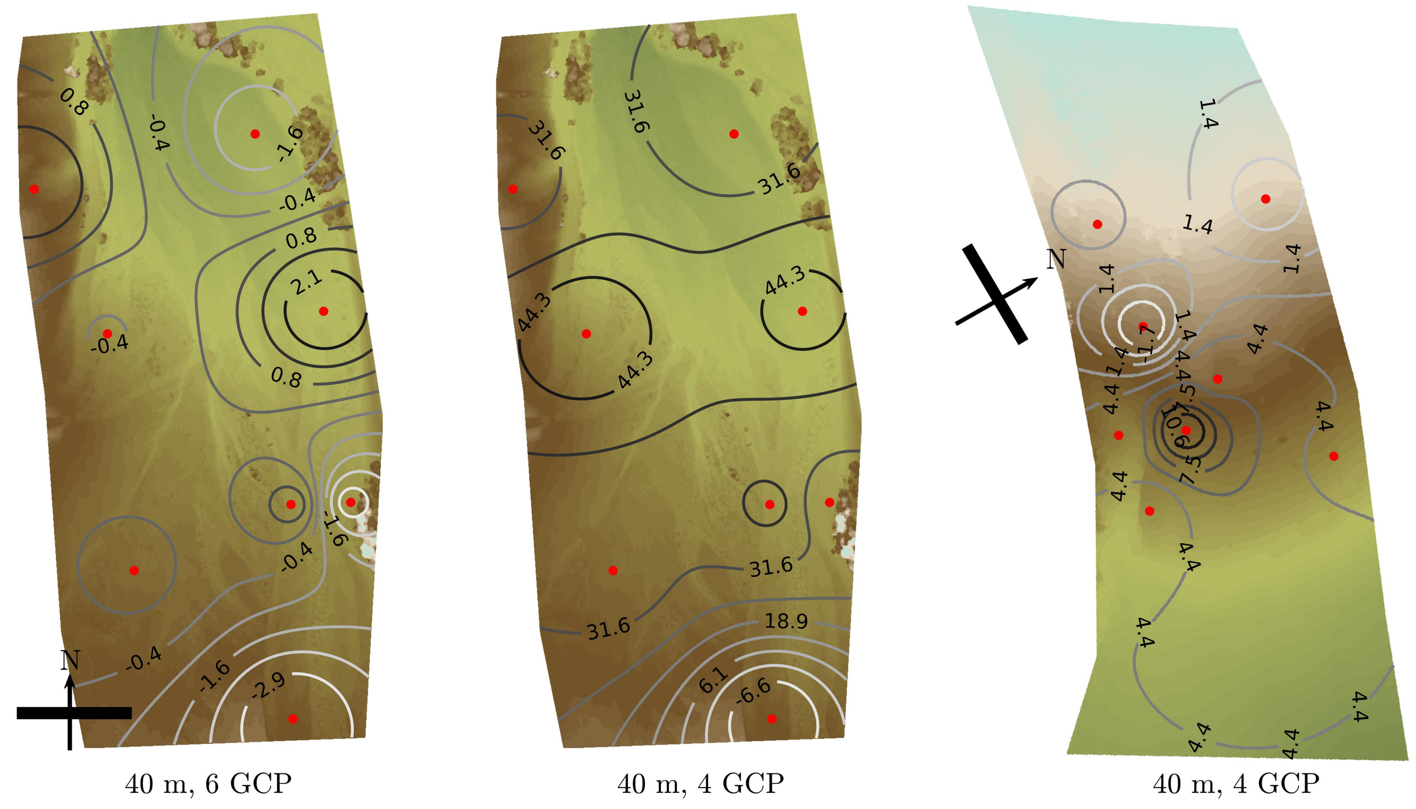

Figure 2: Elevation error distribution of the resulting DSM for 40 m height surveys. Errors are shown only for elevation, since it is the most significant error of the DSM's coordinate system. In terrain color palette: model elevation. In gray-scale: elevation errors in cm. Red dots: check points (CP).

Topographic roughness accuracy vs. Flight height

Considering the digital surface models (DSM) computed using 6 GCP, we assessed the flight height influence on the DSM roughness accuracy. The proper reconstruction of topographic roughness is particularly important when DSM are used in flood modelling or geomorphic change analyses at the sediment scale. We assumed that the model DSM_{40} obtained for the 40–m-high flight was the most accurate in terms of topographic roughness. By using the Geomorphic Change Detection (GCD) software (http://gcd.riverscapes.xyz/), we computed the DEM of Difference (DoD) between DSM_{40} and the models associated to flight heights of 80 m and 120 m. We reported the findings for the nearly-flat area.

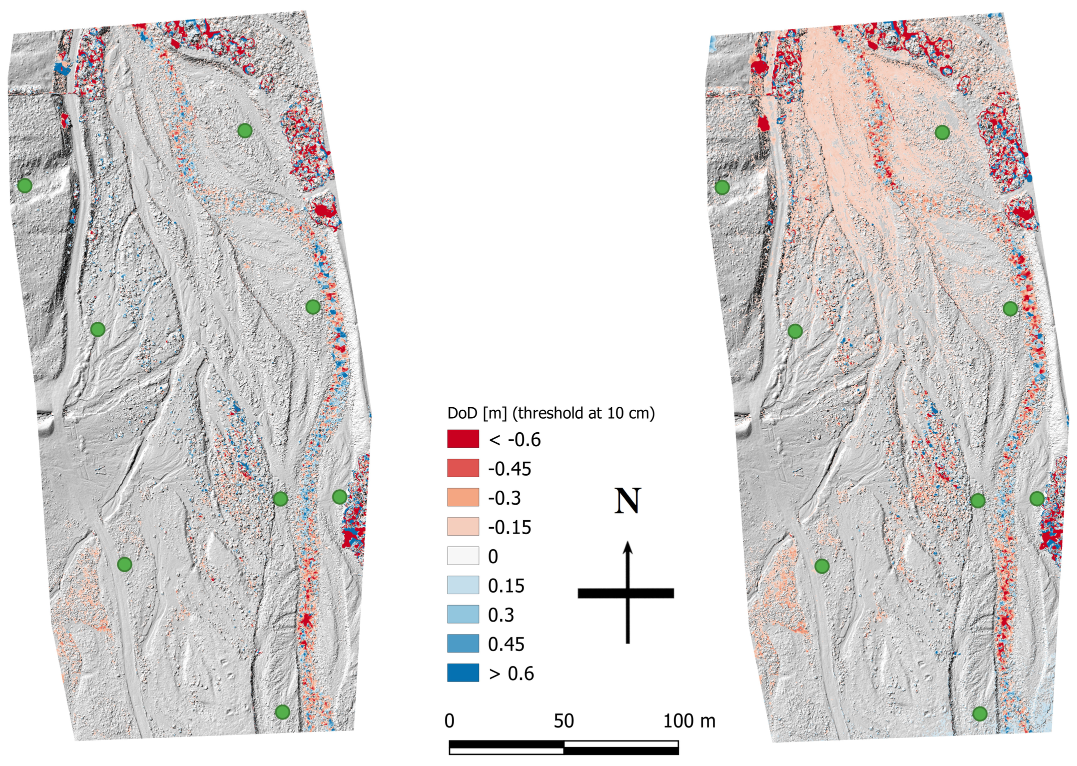

Figure 3: DoD outputs: DSM_{40}-DSM_{80} (left) and DSM_{40}-DSM_{120} (right). Minimum Level of Detection (MLoD) of 0.1 m. Background: hillshade raster at 40 m. Green dots: check points (CP).

DSM_{80} and DSM_{120} resulted "flattened" in the northern sector (see Fig. 3). In particular, **DSM_{120} was characterized by large patches of the dry floodplain with elevation values that exceeded the corresponding ones in DSM_{40} by more than 0.15 m.**

Outcomes

On the steep-slope area with an irregular topography we needed less GCP than on the nearly-flat area to achieve a similar accuracy. On the nearly-flat area, the best results were achieved using 6 GCP, with a X-Y-Z mean error for the 40-120 m flights equal to 3.05 cm. On the steep-slope area, using 4 GCP, we obtained a X-Y-Z mean error of 4.18 cm, while using 6 GCP the precision did not improve significantly (3.85 cm). **6 GCP for 4 has seems an optimal amount. On both areas, using only 3 GCP is not a reliable solution in terms of accuracy, while increasing the GCP number from 6 to 10 does not improve the DSM accuracy.**
To survey a mountain river at sediment scale, it is necessary to use always the same optical settings. The flight height and the focal length of the camera affect the field of view on the vertical shapes. The flight height should be carefully selected for the monitoring campaign according to the survey purpose. **DSM roughness accuracy may be significantly affected by the flight height also on gentle-sloping rough surfaces such as mountain floodplains. Although this flight-height effect is already known in literature, its relative magnitude is also affected by the site-specific topography and surfaces.** Preliminary DoD analysis may be a useful tool also for DSM assessment and UAV survey planning.