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# Recommendations for improving the repeatability of UAV-based topographic surveys using GCPs or direct georeferencing

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UAVs offer the potential for rapid acquisition of accurate and high-resolution topographic data, over broad spatial extents. However, surveys are not always optimally designed to maximise the data reproducibility (measurement precision) which is critical for applications involving change-detection. Here, we illustrate key aspects of survey design that affect reproducibility, and we show how recommendations differ between direct- and GCP-georeferenced surveys. Most UAV surveys are designed based on a conventional aerial survey pattern, which provides a strong basis for ensuring good image coverage. However, weaknesses can be exposed through the typical use of consumer-grade cameras without accurate calibration data, and the practicalities that limit the dense deployment and measurement of GCPs. Such weaknesses degrade the measurement precision, which is a complex function of photogrammetric factors (e.g. image network geometry, tie point quality) and georeferencing considerations (e.g. the number, distribution and ground survey quality of GCPs used for control). Consequently, understanding the precision-limiting factors (i.e. whether photogrammetric or related to georeferencing) can guide decisions for strengthening surveys – e.g. deploying more GCPs or collecting more imagery.

We demonstrate the relative influences of photogrammetric and georeferencing factors by varying the control precision for a $\sim$4700 $m^2$ oblique aerial survey of Badlands in the Central Pyrenees, Spain, 2014. With the survey georeferenced using 19 GCPs measured by GNSS (a Leica Viva GS15 in RTK mode, giving a precision of 14 – 41 mm in the vertical), overall vertical precision was limited by photogrammetric effects (James et al., 2017). Consequently, adding more control would have little effect (results would have been similar if only 8 GCPs had been used for control). However, the survey may have been improved by more or better imagery and a stronger network geometry.

If the survey had been directly georeferenced using known camera positions, then camera positions would have had to be known to $\sim$100 mm to achieve the same overall survey precision. However, if camera positions were known with a precision of only $\sim$500 mm, then the overall survey precision would degrade by a factor of $\sim$3 and become dominated by georeferencing factors. In this case (and with all other factors equal), survey precision could be improved by flying a wider survey, closer to the ground. As directly-georeferenced surveys become more prevalent, a review of survey design practice is strongly warranted to ensure optimum data quality is achieved.

Reference:

James et al. (2017) 3-D uncertainty-based topographic change detection with structure-from-motion photogrammetry: precision maps for ground control and directly georeferenced surveys, https://doi.org/10.1002/esp.4125