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Cost-Effective Non-Metric Photogrammetry from Consumer-Grade sUAS

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The declining costs of small Unmanned Aerial systems (sUAS), in combination with Structure-from-Motion (SfM) photogrammetry, has triggered renewed interest in image-based topography reconstruction. However, the potential uptake of sUAS-based topography is still limited by the need for ground control acquired with expensive survey equipment. Direct georeferencing (DG) is a workflow that obviates ground control and uses only camera positions at image acquisition to solve the photogrammetric equations. However, the absence of ground control poses significant challenges in terms of the data quality of the final geospatial outputs. Notably, it is generally accepted that ground control is required to refine the camera calibration parameters and remove any artefacts of optical distortion from the topographic model. Here, we present an examination of DG carried out with low-cost consumer-grade sUAS. We begin with a Monte Carlo study of surface deformations resulting from perturbations of the radial distortion parameters K1 and K2. We then test a number of flight patterns and develop an explicit approach to error quantification which has allowed us to meaningfully assess the outcomes. Our Monte Carlo analysis shows an important result: There exists families of equifinal solutions of K1-K2 which eliminate systematic deformations in the output model. The equifinal solutions can be expressed as K2=f(K1) and they have been observed for both the DJI Inspire 1 and Phantom 3 sUAS. This approach to camera calibration allows for a DG workflow to produce topography exempt of non-affine deformations, random errors of 0.1% of the flying height, off-vertical tilts below 1° and easily adjusted systematic biases. Whilst not yet of survey-grade quality, these results demonstrate that low-cost sUAS are capable of producing reliable topography products without recourse to expensive survey equipment. We therefore argue that direct georeferencing and low-cost sUAS will transform survey practices in both academic and commercial disciplines.