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Structure from Motion (SfM) photogrammetry applied to historical imagery: plug & play?

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The development of Structure from Motion (SfM) photogrammetry has led to a vast increase and expansion of geomorphological applications. Highly detailed Digital Elevation Models (DEMs) can be efficiently generated from a variety of platforms that cover a large range of spatial scales. For the application of DEMs in geomorphic change analysis, precision and spatial resolution are not of sole importance, but also their accuracy, temporal resolution and temporal coverage. The use of archival imagery may substantially lengthen temporal coverage, allowing quantification of annual to decadal scale landform change. Whilst archival photogrammetry is not new, a question arises as to how applicable SfM methods are as a more cost-effective and straightforward alternative to the conventional approach. Here, we studied a relatively extreme case where we applied SfM techniques to archival aerial imagery, to investigate the decadal evolution of a low relief braided river.

The Borgne is an Alpine river in south-west Switzerland which is strongly affected by flow abstraction for hydropower, allowing the fairly straightforward application of photogrammetry on the near-dry river bed. For 8 sets of scanned historical aerial images in the period 1959-2005 we performed Ground Control Point (GCP) assisted bundle adjustment using both classical archival digital photogrammetry (used as a reference dataset) and SfM based photogrammetry. For the SfM method, no further data were used to constrain camera or exterior orientation parameters a priori, but instead we used these for a posteriori verification. The resulting densified point clouds were registered onto a reference surface based on stable areas, allowing the correction for any systematic error in DEMs that may arise from (random) error in the bundle adjustment.

The obtained results show that the quality of the SfM based bundle adjustment is similar to that of the classical photogrammetric approach. Next to image scale, the quality is strongly driven by ability of computer vision techniques to extract tie-points, which is controlled by image texture (quantified here using entropy) and image overlap (redundancy). Depending on the used image set, these characteristics may therefore be effectively exploited or pose a limitation for application. The quality of the results aside, we found that the recovered bundle adjustment parameters were not necessarily correct and that there was the possibility for a trade-off, between estimated focal length and camera flying height for example, such that the right results were obtained if not for the right reasons. This highlights the need to assess camera and exterior orientation parameters, and to address systematic errors that may evolve from this. For the latter, we found that point cloud registration is crucial, particularly in a low relief environment such as a braided river, for accurate change quantification and geomorphic interpretation. We conclude that, given a suitable set of images and considering principles of classical photogrammetric analysis, SfM methods can be effectively applied for archival imagery analysis, but that this is by no means a plug and play methodology.