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Multi-epoch bundle block adjustment for processing large dataset of historical aerial images

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After World War II, aerial photography i.e. vertical or oblique high-resolution aerial images spread rapidly into civil research sectors, such as landscape studies, geologic maps, natural sciences, archaeology, and more. Applying photogrammetric techniques, two or more overlapping historical aerial images can be used to generate an orthophoto and a 3D point cloud, wherefrom a digital elevation model can be derived for the respective epoch. Combining results from different epochs, morphological processes and elevation changes of the surface caused by anthropogenic and natural factors can be assessed. Despite the unequalled potential of such data, their use is not yet fully exploited. Indeed, there is a lack of clear processing workflows applying either traditional photogrammetric techniques or structure from motion (SfM) with camera self-calibration. In fact, on the one hand, many SfM and multi-view stereo software do not deal with scanned images. On the other hand, traditional photogrammetric approaches require information such as a camera calibration protocol with fiducial mark positions. Furthermore, the quality of the generated products is strongly affected by the quality of the scanned images, in terms of the conservation of the original film, scanner resolution, and acquisition parameters like image overlap and flying height.

To process a large dataset of historical images, an approach based on multi-epoch bundle adjustment has been suggested recently. The idea is to jointly orient the images of all epochs of a historical image dataset. This recent approach relies on the robustness of the scale-invariant feature transform (SIFT) algorithm to automatically detect common features between images of the time series located in stable areas. However, this approach cannot be applied to process digital images of alpine environments, characterized by continuous changes also of small magnitude that might be challenging to automatically identify in image space. In this respect, our method implemented in OrientAL, a software developed by TU Wien, identifies stable areas in object space across the entire time series. After the joint orientation of the multi-epoch aerial images, dense image matching is performed independently for each epoch. We tested our method on an image block over the alpine catchment Kaunertal (Austria), captured at nine different epochs with a time span of fifty years. Our method definitely speeds up the process of image orientation of the entire data set, since stable areas do not need to be masked manually in each image. Furthermore, we could improve the orientation of images from epochs with poor overlap.

To estimate the improvements obtained with our methods in terms of time and accuracy of the image orientation, we compare our results with photogrammetric and commercial SfM software and we analyse the accuracy of tie points with respect to a reference Lidar point cloud. The work is part of the SEHAG project (project number I 4062) funded by the DFG and FWF.