Large scale airborne city capturing - challenges and opportunities

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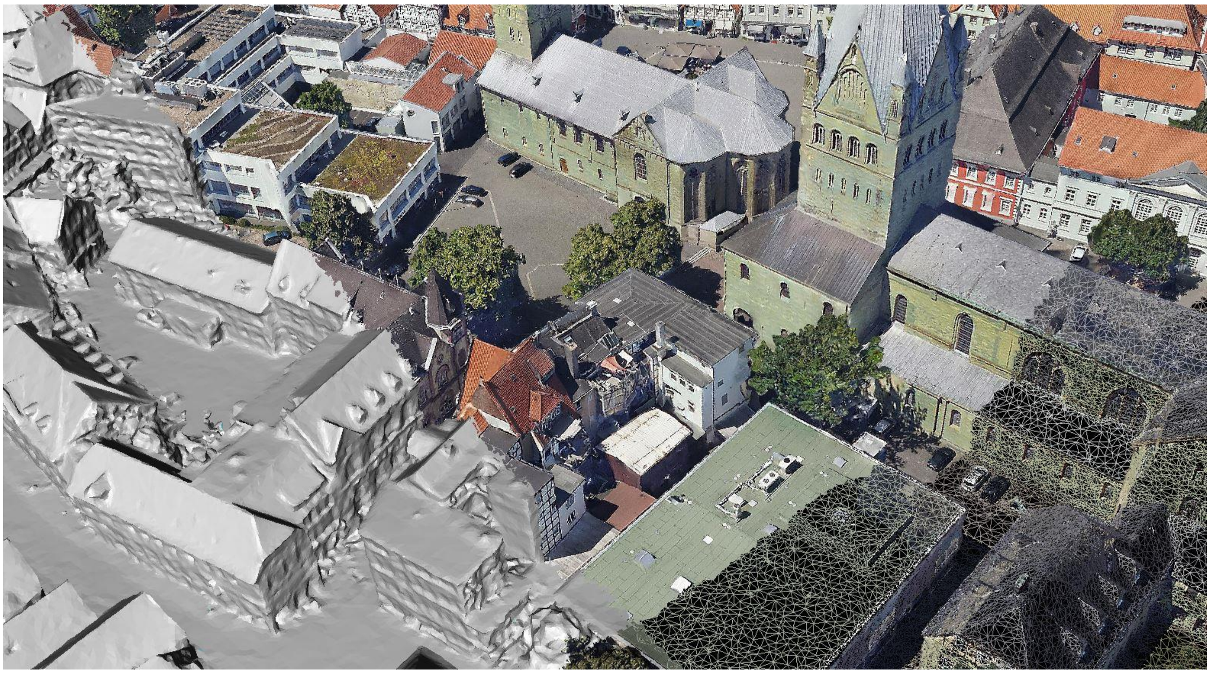

The demand of 3D Meshes, Point Clouds and True Orthophotos increases rapidly – so do the requirements in respect to resolution and capturing speed. Cities with hundreds of squarekilometers area are captured with few centimetres resolution and with that terabytes of data are acquired within hours. Photogrammetry enables a fully automatic approach in deriving 3D surface geometry from images. The resulting data serves for various applications in a rapidly growing market – including mapping, city planning, forestry, environmental monitoring, disaster management, Smart City or BIM.

The SURE Software

The SURE Software is a *Dense Image Matching* software enabling the automatic computation of Point Clouds, True Orthophotos and Textured Meshes for a given set of images and their orientation from Aerialtriangulation. It uses a variation of the *Semi Global Matching* algorithm for the dense stereo matching, which opposed to the original algorithm works hierarchically and is thus more efficient as well as adaptive to scenes with large depth variations. This enables fast processing of demanding scenes such as Oblique city capturing while preserving sharp edges at discontinuities. Furthermore, a *multi-stereo triangulation* exploiting the redundancy between observations for outlier filtering and noise reduction is used. Point Cloud filtering modules in 2.5D and 3D enable the derivation of clean and uniformly sampled Point Clouds. True Orthophotos are produced by remapping the original images according the the Digital Surface Model and blending them while optimizing texture content. Due to the high quality DSM, True Orthophotos directly serve as an orthographically correct Orthophoto – without the need of manual seamline editing. 3D Meshes are derived from the Point Clouds and can be automatically textured using the projection to different views, an optimization of optimal texture as well as texture blending.

Requirements of professional production

In professional data production, the requirements regarding accuracy, scalability, production efficiency and costs need to be balanced. This implies particularly the ability to scale to datasets of a few ten thousand large frame images per block on common hardware. Besides adaptive and efficient resource usage, long term stability and abilities to distribute processing on several machines play an important role. Since its introduction in 2013, the SURE software has been heavily used in the mapping industry for large scale projects for countrywide production as well as city mapping. For example, in Turkey more than 850 cities were processed involving more than 350000 large frame images for True Orthophoto and DSM production with 10cm ground resolution. Besides stability and scalability also output formats and subsequent workflow requirements should be covered. For example, the ASPRS standard Point Cloud format *las* is used to write Point Cloud data while maintaining the colour information of the original images in full 16 Bit with up to 4 channels as well as meta information such as the Point Source (image number) and the redundancy of image measurements for each point. True Orthophotos and DSM images are written as standard georeferenced tif images – compatible with common GIS solutions. Textured Textured triangle meshes can be written to common formats such as *obj,* but also as *tiled Level of Detail structures* enabling efficient visualization and streaming for example with the *osgb* or *Cesium tile* standard.

Custom workflows

Custom workflows are required to combine processing methods from different domains and to interact with data within the processing steps. For example, Point Cloud classification can be used to modify data being extracted by *Dense Image Matching* before using it for True Orthophoto production or to automatically augment data for further analysis in a GIS context. Demanding surfaces such as water can for instance lead to issues in the reconstruction and with that to insufficient output quality in these areas. For this purpose, the SURE software uses a modular concept – enabling data manipulation between processing steps. For instance, water points can be automatically cropped and set to an equal level by using water polygons within a 3rd party software before using the result within the True Orthophoto and textured Mesh production.

Besides automatic and semi-automatic manipulation with such software solutions, the SURE Software enables also manual data editing through a *Mesh Editor.* Within this editor, a triangle based representation is used to better visualize depth through shading of a seamless surface. Opposed to Point Coud editing, this enables the differentiation of an edge versus other surfaces without using colour information. Furthermore, the SURE Editor is using a *paged Level-of-Detail* structure to stream large Meshes from the hard disk – enabling efficient editing. The editing comprises also a change tracking and with that an undo/redo function. Also, texturing can be applied where only the edited tiles are re-textured. Besides the Meshes being produced in 3D, also 2.5D Digital Surface Models can be edited as the SURE Software can dervive a 2.5D Mesh from the DSM in the same tiling structure. By sampling the resulting points from the Mesh, the edited result can be written again as Point Cloud and thus be used in the DSM and True Orthophoto production workflow.

Data acquisition

The quality of the imagery defines the output quality of 3D and 2.5D products. The precision of each point is directly depending on the geometric resolution – defined by the ground resolution (GSD). The radiometric quality is of particular importance, since the colour or grey value is the measured signal in the pixel-wise matching and reconstruction process. If insufficient texture is available due to insufficient light – represented by the signal to noise ratio, the matching process will lead to lower point quality. On the opposite, strong radiometric signal and sharp texture lead to excellent subpixel measurement accuracy and thus more precise 3D points. Consequently, sensor quality as well as exposure conditions and parameters play an important role.

The image block configuration – mainly defined by the *image overlap,* defines the redundancy of stereo measurements as well as the potential intersection angle. Even though large intersection angles close to 90 degrees would theoretically lead to optimal height precision, only limited intersection angles or base-to-height ratios should be used in practice in order to guarantee sufficient image similarity to enable successful pixel to pixel matching as well as limiting the amount of occlusions.

The resulting flight planning thus needs to consider these constraints as well as enable a sufficient redundancy. In the aerial mapping industry, an 80% forward (in-strip) overlap has been proven as a strong benefit for the output quality without additional flight costs. The sideward overlap should be selected according to the application. Whereas 30% sideward overlap can be sufficient of the countrywide acquisition of only slightly undulating landscape from higher altitudes, more demanding scenes such as urban areas with larger buildings and likelihood of occlusions require about 60% sideward overlap up to 80% for skyscrapers.

In order to determine the optimal overlap – while considering the scene type and the properties of the imaging sensor, a generic approach is required. It describes the image overlap in combination with building lean for planning low occlusion datasets by considering the *Central Image Contribution* (also referred to as *Net-Image)*. This central part of the image is defined by the area between the overlaps or the counter percentage (e.g. 60%/30% => the 40%,70% of the image center). Within this *Central Image Contribution*, the occlusions caused by the building (or any object) lean should be minimized - e.g. to less than 20 pixels. It can be estimated as the half of the opening angle of the *Central Image Contribution* - leading to the maximum building lean angle at the border of the *Central Image Contribution*. By introducing a maximum building height, the effective maximum occlusion can be estimated. As this value can be determined in pixels, both scene properties as well as camera properties are considered.

Conclusion

Data capturing as well as flight planning need to consider geometric quality, radiometric quality and an image overlap according to the scene type. A generic approach for determining an optimal overlap has been presented. Automatic extraction of 2D and 3D mapping products as well as custom workflows as available with the SURE Software are required to match the needs of professional production.