

ON THE ACCURACY OF 3D LANDSCAPES FROM UAV IMAGE DATA

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1. PROBLEM

Aerial images taken by a UAV can be used for many purposes. The most obvious ones are the generation of orthophoto's, and the surveillance of ground targets. In addition, structure from motion algorithms have enabled the creation of dense digital terrain models, in other words a complete 3D model of the overflown terrain. As real world applications using 3D models become more demanding, a rough approximation is not good enough anymore. For example, city planning requires models of sub-meter accuracy, a task which is currently performed by surveyors. A UAV offers the benefit of being both cheaper and faster than surveyors. The question however is whether they can be accurate enough to complement (or even replace) surveyors as the method of choice for applications requiring high precision 3D models. It turns out that under certain conditions the accuracy of the model matches the accuracy of surveyor generated measurements.

2. METHODOLOGY

In order to evaluate the accuracy of the 3D model we limit ourselves to a specific site. It is an area of about 1500 x 300 m, containing a long, flat-topped and man-made hill, created from leftover sand and mud from dredging operations. The view in Google Maps of this area is shown in figure 1. An orthophoto generated from UAV data is shown in figure 4. The outdated image from Google shows a central area which is not yet filled up, whereas the more recent orthophoto based on the UAV images shows a complete hill. The raw data used to create the 3D model are pictures taken by a UAV from the company Gatewing [1], a spin-off from Ghent University. The UAV flew at an average altitude of 150 m and took 10 megapixel pictures, giving an average pixel size of about 5 cm. In total 439 pictures were taken in 5 flight lines with a 90% overlap in a flight line and a 60% overlap between flight lines, allowing for good image matching and good stereovision. Some example images are shown in figure 2.

Ground truth for the terrain was available as a few thousand points measured by surveyors in 2007 (for the estimation of the volume of the hill). A 3D model of these points is shown in figure 3. We also created our own ground truth by placing cross-shaped markers on the terrain and precisely measuring their GPS position, with an accuracy of about 5 cm (using DGPS and FLEPOS post-processing [2]). These markers are clearly visible in the UAV pictures and act both as ground control points and as a means of evaluating the model accuracy.

Practically the 3D model was created using standard structure from motion techniques. First feature points are extracted in all images (e.g. SURF [3]) and are matched with each other. We use the GPS information from the UAV to speed up the matching process by only comparing images that we know can overlap. Then the pictures are roughly positioned with RANSAC, after which a bundle adjustment is performed to minimize the total reprojection error. Camera calibration is included in the optimization equations, however we also calibrate the camera in advance to start the optimization closer to the global optimum [4]. We increase computation speed by exploiting the sparsity of the equations [5]. This gives a sparse 3D model, which is used as the input to a multi-view stereo method [6], which creates an arbitrarily dense cloud of points. The points are then meshed with a 2D Delaunay triangulation, and some noise filtering is applied, giving the results of figures 4 and 5. Figure 5 is actually the 3D representation of the area shown in the left-most image of figure 2.

*This work was performed as part of an IWT project between Ghent University and Gatewing.



Fig. 1. Google maps view of the area used for evaluating the accuracy of 3D generation.



Fig. 2. Three examples out of 439 pictures taken by the UAV flying over the terrain. The original picture size is 3648 x 2736 pixel.

To evaluate this model we include the marker positions in the optimization process and compare their computed position with their DGPS-based measured position. For 14 markers the results are shown in figure 6(a), distinguishing between the x, y and z directions. The error is quite high at up to 5 meter. However it is in the form of a global bias, a translation of the entire model. The cause of this is that for these measurements only the GPS information of the UAV was available, which is very inaccurate.

When we include some of the markers as ground control points in the optimization process, we will actually pull the entire model closer to its real position. Adding 4 of the 14 markers spread evenly over the terrain, we obtain much better results for the other markers, as shown in figure 6(b). We now achieve an accuracy of 10 to 20 cm, which comes close to the accuracy of the DGPS measurements.

3. CONCLUSIONS

We conclude that the current 3D generation method reaches an average accuracy of about 10 to 20 cm in all directions, and this for a flying height of 150 meter and pixel size of 5 cm. We must note however that this good result is obtained with the inclusion of a few ground control points, spread evenly over the terrain. So ground based surveying is still needed, but only takes a fraction of the time required without a UAV. When no ground control points are used, the accuracy is about 5m. The accuracy of 10 to 20 cm is sufficient for many practical applications, even though there is still room for improvement. For example, adding more ground control points will further increase the precision. This of course has to be balanced by the amount of manual labor required, both to place and measure the markers, and to add them to the workflow. Better pixel correlation methods can also further improve the results, at the cost of computation time.

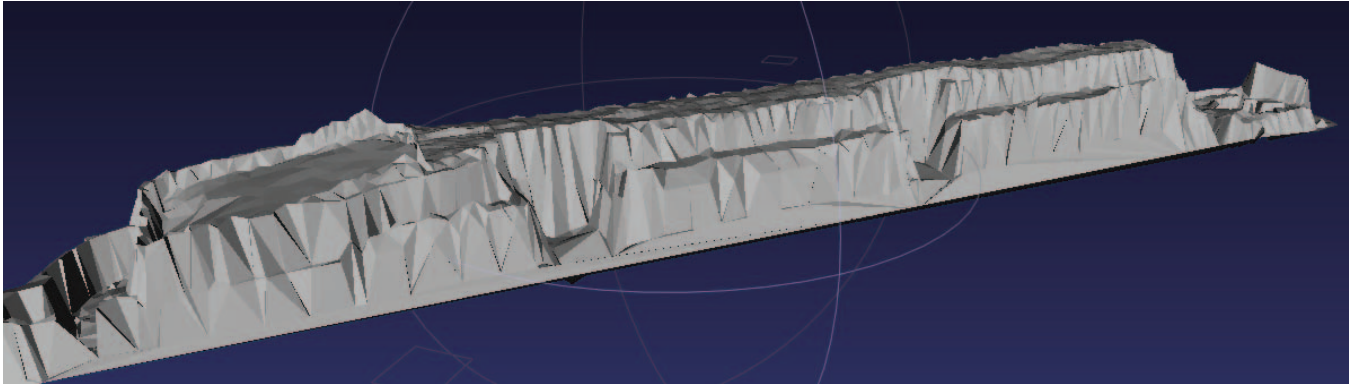


Fig. 3. 3D model of ground truth data based on about 1000 surveyor points (with a 10x exaggerated height to clearly show the 3D structure).



Fig. 4. Orthophoto created by viewing the generated 3D model top-down, measuring approximately 1000m x 200m.

4. REFERENCES

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Fig. 5. Close-up of the dense generated 3D model, showing part of the highway and the complex shape of the hill. This subsection contains around 1 million vertices.

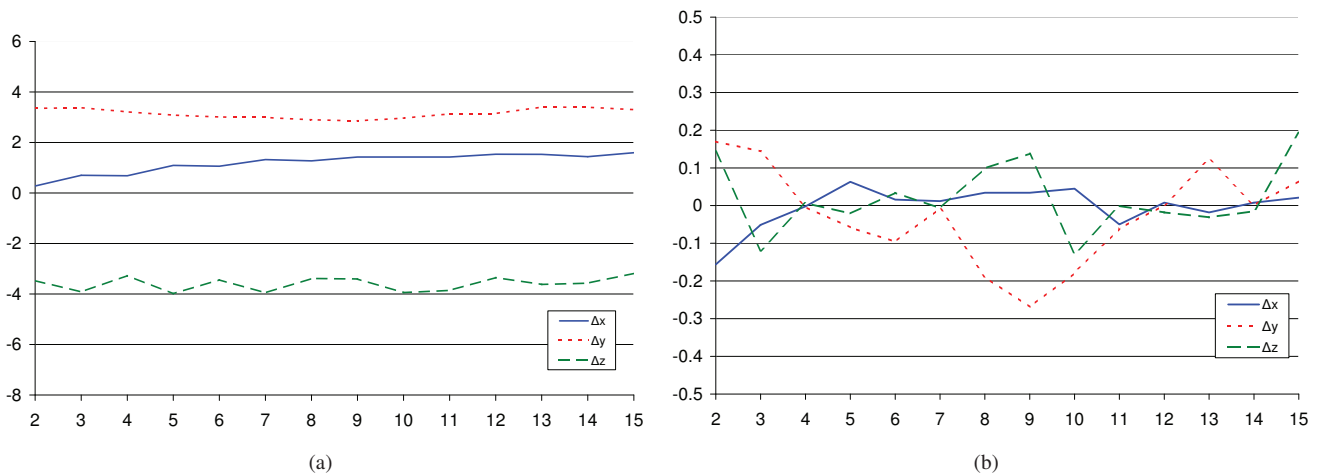


Fig. 6. The difference in meter between measured and computed marker positions. (a) No ground control points added into the calculations. (b) Markers 4, 7, 12 and 14 added as groundtruth into the calculations.