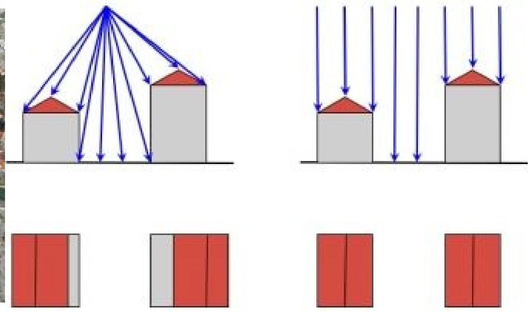
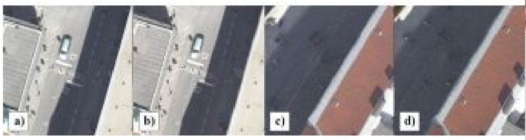
BALANCING ECONOMIC COSTS WITH AESTHETIC APPEARANCE

Automatically produced true orthophotos for large urban areas





In orthophoto projects of dense urban areas, true orthophotos are preferred over traditional orthophotos because they put building roofs into the correct horizontal position. However, there is still a widespread belief that the production of a true orthophoto is expensive and demanding. The authors set out to explore whether that really is the case based on a study of the production of a true orthophoto of the Municipality of Ljubljana, Slovenia.

Before producing a true orthophoto for the entire municipality of Ljubljana, Slovenia, the authors first tested various approaches in a smaller area in order to find the most economical workflow. One approach used a combination of a digital terrain model and a vector digital building model, and another approach used an automatically generated digital surface model. The resulting orthophotos were then compared against a traditional orthophoto in terms of aesthetic appearance and the manual work needed. Based on the findings, the team decided to use a true orthophoto based on an automatically generated digital surface model. The case study and the final project are outlined below.

Figure 1: Depiction of buildings in a traditional orthophoto (left) and a true orthophoto (right).

Differences between traditional and true orthophotos

An orthophoto is a photo or an image that is corrected for projection distortions. It has a defined scale and can be used similarly as a planimetric map. Orthophoto projects aim to deliver a seamless orthophoto mosaic produced from single rectified images. To produce an orthophoto, georeferenced aerial images and a digital reference surface model are needed. Traditional orthophotos have been produced worldwide for more than 30 years, being an indispensable data layer in many GIS applications. In traditional orthophoto production, the reference surface is a digital terrain model. As a consequence, objects above the terrain (e.g. buildings, vegetation) are not depicted in the correct horizontal position (Figure 1). In true orthophoto production, a digital building model is considered in built areas, or a digital surface model including vegetation cover is used. In true orthophoto production, the algorithms have to solve two main problems: detection of hidden areas caused by the objects above the terrain in the original image, and prevention of double mapping in these areas. To fill in the missing content in the hidden areas, image overlapping must be at least 50% in both directions.

Figure 2: Examples of double mapping in the true orthophoto as a consequence of inaccurately defined roof edges.

Study area and input data

The study area was composed of a densely built-up area in the centre of Ljubljana (700m x 500m) and a suburban settlement with residential houses (500m x 400m), thus covering two typical urbanization types. Georeferenced aerial images of 10cm ground sample distance (GSD) and 70%/50% overlapping, as well as a Lidar point cloud with a density of 18 points/m^2 were the main input data. Both datasets were collected in the same aerial survey in April 2019. From a classified point cloud, a digital terrain model and a digital building model were produced (using TerraScan and TerraModeler by TerraSolid). A vector digital building model was first created automatically, but a lot of additional manual work was needed to improve the model due to complex building envelopes in the old city centre. If the edges of roofs are not defined accurately, double mapping occurs in the orthophoto (Figure 2).

Figure 3: Comparison of a true orthophoto, shown in (a), (c) and (e), with a traditional orthophoto, shown in (b) and (d). Black polygons in (a) define hidden areas in the traditional orthophoto. The three bridges in the centre of Ljubljana are visible in the upper left corner of (a).

The results

A traditional orthophoto (in TerraPhoto) and two versions of a true orthophoto were generated from aerial images and a digital terrain model. In the first version, a combination of a digital terrain model and the previously described vector digital building model (in TerraPhoto) was used. The second version was produced in an almost completely automatic procedure in the nFrames SURE software. A digital surface model in the form of an irregular triangulated network was generated from a photogrammetric point cloud, produced with an image matching algorithm. Figure 3 clearly shows the advantages of a true orthophoto over a traditional orthophoto.

Figure 4: Visual comparison of true orthophotos: (a) and (c) are produced from a vectorized building model, while (b) and (d) are produced from a digital surface model.

In addition, a visual comparison of both versions of the true orthophoto revealed only small differences in the roof edges. In the version based on the automatically produced digital surface model, the roof edges are slightly serrated which is a negligible shortcoming in the otherwise good overall aesthetic quality (Figure 4). One advantage of a true orthophoto produced from a digital surface model is that trees are depicted in the horizontally correct position (Figure 5).

Based on an estimation of the manual work needed in the production of each orthophoto type, the team concluded that the most labour-intensive approach is the production of a true orthophoto based on a combination of a digital terrain model and a vector digital building model. This requires approximately two times more manual work than the production of a traditional orthophoto. On the other hand, an automatically produced true orthophoto takes around 25% less time to produce than a traditional orthophoto. After considering all these aspects, the authors decided to apply the automatic true orthophoto production line in the operational project.

Figure 5: Horizontal position of a tree: (a) vectorized from the point cloud, (b) in a true orthophoto produced from a vectorized building model, (c) in a true orthophoto produced from a digital surface model.

A true orthophoto for Ljubljana

Ljubljana, the capital city of Slovenia, has around 290,000 inhabitants and comprises an area of around 275km^2. Like any large city exposed to rapid changes in urbanization, the municipality requires up-to-date geodata for decision-making purposes. At the national level in Slovenia, a traditional orthophoto is available every three years in 25cm GSD. However, this product does not suit the needs of the Municipality of Ljubljana. In 2020, the municipality therefore funded the production of a true orthophoto mosaic, which was carried out by Flycom Technologies. Aerial data collection was done in April 2020 with image overlapping 80%/60% (and 80%/80% in the centre of the city), with 5cm GSD. After accomplishing aerial triangulation of images (in Match-AT by Trimble Inpho), a true orthophoto was produced (in SURE) based on a digital surface model (Figure 6). The estimated horizontal accuracy, calculated from the ground checkpoints, was 0.04m in both X and Y directions. As an example of data visualization, a photo-rendered 3D mesh of the city centre was created from nadir images (Figure 7). Based on these good results, the Municipality of Ljubljana has decided to finance the annual production of a true orthophoto from now on.

Figure 6: A section of the final true orthophoto mosaic of Ljubljana city centre (in 2020).

Conclusion

The success of this large-scale project shows that the automatic production of a true orthophoto is already fully operational in real life. The resulting true orthophoto mosaic is of good quality and requires much less manual work than other approaches, thus enabling a substantial portion of the final project costs to be saved. Needless to say, such an approach requires appropriate software, powerful computers and investment in staff education. However, these initial investments can be quickly recouped in the subsequent projects. The authors are keen to point out that a true orthophoto requires a larger overlapping of aerial images than a traditional orthophoto. However, this cost represents only a small portion of the final costs. Considering all the aspects discussed here, the authors conclude that there is no reason not to produce a true orthophoto in an almost fully automatic way in urban areas.

Figure 7: Photo-rendered 3D mesh of Ljubljana city centre (in 2020).

Further reading

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Haggag, M., Zahran, M., Salah, M. (2018). Towards Automated Generation of True Orthoimages for Urban Areas. *American Journal of Geographic Information System*, 7 (2), 67-74. DOI: 10.5923/j.ajgis.20180702.03

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