TOWARDS PRODUCT SPECIFICATION FOR URBAN AREAS

Ortho-imagery: Geometric Accuracy Assessment

Anomalies such as building-lean result from the processing of traditional orthorectified imagery and this limits its use in urban areas. However, the arrival of digital sensors has meant fully orthorectified products coming onto the market. The authors test the positional accuracy of fully orthorectified imagery for urban areas and suggest a product specification.

Orthophoto production used to be mostly limited to medium and small-scale applications, and even in the 1990s this market remained so underdeveloped that line-map restitution from stereo imagery was cheaper than producing large-scale orthophotos. Orthorectification transforms an image from a perspective projection to an orthogonal one; the image takes on the geometric characteristics of a map. Traditional orthophoto products are obtained by rectifying aerial photos using coarse ground elevation models. For built-up areas the results are poor because objects above ground level, such as rooftops, are not positioned correctly and buildings typically appear to lean. In fully orthorectified products these effects are removed by using greatly overlapping imagery and a dense Digital Surface Model (DSM). The resulting image shows real near-vertical views for every position.

Cm-level Comparison
To assess the accuracy of fully rectified orthoimage products we compared images with three Ground Sampling Distances (GSD) and from two types of sensors with ground surveys and aerial photo surveys. In addition, elevated checkpoints located on buildings were made on the images with the two smallest GSDs. By using ground-data collected independently using state-of-the-art survey techniques within a precise geodetic framework comparisons could be made at centimetre level. Our test is based on scientific collaboration between the Joint Research Centre (JRC) of the European Commission with the Vlaamse Instelling voor Technologisch Onderzoek (VITO, Belgium), Netmanagement NV and ISTAR SA (France). It follows on from an earlier study by ISTAR on the application of TrueOrtho imagery in rural zones (see GIM International, June 2004, pp. 35-37).

Gent, Mol and Mausanne
Three test sites were selected; two, Gent and Mol, are in Flanders, Belgium, and one in Mausanne, Southern France. Gent is one of the major Flemish towns that in February 2003 received a partial and provisional object-oriented large-scale base map (GRB), together with a conventional 1:4,000 orthophoto based on a flight of March 2000. An HRSC-A (High Resolution Stereo Camera â€“ Airborne) flight was made on 11th May 2001 for the ISTAR City View Catalogue. The HRSC-A is a 3-line scanner developed by the German Aerospace Agency DLR. All data was referenced to the pre-FLEPOS GENT01 GPS reference station; FLEPOS is the Flemish Positioning Service, the Flanders RTK GPS network. Of the potential test area of 20km2 0.25km2 was available and used in the test. An ADS40 (Airborne Digital Sensor developed by Leica Geosystems) survey was carried out in Mol during 2003 covering over 80km2, terrestrial survey data from Netmanagement NV being used over the area. Data was collected from September to November 2002 and covers a site of 3km2. Both datasets were based on FLEPOS services. Mausanne is a test site for the Agriculture and Fisheries Unit of the JRC. In 2003 the JRC commissioned an ADS40 survey of the area to review digital sensor potential for common agriculture policy purposes. The TrueOrtho test area covers some 800km2.

Data Overview
All TrueOrtho products were produced by ISTAR. The GRB-dataset of Gent is compiled using a combination of photo restitution and terrestrial survey techniques; OC GIS-Vlaanderen assessed its quality according to ISO2859 sequential sampling procedures. From the many GRB features, sewage manholes measured with a total station were selected as ground-level data. Elevated coordinates were extracted from building outlines originating from stereo photographic restitution.
In Mol a contractor surveyed the area according to a pre-specified standard, ensuring compatibility and potential for integration into the GRB dataset. Since no aerial imagery was used an additional terrain visit was required to identify buildings with vertical faÃ§ades without any roof overhang. Assuming that what could be located in the terrain is seen from the air, selected building corners served as elevated coordinates. As in Gent, manholes provided ground-level data. The Mol survey map passed the quality control set by OC GIS Vlaanderen based on an ISO2859 two-point sampling procedure. For Mausanne ground-level data was collected via dual-frequency, carrier-phase GPS receiver over a five-day JRC measurement campaign; 33 well defined points such as road signal marking and curb-stone corners were measured. Spruyt and Kay published the results of the comparison in May 2004.

Data Processing
All data processing was done within an ESRI ARCGIS and Arc/INFO workstation software environment.

- The Gent GRB-dataset was converted from the Belgian Lambert Conical Conformal BL72 to the UTM31N used by City View. The runtime P7 algorithm provided by the Belgian National Mapping Agency (NGI) was used to verify the conversion. The conversion ran well only for shape-file formats via the ARCGIS conversion wizard; grids and coverages could not be correctly converted within the workstation environment and therefore all images were represented in their original coordinate system.
- Shape files of the Gent GRB dataset and the Autodesk format files of the Mol GRB survey were converted into ESRI coverages.
- An experienced JRC photo-grammetrist located manholes and building outlines on the orthoimages using a generalised map as guidance. Selected data-points that caused identification problems were ignored so as to avoid blunder errors; in Gent the black-and-white image proved poorly suited for locating manholes.
- The vertices collected from the orthoimages were converted into point coordinates and compared with the nearest coordinate pair of the surveyed reference data.
- Elevation above ground was assessed via the DSM by computing the difference between the average of three to four height measurements at 4-pixel distance from the building at ground level and an average of the same number of points on the roof.
- For Mausanne the GPS-measured positions were directly identified on the true ortho; no further pre-processing was required.

Results

The Figures show residuals for Gent and Mol as a function of elevation above ground level. Zero elevations refer to manholes, non-zero elevations to building corners. No straightforward relation between elevations and residuals appears in either figure. However, in Figure 5 the spread for building points is much higher than for manholes. It is thus feasible to distinguish ground-level performance from elevated data performance. Figure 6 presents distributions of ground and elevation classes; although the median values for Gent confirm the trend identified in Mol their distributions do not give evidence of significant class distinctions. This might, however, reflect difficulties in identifying manholes in the black-and-white HRSC image; over the small test area used there was little contrast with the street pavement.

Analysis

Accuracy is proportional to ground sampling distance (pixel size) for ground-level data. For the three test areas ground-level accuracy is better than one pixel RMSE2D, whilst the elevated-data accuracy ranges from 1.5 to 2 pixels RMSE2D, although the values are unrelated to building height. The achievable accuracy is much better than the target specification and better than the â€˜rule of thumbâ€™ of two pixels used for estimating accuracy in traditional orthophotos. As compared with independent survey data the images thus prove to be well suited for urban applications.
The similar values for elevated data for Mol and Gent, 23.7cm and 24.6cm respectively, may indicate that accuracy does not depend only upon pixel size but also on DSM resolution, 100cm for both. An alternative explanation for the similarity lies in the photo-mapping and photo-restitution process. Building points in the Gent image (pixel size 25cm) could be well identified, whilst in Mol (pixel size 16cm) discrepancies may be introduced by measuring faÃ§ade top (possible overhangs) rather than faÃ§ade base. But the particular production processes used make it hard to generalise on actual cause here.
The visual differences in Figures 2c and 3c are not reflected in the quantitative results. Indeed, the ADS40 provided a high-quality DSM approximating very well to the building contours. The HRSC DSM appears much more blurred. Nevertheless, for both sensors correspondence between rectified image and reference survey data is high (Figures 2a and 3a). Figures 2c and 3c show also that the DSM â€˜objectâ€™ is wider than the actual building, so that the faÃ§ade top in the DSM may match a position on the â€˜extendedâ€™ building roof. During TrueOrtho production pixels at the border of a building could have been retrieved from a vertical view input pixel; this would reduce the effect of building height on horizontal shift such as observed. But shift may also depend upon DSM quality and as such would be minimal for features at ground level.

Concluding Remarks

The better the required accuracy, the denser the DSM. This has an impact on the technology used to acquire the DSM and thus on the cost of production. However, the completely automatic removal of anomalies is wishful thinking. Therefore what is needed as a key condition is the introduction of a widely accepted standard that specifies criteria under which an orthorectified image may bear the prefix â€˜fullyâ€™. Although the basic principles have been known for over a decade such a standard has not yet been established. The scientific literature provides few clues for deciding acceptable levels of anomalies and on determining costs to limit them. We therefore feel, based on the empirical results of our tests, that the time is right to put forward a provisional product specification as given in the textbox. We welcome any exchange of ideas to extend the debate on this emerging issue.

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Further Reading

- Spruyt P. and Kay S., Digital Airborne Orthoimagery: quality assessment test with Leica Geosystems ADS40, GIM International Vol. 18 No. 6 pp. 35-37, June 2004.