IMPROVING SPATIAL INFORMATION EXTRACTION FOR LOCAL AND REGIONAL AUTHORITIES USING VERY-HIGH-RESOLUTION DATA – GEOMETRICAL ASPECTS

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ABSTRACT :

The purpose of the presented research project is to investigate how present-day EO-technology can support local and regional decision-making, particularly in Belgium, and to develop prototype versions of value-added products that fulfil some of the actual information needs, as expressed by Belgian authorities at the local and at the regional level. To accomplish this goal the proposal addresses both technical and user-oriented issues, and builds on the experience of five research teams, each with its own background and particular know-how. The most important objectives of the project are:

- to define optimal methods for improved spatial information extraction from high- and very-high resolution data, based on innovative processing techniques;
- to identify useful EO-applications at the level of local and regional decision making that are made possible by applying the information extraction methods that will be developed; in this case especially 3D information
- to define and develop value-added core data products that will support these applications, and that can be consulted with easy-to-use, widely available IT-tools (CD-ROM, Internet, …).

One of the technical research modules is focussing on the geometrical aspects of VHR data processing. In terms of spatial resolution, VHR data have the required level of detail to resolve individual objects in the landscape, in a similar way as airborne data. As such, they have the potential of becoming a useful data source for the extraction of detailed, object-related information, and for the production of large-scale cartographic reference data. The geometry of VHR sensor data, however, completely differs from the geometry of aerial photographs (Bethel et al., 2001). Research is going on to evaluate the geometric qualities of present and future VHR standard data products, from the moment they become available, and to examine what level of geometric accuracy is attained with these data, depending on image parameters, processing strategies, and terrain characteristics (Zhou and Li, 2000).

The main objectives of the research module on geometric aspects of VHR data processing are:

a) to define an optimal procedure for the derivation of envelope DSMs (Digital Surface Models) and ortho-photoplans from VHR data;
b) to develop a theoretical model to study the effect of the oblique viewing angle of VHR data on image displacements caused by building height and relief;
c) to evaluate the geometric accuracy of satellite-derived envelope DSMs and ortho-corrected image data in comparison with similar products obtained by means of large-scale aerial photography.

The module about geometrical aspects is divided into six specific tasks.

a) GPS database creation
b) Creation of reference envelope DSMs based on aerial photography
c) Ortho-rectification of VHR images and aerial photography based on reference DSMs
d) Evaluation of the quality of VHR geo-referenced data
e) Modelling of displacements caused by terrain morphology and sensor viewing angle
f) Development of envelope DEMs from VHR stereoscopic imagery

The project is now in the stage where the quality of the georeferenced and orthorectified data is evaluated.

1. INTRODUCTION TO THE SPIDER PROJECT

In spite of the high output of Earth Observation (EO) research over the last three decades, the number of operational applications that are based on EO-technology, or the use of EO-derived products, is relatively low. While EO-derived information has some clear assets compared to spatial information derived from more traditional sources, the incorporation of EO-based proc-esses of information retrieval into mainstream spatial decision support is still limited. This is especially so in the area of local and regional decision-making. There are various factors that may explain why EO-technology so far is not being adapted as a standard tool by local and regional authorities.

Some of the impediments to making satellite-derived informa-tion truly useful for local and regional decision making have to do with the level of spatial and thematic detail that can be at-

tained with EO-technology. While computer-assisted methods for multi-spectral (and multi-temporal) classification of traditional high-resolution data (Landsat MSS, TM, SPOT,…) are well-established, and have been applied with success to identify major land-use/land-cover (LULC) classes at the medium scale, the practical utility of the information that is derived in this manner for local and regional authorities is limited. Indeed, to focus on local and regional land management issues, thematically rich and spatially detailed LULC information is needed that cannot be obtained from traditional space-borne sensor data.

With the launch of IKONOS and QuickBird, which produce very-high-resolution (VHR) data below 1m-resolution in the panchromatic mode and 4m-resolution in the multi-spectral mode, a new era in EO-research and application development has begun. Although the cost of the data is still high, one may assume that the price of VHR-images will lower in the years to come, as more suppliers of this type of data enter the market. This will certainly create interesting opportunities for cost-effective use of these data. Indeed, for local and regional authorities, which so far have not been able to take enough benefit from EO-technology, the move towards VHR data might fulfil long-stated expectations, and certainly increases the potential for developing a whole range of new EO-based solutions in this area. It is therefore clear that new efforts should be made to define optimal strategies for EO-based information extraction that can be applied in urban and regional decision-making. Such strategies may rely on the use of VHR images as a data source on its own, but should also take full benefit of the possible advantages of combining VHR data, high-resolution (HR) data, and other, non-satellite data sources in the different stages of the information extraction process.

Next to technical issues, there is a need for a more user- and problem-oriented approach in EO-related research. Indeed, technical impediments are not the only reason why remote sensing technology is not used up to its full potential by local and regional authorities. A second important reason for the limited use of EO-technology in regional and local decision-making is that so far decision support issues have in general not been a key focus for technical and scientific developments in remote sensing. Local and regional decision makers not only need thematically rich and spatially detailed data, yet they also need meaningful access to these data (Arnold et al., 2000). Incorporation of remote sensing technology into the mainstream of decision support can only be achieved by way of a value-added approach. Research results have to be transformed into simple, meaningful products that address the needs of the end user, and that are made accessible through integration with easy-to-use, widely available IT-applications.

In this framework, five research teams of four belgian universities (VUB, ULB, Ulg and Ugent) are working on the SPIDER project (Improving spatial information extraction for local and regional authorities using very-high-resolution data), funded by the Belgian Federal Science Policy Office.

2. GEOMETRICAL ASPECTS OF VHR SATELLITE DATA

The teams of Ugent and Ulg cooperate in the field of the geometrical aspects of VHR satellite data. In terms of spatial resolution, VHR data have the required level of detail to resolve individual objects in the landscape, in a similar way as airborne data. As such, they have the potential of becoming a useful data source for the extraction of detailed, object-related information, and for the production of large-scale cartographic reference

data. The geometry of VHR sensor data, however, completely differs from the geometry of aerial photographs (Bethel et al., 2001). Research is needed to evaluate the geometric qualities of present and future VHR standard data products, from the moment they become available, and to examine what level of geometric accuracy can be attained with these data, depending on image parameters, processing strategies, and terrain characteristics (Zhou and Li, 2000). The main objectives of the research module on geometric aspects of VHR data processing are:

a) to define an optimal procedure for the derivation of DSMs (Digital Surface Models) and orthophotoplans from VHR data;

b) to develop a theoretical model to study the effect of the oblique viewing angle of VHR data on image displacements caused by building height and relief;

c) to evaluate the geometric accuracy of satellite-derived envelope DEMs and orthocorrected image data in comparison with similar products obtained by means of large-scale aerial photography.

3. STUDY AREAS

The belgian cities of Brussels, Liège and Ghent were selected as study areas for the research. Each study area is about 11 by 11 km which corresponds to the size of one VHR image. Within each area a number of test zones and confidence sites are selected, based on their different type of urban and topographical morphology.

4. STRUCTURE OF THE RESEARCH MODULE

4.1 GPS database creation

To develop DSMs from aerial photographs and stereoscopic VHR imagery, a large set of Ground Control Points (GCPs) will be measured in the field for each of the test zones, and confidence sites using GPS in realtime and differential mode. Points that will be measured include corners of crossroads, easily recognisable points along ditches and canals, etc. GCP sampling density will be higher within the confidence sites, as for these areas more accurate reference DSMs will be developed.

4.2 Creation of reference DSMs based on aerial photography

In the first phase of the project, reference DSMs will be developed for two of the three test zones (for the Brussels area a reference DSM is already available), using aerial photographs at a scale of 1:12000 and a resolution of 14 cm. For the confidence sites within each zone, more precise DSMs will be built, based on larger scale aerial photography (1:4.000, resolution). The high resolution of the 1:12.000 series allows an alternative for the confidence sites where 1:4.000 aerial photographs are not available. The DSMs will be used as a reference for ortho-rectifying the VHR images prior to classification, and will also enable us to compare the geometric accuracy of DEMs and ortho-photoplans derived from VHR stereoscopic imagery with those obtained by means of aerial photography.

4.3 Ortho-rectification of VHR images and aerial photography based on reference DSMs

VHR images obtained for the three study areas will be ortho-rectified prior to the classification phase, using the reference DSMs mentioned in *4.2 Creation of reference DSMs based on aerial photography*. VHR data and aerial photographs for the

confidence sites in each of the three study areas will be ortho-rectified separately, based on the more accurate, site-specific envelope DEMs. The ortho-rectified data for the confidence sites will be used to produce visually interpreted, high-quality reference data sets, which show the spatial distribution of various surface types for each site. These data sets will be used to validate the output of automated surface type classification procedures to be developed in this project.

4.4 Evaluation of the quality of VHR geo-referenced data

Former experience with geo-referenced IKONOS data indicates that coordinates of well recognisable points in the images do not conform with real world coordinates as found on topographical maps, or as measured with GPS. The geometric precision of VHR data, delivered by Space Imaging or other, future providers of VHR imagery, will be systematically evaluated, using the GCP information. Also, it will be investigated if geometric accuracy can be improved by way of additional 2D-corrections, using a large number of GCPs. Finally 2D-georeferenced images will be compared with ortho-rectified images in terms of their geometric accuracy for both a flat area (Ghent) and a hilly area (Liège). This will provide useful information about the limitations of 2D-corrected data, and the necessity of acquiring ortho-rectified data, for different kinds of applications in each of the studied areas.

4.5 Modelling of displacements caused by terrain morphology and sensor viewing angle

The oblique viewing angle of images produced by VHR sensors like IKONOS has a strong influence on the geometrical displacement of objects, and on the occurrence of hidden areas in the image. The magnitude of displacement and the percentage of hidden areas are determined by the interaction between viewing angle, position of the sun, object height, and terrain characteristics (slope, aspect). In other words, the range of viewing angles that can be considered acceptable for purchasing an image of a certain area will depend on the morphological characteristics of the area. To study the interaction between all parameters involved, a theoretical model will be implemented. First, the model will be used to systematically study the impact of viewing angle on object displacement, shadow length and size of hidden areas in an image, by simultaneously varying the different morphological parameters. Next, the impact of viewing angle on the geometry of the image will be simulated for Ghent (basically flat area) and Liège (hilly area), using the theoretical model and the reference envelope DEMs developed for the two regions. Simulation modelling of this kind may be very useful to determine the maximum viewing angle that can be tolerated for each study area, and can also be applied to other areas.

4.6 Development of DSMs from VHR stereoscopic imagery

If VHR stereo couples can be obtained in the course of the project, then two DSMs will be constructed, one for Ghent (flat area), and one for Liège (hilly area). The 3D-geometrical accuracy of both DEMs will be evaluated by means of an independent set of GCP taken from the GCP database developed. Also, the geometrical accuracy of both DSMs will be compared with the accuracy of the reference DSMs, derived from aerial photography at scales of ±1:12.000 and 1:4.000. If no stereo couples can be obtained, we will try to acquire oblique (not stereoscopic) image couples that are taken from more or less perpendicular viewing angles. In this case, a large number of GCP's will be needed to estimate (by regression) the kappa, phi and omega parameters of both images. Once these parameters are known a DSM can be derived, although the geometrical error will be larger than for a DSM derived from a real stereo model (see also risk factors, below). The satellite-derived DSMs will be used for ortho-rectification of VHR imagery. The accuracy of the ortho-rectified images will be compared with ortho-rectifications of the same images, based on the reference DSMs.
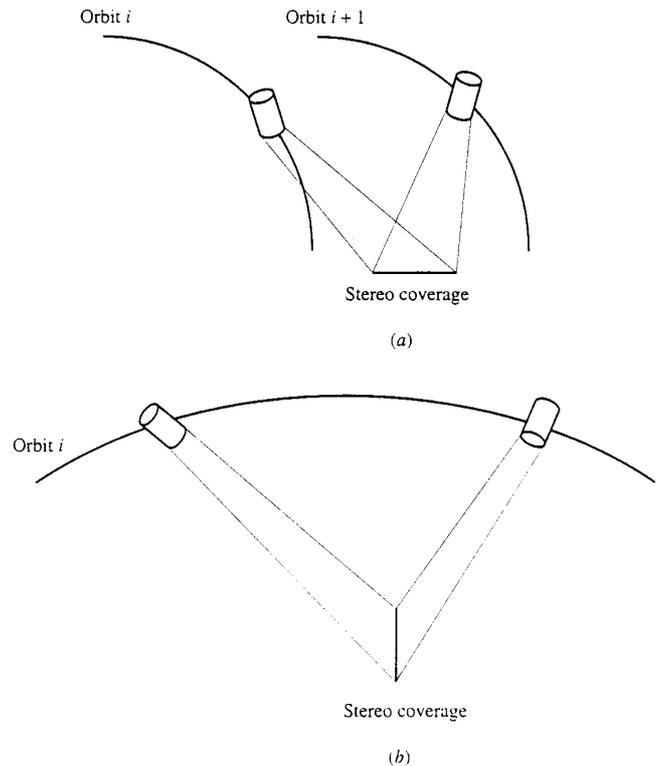

Figure 1. Cross track (a) and along track (b) stereo observation for satellite images. Most VHR sensors use the along track stereo.

5. PRELIMINARY RESULTS

5.1 DSM generation and orthorectification of aerial photographs

Two types of DSMs are made, one for the test zones and one for the confidence sites. For each test zone a 1m resolution grid DSM is created based on the 1:12.000 photographs. The resolution of the corresponding orthophoto is 61 cm, to obtain a similar resolution of the QuickBird sensor. The quality of the DSM is evaluated, based on the visual interpretation of errors in the orthoimages e.g. blurring, double image, … (Manzer, 1996).

Where the 1:4.000 photographs are available for the confidence sites, they were used to generate a 0.2 m grid DSM

And a corresponding orthophoto at the same resolution. In other cases the 1:12.000 was used for the confidence sites, to create a DSM.

5.2 Orthorectification of VHR satellite images

For the IKONOS and QuickBird images, the situation for orthorectification is quite different. To allow a full 3D orthorectification of these VHR images a sensor model is required to perform interior orientation. This way, the true

orthophoto of the satellite images is possible, combined with the collected GCPs and the DEM derived from aerial photography. Currently, only the QuickBird image for Ghent is orthorectified. For the other study areas images are ordered. With the QuickBird data the RPCs (Rational Polynomial Coefficients) were delivered with the data. For the IKONOS image this was not the case, and the RPC should be purchased separately. These RPC are needed for the image calibration (i.e. similar to the interior orientation with aerial pictures). The coefficients can be calculated from the GCPs, though this is not advised since it gives less accurate coefficients then those delivered by Digital Globe and Space Imaging.

In the orthorectified images the residuals of the GCPs are 1 m or less for the panchromatic QuickBird image, and 2.4 m for the multispectral image.

5.3 Evaluation of the quality of VHR geo-referenced data
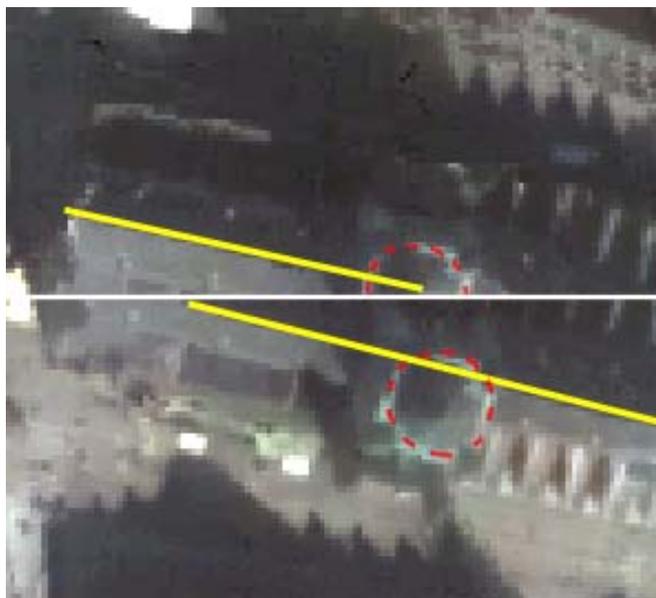

Figure 2. QuickBird image showing St. Nicolas Church in the centre of Ghent. Above : orthorectified image , below : non-rectified image.

Figure 2 clearly shows the need for orthorectification and gives a qualitative indication of the georeferincing and orthorectification. The picture shows that the image objects are displaced not only regarding to the coordinate system (Belgian Lambert 72) but also relative to each other. In the lower part of the image we can see clearly that the tower of the cathedral is not on the central axis, where this is the case in the upper part of the image.

The next step in the project is the quantitative analysis of the orthorectofied QuikBird image for Ghent.

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