Acquiring spatial information from digital ortho-images: an unconventional approach

Author(s):
Baltsavias, Emmanuel P.; Armenakis, Costas; Regan, Anna Marie

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Emmanuel P. Baltsavias  
Institute of Geodesy and Photogrammetry  
Swiss Federal Institute of Technology (ETH)  
ETH-Hoenggerberg  
CH-8093 Zurich, Switzerland

Costas Armenakis, Anna Marie Regan  
Geomatics Canada  
Centre for Topographic Information (CTI)  
615 Booth St., Ottawa  
Ontario K1A 0E9, Canada

Abstract

Recently production of digital orthoimages has become more commonplace due to the development of more powerful computers with sufficient resources, easier acquisition of input data, increased generation of digital data, development of many commercial orthoimage production systems, and new application areas, particularly in connection to GIS and digital mapping. The increasing importance of orthoimages is also indicated by many orthoimage generation projects on national, regional and local levels, and the use of orthoimages as basemap layer within GIS. The paper presents different applications on generating and updating of spatial databases using mono orthoimages and orthorectified stereo images. Used methodology and some results from ongoing projects at the ETH and CTI will be outlined.

1. Introduction

CTI is using digital mono orthoimages in an operational environment for map updating. A pilot project at CTI on revision of 1:50,000 National Topographic DataBase (NTDB) data using mono orthoimages and heads-up digitising is presented. At ETH research is conducted on the use of mono orthoimages and orthorectified stereo images for accurate 3D measurements, correction of Digital Surface Models (DSM) and modelling of buildings.

2. Revision of 1:50,000 NTDB data

2.1 Methodology

CTI is responsible for the maintenance of the NTDB and the production of the National Topographic Series maps for Canada at scales 1:50,000 and 1:250,000. To meet these requirements, CTI is implementing a fully digital process using Digital Photogrammetric Workstations (DPW) and GIS mapping systems for automating processes and aiming at cost reduction, faster turnaround time, improved quality, variety of products, and client satisfaction. An investigation was performed to evaluate the potential of updating a 1:50,000 topographic data set using digital orthoimages generated from new aerial photography at scale of 1:60,000. Database updating from digital images, and map production require the following steps:

- change detection
- extraction of new features
- feature classification
- integration of old and new data in the database
- cartographic representation and production of revised maps
Updating of the vector map data was performed using the mono-orthocompilation technique, i.e. the on-screen digitization of planimetric details from “new” orthoimage-mosaics displayed as a backdrop to the 1:50,000 “old” vector data. Figure 1 shows the work flow. Attribute changes in the data are applied based on information collected during the field verification. The contours and height information of the planimetric features can be derived from the DEM.

2.2 System requirements

To meet the requirements for updating, certain system functionality is needed, such as: scanning of the aerial photographs, production of orthoimages and mosaics from existing DEM or by generating the DEM from the newly digitized photographs using image matching techniques, image processing functions, integration of vector and raster data capabilities, topology creation and cartographic representation. These capabilities are found in DPWs and vector-raster GIS. The Leica/Helava DSW 100 was used for film scanning and the Leica/Helava DPW770 for the production of the orthoimage-mosaics. For the actual revision operation from the orthoimage-mosaics the CARIS GIS - a vector-based topographic mapping and GI system with raster data handling capability - was used.

2.3 Orthoimage-mosaics

The area covered by the data set is 32x26 sq. km. Twenty five aerial photographs were scanned at 1000 dpi (ground pixel size of 1.5m). The DEM was generated on a 50m grid and had an estimated RMSE of 1.5m. The orthoimages had a pixel size of 2m. Due to the large size of the mosaicked raster file (about 240Mb) the mosaic was divided into four quads with each quad.
being a more manageable 70Mb. The accuracy of the orthoquads was evaluated by use of check points with known coordinates from the aerotriangulation. The standard deviation of the coordinate differences were ±1.17 to ±1.67 m in x and from ±1.50 to ±2.69 m in y.

2.4 Vector data revision

Change detection was performed visually by displaying the superimposed old vector and the new orthoimage to determine areas of change. Field verification photo-prints for classification of roads, and noted additions, deletions and changes of features were used as well. The updating of features were based on the following elements:

- amount of change detected (spatial and semantic)
- accuracy of the existing feature
- topology
- feature morphology
- significance of the feature

The updated data was also time-stamped. This enables the identification of all revised features for quality control, cartographic representation, and spatio-temporal GIS applications. A tile approach was used for the revision process, where the operator steps through the data set in small virtual map tiles, revising all the features before moving to the next tile. Basic image enhancement, a stereoscope, and the photography with field information were used to facilitate feature identification, such as watercourse and permanent snow and ice (glaciers). Figure 2 shows the old and the updated vector data of the Athabasca River features.

The old data set was cartographic data and required a slightly different approach for revision than a positional data set. The WYSIWYG capability of CES allowed the operator to turn feature symbology on and view the cartographic representation of features. This was useful for judging if the existing feature was within the tolerance of map accuracy. For example, a railroad that was positionally “incorrect”, but cartographically acceptable as shown with the displayed symbology, was not edited. The existing contours were superimposed with the ones generated from the DEM used for the production of the orthoimages. This preliminary comparison showed that it was not necessary to replace them. However, some editing of the contours was required due to changes in the planimetric data. The estimated time in days required for updating this specific data set (excluding field work) was:

<table>
<thead>
<tr>
<th>Activity</th>
<th>Days</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preparation</td>
<td>6</td>
</tr>
<tr>
<td>Aerotriangulation</td>
<td>5</td>
</tr>
<tr>
<td>Production of orthoimage-mosaics</td>
<td>10</td>
</tr>
<tr>
<td>Revision/Recompilation</td>
<td>30</td>
</tr>
<tr>
<td>Quality control</td>
<td>4</td>
</tr>
<tr>
<td>Total</td>
<td>55</td>
</tr>
</tbody>
</table>
3. 3D coordinate measurement using orthorectified stereo images

Orthoimages of the same region from each of the images of a stereo pair can be created. The use of such orthorectified stereo images can serve several purposes, all of which are based on the ability to determine 3D coordinates using corresponding points in an orthorectified stereo pair. Correct X, Y, Z measurements can be made, even if the underlying DEM is totally incorrect. The procedure is the following. The point to be measured (P') is selected in one of the images with the cursor, and measured in the second image (P'') either manually, or by image matching. The resulting pixel coordinates are transformed to planimetric coordinates (X', Y', and X'', Y'') and their heights (Z', Z'') are interpolated from the DEM. These two sets of X, Y, Z values are transformed into photo coordinates (x', y' and x'', y''), using the known interior and exterior orientation. These two image points are corresponding points, if the transformation from the photo- in the pixel-coordinate system is accurate. Through intersection of the corresponding rays, and if the interior and exterior sensor orientation are known with sufficient accuracy, correct X, Y, Z coordinates can be computed, even if the starting DEM is erroneous.

The accuracy of object coordinate determination by the above method can be as high as the accuracy that can be achieved using the original unrectified digital images. To check the validity of the procedure a controlled test was performed by introducing various known errors in the DEM and generating an orthorectified stereo pair for each DEM. The object coordinates of discrete points were determined by the above procedure and were found to be almost identical (RMSE was 0.1 m) independently of the introduced DEM errors. Thus, the internal (relative) precision of the method is excellent; the absolute accuracy, assuming well calibrated cameras, depends on the accuracy of the point measurement accuracy, the exterior orientation, and the

Figure 2. Old (left) and revised (right) vector data of the Athabasca River features.
geometric accuracy of the scanner. The 3D coordinate measurement procedure using orthorectified stereo images can be used in different applications and in particular for DEM correction, measurement of non-terrain objects (like buildings), and easy establishment of many control points to check the orthoimage accuracy.

4. Building modelling by using orthoimages and DSMs

A research group at ETH has developed operational procedures for the automatic detection and vectorisation of buildings from digitised 1:25,000 topographic maps with ca. 95% success rate. In some applications the coarse height of the building is needed, information which is however not included in the maps. This information can be acquired by the following procedure. The vectorised buildings are overlayed with an orthoimage (Figure 3), heights within the building roof are determined, and an average or maximum height of the building is estimated by robust procedures that exclude gross errors and spikes due to small objects like chimneys. The height determination can be performed by matching corresponding features on the building roofs in orthorectified stereo images as previously explained (Figure 4). This procedure can be automated because the known position of the buildings restricts the search space of the matching, and only a coarse building height, i.e. no precise 3D description of the roof, is needed. If no DEM exists, and thus no orthoimages can be generated, then image matching procedures can be used with the original unrectified images to derive a digital model of the visible surface. Through overlaying of the building outlines and the DSM and robust filtering, again a coarse building height can be estimated. This procedure can lead to rapid establishment of 3D building databases, an important practical application.

A second application refers to a project at ETH on semi-automated building extraction from aerial images. In this case the extracted buildings must be accurate and the roof model is more complicated than a simple horizontal plane. Orthoimages and DSMs are used to provide an indication as to where the buildings are, and an approximation of their shape and size. The detection of buildings using orthoimages is based on the following principle. Orthoimages from a stereo pair should ideally be identical. Since the buildings are not included in the DEM which is used for the orthoimage generation, they are radially displaced in the orthoimages. A subtraction of the two orthoimages will indicate regions (of large differences) where buildings are, but also other regions like forests etc., so building detection by this approach can not be easily automated. In automatically generated DSMs on the other hand buildings will generally appear as positive bumps, whereby matching errors can not be excluded. By combining the informa-
tion from the orthorectified stereo images and the DSM, a classification of colour images, texture, amount and length of straight lines at the image position of the detected 3D bumps, and some assumptions on the building shape and size, buildings can be extracted and separated from other bumps like trees etc. Additionally, subtraction of orthorectified stereo images that are generated by a DSM can be used for quality control of the DSM and manual or automatic corrections (Figure 5). In regions of large differences either DSM errors or radiometric differences will exist.

Figure 4. Left: orthorectified stereo images. Right: roof measured from stereo orthoimages (by image matching) and unrectified stereo images (manual measurements).

Figure 5. Subtraction of stereo orthoimages that are generated by the use of a DSM. Regions of large differences (dark or light regions) indicate DSM errors. Errors occur especially close to surface discontinuities, e.g. buildings.

5. Conclusions

The use of orthoimages for monoscopic updating of a 1:50,000 vector data set has demonstrated the potential and merits of this approach. From the technical point of view this approach facilitates the change detection and ensures uniform and improved accuracy throughout the data set. From the operational perspective this approach significantly reduces the time to perform
revision compared to analogue methods, allows time-stamping of the revised data and facilitates the quality control process. From the systems point of view the combination of the Leica/Helava DPW770 for the production of the orthoimages with the CARIS GIS offering real vector-raster integration for the revision of the existing 1:50,000 digital databases proved to be successful.

Using orthorectified stereo images 3D measurements can be performed. Orthorectified stereo images can be used in combination with planimetric map features to derive a coarse 3D model of buildings, or with DSMs and other image and object model related information to detect approximate position, shape and size of buildings, information which can be used in a subsequent processing for detailed building modelling.

Biographies:

Emmanuel P. Baltsavias received his Dipl. Ing. from the National Technical University, Athens in 1981, M.Sc. from Ohio State University in 1984, and Ph.D. from the Swiss Federal Institute of Technology, Zurich in 1991 where he currently works. His research interests are digital photogrammetry, image analysis, remote sensing and GIS.

Costas Armenakis works as research scientist in the Canada Centre for Topographic Information (CTI), Geomatics Canada, NRCan. He holds a Dipl. Ing. degree from the National Technical University of Athens, Greece, and M.Sc.E. and Ph.D. degrees from the University of New Brunswick, Fredericton, Canada. His work at CTI focuses in the development and demonstration of applications in the areas of digital photogrammetry, digital map revision, image mapping and temporal geographic information. He is a registered Professional Engineer of Ontario.

Anna Marie Regan works as an engineer in the Canada Centre for Topographic Information, Geomatics Canada, NRCan. She holds a B.Sc. in Surveying Engineering from the University of New Brunswick. She has been involved with digital mapping and geographic information systems for ten years, with the past three years devoted mainly to implementing the CARIS map revision system. She is a registered Professional Engineer of Ontario.