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LARGE SCALE CITY MAPPING USING SATELLITE IMAGERY

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Abstract. The rectification of high resolution digital aerial images or satellite imagery employed for large scale city mapping is modern technology that needs well distributed and accurately defined control points. Digital satellite imagery, obtained using widely known software *Google Earth*, can be applied for accurate city map construction. The method of *five control points* is suggested for imagery rectification introducing the algorithm offered by Prof. Ruan Wei (Tong Ji University, Shanghai). Image rectification software created on the basis of the above suggested algorithm can correct image deformation with required accuracy, is reliable and keeps advantages in flexibility. Experimental research on testing the applied technology has been executed using *GeoEye* imagery with *Google Earth* builder over the city of Vilnius. Orthophoto maps at the scales of 1:1000 and 1:500 are generated referring to the methodology of *five control points*. Reference data and rectification results are checked comparing with those received from processing digital aerial images using a digital photogrammetry approach. The image rectification process applying the investigated method takes a short period of time (about 4–5 minutes) and uses only five control points. The accuracy of the created models satisfies requirements for large scale mapping.

Keywords: digital photogrammetry, satellite imagery, image rectification, city mapping, orthophoto maps.

1. Introduction

Modern digital photogrammetric technology combining image processing techniques allows to determine the position of the objects in a three dimensional space from aerial photographs or remote sensing imagery recorded in digital representation. Digital image processing has a possibility of increasing mapping efficiency because almost all procedures are automated (Ruzgienė 2007). Therefore, the photogrammetric processing of images becomes easier and provides required precise data for geodesists, cartographers, geographers, forest engineers, geologists, GIS users, etc.

Digital orthophoto maps are one of the most frequently used products and can be successfully incorporated as background information in GIS (Heipke 2004; Konecny 2003). Nowadays, a very popular virtual globe map from *Google Earth* and geographical information obtained from satellite imagery are widely used for various survey applications, Earth surface mapping, monitoring environment disasters, etc. (Jacobsen 2007).

The integration of data received from aerial images or satellite imagery with appropriate resolution in most digital maps as well as cartographic and geographic data sets is very desirable (Ewiak, Kaczynski 2010; Jacobsen 2006). Raw digital images contain internal geometric distortions that are the results of the image acquisition process (Luhman *et al.* 2006). These distortions can arise from sensor's plane tilt, variations in sensor altitude, Earth curvature, lens distortion, terrain relief, etc. Therefore, original (row) imagery needs rectification and transformation (Manual… 2004; Wolf, Dewitt 2000). A correctly processed digital map is free of significant geometric distortion and transformed to the local used projection and coordinate system.

Professor Ruan Wei from Tong Ji University, Shanghai, China introduced a reliable and practical method (Five Control Point's Rectification of Digitized Image) for creating a city map at the scales of 1:1000 or 1:500. One of the methods for generating a reliable rectification model for city map construction is announced in Japan patent *P2000-298430A* (Ruan 2008) where image rectification processes require more than nine control points and accuracy cannot satisfy the need for mapping at a scale of, e.g. 1:500.

The aim of research is to perform a comparison test integrating data sets from aerial photography at a scale of 1:6000 and satellite imagery from *Google Earth* investigating the potential and accuracy of the suggested *five control points* method for getting the highest efficiency of city modelling.

2. Methodology, Algorithm and Software Description

The effects of camera tilt raise the images of geometric deformation. Similar effects can be eliminated by applying an appropriate rectification method of digital images for a precise and reliable correction of the image planes to the object plane.

When using the suggested method of *five control points*, varying scale city maps can be constructed and follows the digital photogrammetric method for rectifying digitized images with correction to deformations.

The theoretical basis applied to the algorithm is interpolation using surface splines. Image rectification results fit very well for large scale maps using only five rectifying points. Accurate digital rectification, which gradually corrects deformations avoiding deviation that results from translating or rotating surfaces, can be performed. The obtained results show that any staff participating in a survey can accurately create a city map using high resolution imagery. The presented method is reliable and could be applied in practice.

The image of various deformations, including coordinate conversion, scale deformation, spin and translation is rectified using one of the formulas for corrections (Ruan 1988). For each point on the digital image, use the following formula applicable to calculate the meanings of independent points x and y considering weighted deformations (Ruan 2008):

$$W(x,y) = A + Bx + Cy + \sum_{i=1}^{N} F_i r_i^2 \ln r_i^2, \tag{1}$$

where $r_i^2 = (x - x_i)^2 + (y - y_i)^2$, $N \geq 5$.

Formula (1) is applied for calculating *A, B, C,* (i = 1, N) where a total quantity of unknowns in the rectification model is $N+3$. The deformation of control points N is known. Therefore, equation N could be constituted. Adding three balance equations, all unknown variables can be solved out.

Software characteristics. Software based on the algorithm of *five control points* and created by Qian Yi Xiang is simply to operate, as only a procedure of selection, data input and not very skilled operator are required for image rectification that can be completed within a short time. For example, only the period of 5–10 minutes is needed to make a picture of a size of 40×50 cm.

Image processing steps include scanning an image into computer, input of control point coordinates, the identification (recognition) of rectification points on the picture, supplying mapping scale, the rectification process and obtaining the corrected images.

The mapping process involves getting data from the measurements of rectification points identified in an aerial picture, digitization according to the scale with the help of *Photo Rectification* software, constructing a photo map and drawing a map using advanced software *Southern CASS 4.0*.

The operating process of sample rectification covers choosing the needed aerial picture (image format – *∗bmp*), opening the original map file, choosing the area of the control point precisely identifying control points (Fig. 1a), input data (x, y) to the file–frame (Fig. 1b), setting mapping data (scale, coordinates system) and starting the image rectification process (Fig. 1c). The procedure covers the processes of drawing construction (measurement of topographic features) having a rectified picture and the creation of a map referring to raster images using *Southern CASS 4.0* software.

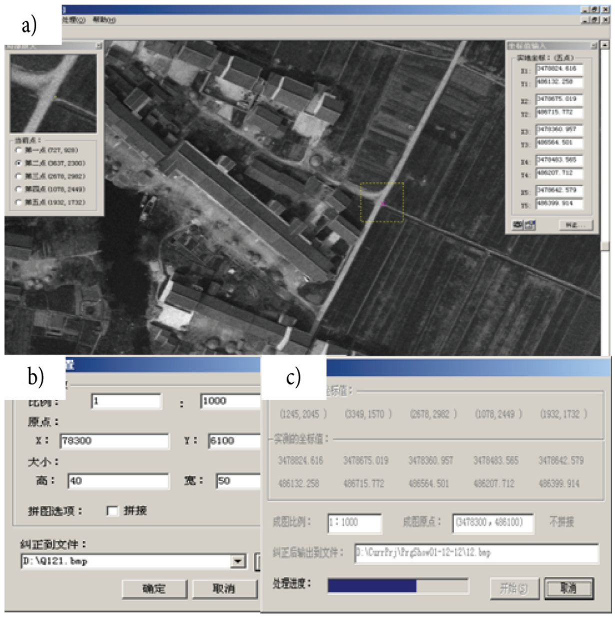

Fig. 1. The sample mapping process:
a) identifying the control point; b) framing;
c) obtaining rectification data

3. Experiments and Evaluation

Experimental photogrammetric procedures have been performed using *GeoEye* satellite imagery with *Google Earth* builder in the northern part of Vilnius city (Fig. 2).

Fig. 2. The experimental area – a fragment of the satellite imagery of Vilnius city using *Google Earth*

Aerial pictures were used for determining the coordinates of control points. Image material includes aerial pictures created by the analogue aerial camera *RMK TOP* in a usual format of 23×23 cm from the airplane at a height of 1000 m and used for digital photogrammetric processing. The mean scale of analogue aerial photos is 1:6000. Analogue diapositives were converted into the digital format employing professional scanner *Microtec ScanMaker 8700* with a pixel size of 14 µm. The camera calibration certificate was at researcher's disposal. A focal length of the camera equals to 53.604 mm.

One of main tasks was properly selected control points for imagery rectification. Using the workflow of processing photogrammetric digital images implemented in the Digital Photogrammetric System (*DDPS*) (Donnay, Kaczynski 2005), the selected coordinates of control (rectification) points (Fig. 3) have been determined. Software *DDPS* was developed within the framework of a cooperative project between the Surfaces Laboratory, Department of Geomatics, University of Liege (supervised by Prof. J. P. Donnay), Belgium and the Institute of Geodesy and Cartography, Department of Photogrammetry (supervised by Prof. R. Kaczynski), Poland. *DDPS* is a complete and integrated photogrammetric package with user–friendly interface easy for usage.

Imagery rectification procedures were completed at the School of Computer Science and Technology, Soochow University, China using the method of *five control points*. Figure 4 shows all selected control points for image rectification. The results from image rectification are presented in Figure 5.

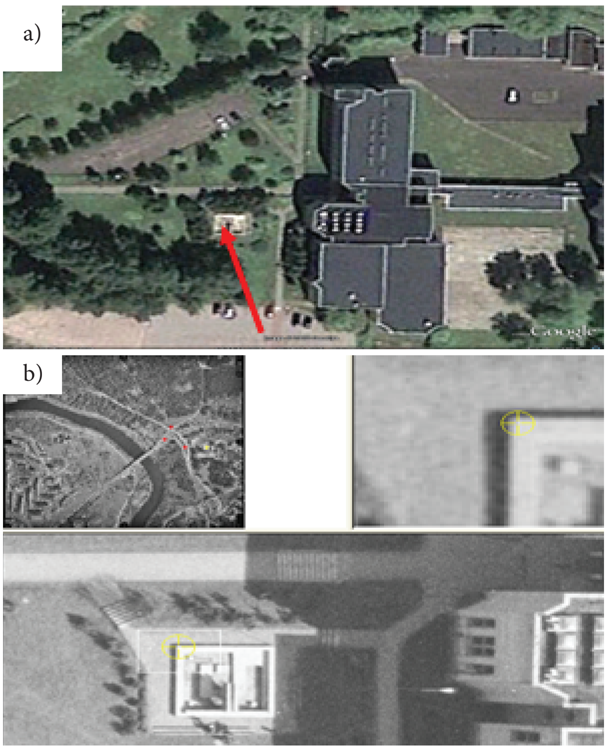

Fig. 3. A fragment from selecting control points (a), determining their coordinates (b)

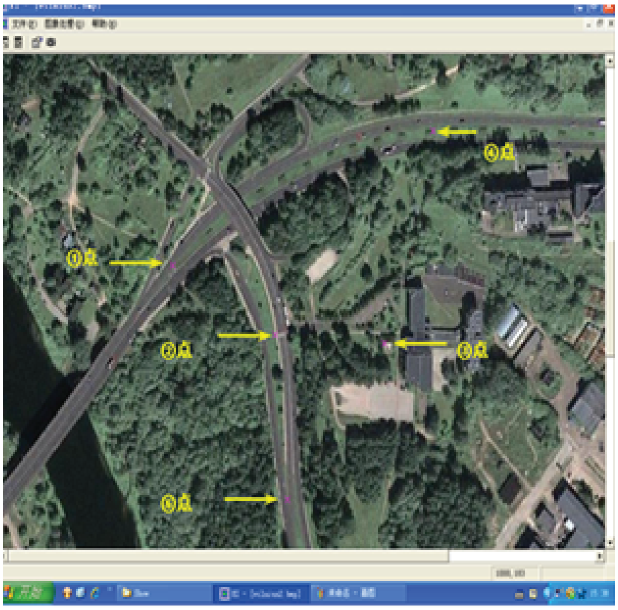

Fig. 4. Selected five rectifying (control) points

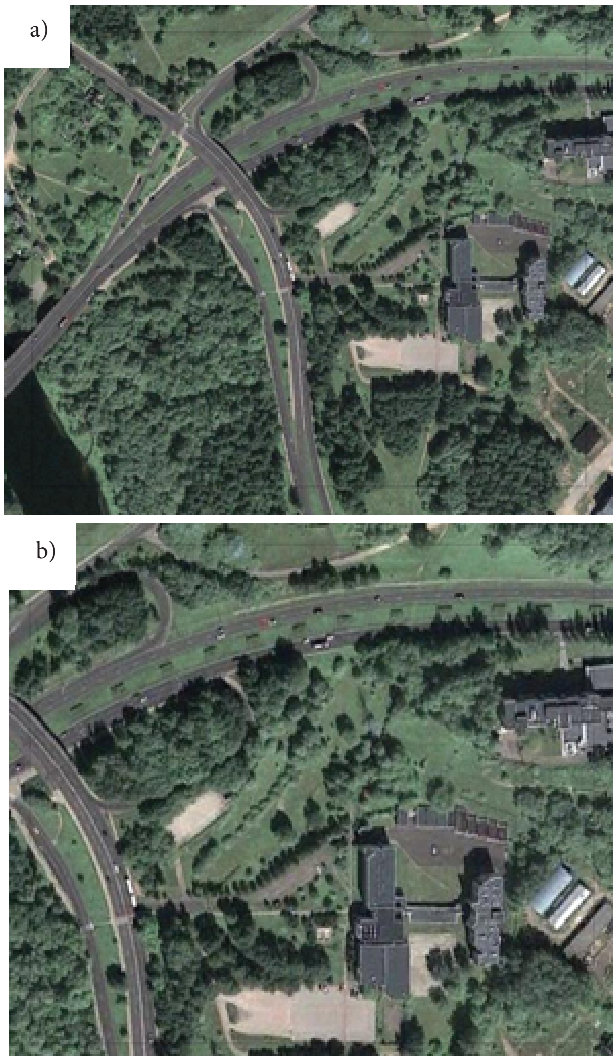

Fig. 5. The results obtained from imagery rectification – orthophoto images at the scales of a) 1:1000 and b) 1:500

The next step of investigation has been based on the analysis of the geometric accuracy of rectification results. Data on reference and rectification are checked comparing with the results obtained from the process of processing digital aerial images using a digital photogrammetry approach. Digital photogrammetric workstation *LISA* has been applied for checking the results received from image rectification measuring approximately 120 points. Digital photogrammetric software *LISA* with the extensions of *LISA FOTO* and raster GIS software *LISA BASIC* developed at Hannover University, Germany has a number of possibilities of image processing (Linder 2009).

The image rectification results of accuracy evaluation were compared with the results of the stereoscopic measurements of the same points. The geometric accuracy (2) – Root Mean Square Error (RMSE) of the investigated rectified images at different scales (1:500 and 1:1000) has made 6 cm and 15 cm respectively.

$$RMSE = \sqrt{\Delta_x^2 + \Delta_y^2}, \qquad (2)$$

where $\Delta_x = X - X'$, $\Delta_y = Y - Y'$, X and Y are horizontal coordinate values of the points identified in the orthophoto; X' and Y' are horizontal coordinate values of the points of higher accuracy stereoscopically measured using analytical photogrammetric methods.

An obtained accuracy result fulfils the requirements for topographic mapping at the scales from 1:500 to 1:2000.

4. Conclusions

Digital satellite imagery using *Google Earth* can be applied for accurate city mapping when the rectification of imagery has been processed using *five control points* technology introducing the algorithm proposed by prof. Ruan Wei (Tong Ji University, Shanghai, China).

The image rectification process takes a short time (about 4–5 minutes) and uses only five control points.

Satellite or aerial images need to be well distributed and accurately defined control points. Some difficulties in finding points clearly seen on imagery may occur. Control points having significant height differences are not desirable (e.g. points on building roofs etc.).

The accuracy of the created models satisfies requirements for large scale mapping.

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Research interests: digital photogrammetric mapping, image interpretation, features extraction from remote sensing data.

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