COMBINATION OF SATELLITE IMAGE PAN IKONOS – 2 WITH GPS IN CADASTRAL APPLICATIONS

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ABSTRACT

In this paper is investigating the possibility of the application of panchromatic image, with spatial analysis 1 meter, from the satellite IKONOS-2 in the Hellenic Cadastre for suburban regions. This possibility is estimated via the technical specifications of the Hellenic Cadastre.
For the achievement of this aim, two orthoimages were produced with two different methods. The first method led to an orthoimage production by using control points that were received from map digitization in scale 1:5000, while the second method led to an orthoimage production using control points that were received from measurements, which were realized with the Global Positioning System (GPS). The application aim of these two methods was on the improvement of orthoimage accuracy with the second method as well as the two methods evaluation. Moreover, the two orthoimages' accuracy was estimated based on the technical specifications of the Hellenic Cadastre for suburban regions. Finally the two methods were evaluated taking into consideration the results for the orthoimages accuracy and the technical specifications of Hellenic Cadastre for suburban regions.

1. INTRODUCTION

The object of this paper is the estimation of the potential use of satellites panchromatic images, from satellite IKONOS-2 in cadastral applications for suburban regions, where the cadastral maps' designing scale is 1:5000.

For the realization of this, two orthoimages were produced using two different methods. The first method led to an orthoimage production using control points that were received with map digitalization in scale 1:5000, while second led to an orthoimage production using control points that were received by measurements realized with the Global Positioning System (GPS).

The application aim of the two methods, in receiving the control points' coordinates was the improvement of the orthoimage's accuracy. Therefore, GPS was used in order to measure control points.

The data that was used were one panchromatic image, with spatial analysis 1 meter, from the satellite IKONOS-2, that was acquired in March 2000, the region's Digital Terrain Model (DTM), a surveying diagram of the same area in scale 1:5000 of the year1978 and the coordinates of 7 points in Hatt projection of the national network.

The software that used was the following:
- Erdas Imagine 8.5 (for image rectification)
- Microstation `95 (for the coordinates reception of control points with digitalization)
- Leica Ski Pro (for the coordinates reception of control points measured with GPS)
- ISTOS 2000 (for the various transformations from one projection to another)

2. AREA OF INTEREST AND DATA DESCRIPTION

The area of interest is the Prefecture of Thessaloniki and in particular southeastern department of the municipality of Pylaia. The study region covers an area approximately 5km x 5km and can be characterized as suburban with few buildings and soft slope. (Figure 1)
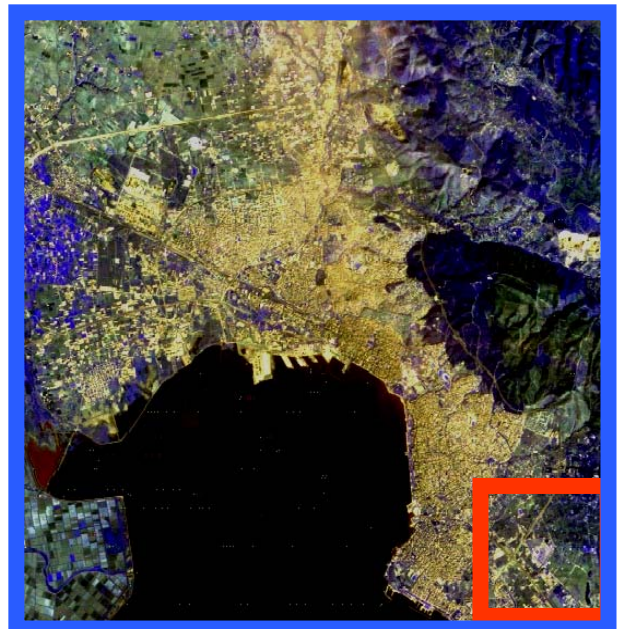

Figure 1. The area of interest

The data that were used for this application are the following:
- The panchromatic image with one-meter spatial analysis and with one band from satellite IKONOS–2, which was received in March 2000. The image's radiometric analysis was

11 bits per pixel that correspond in $2^{11} = 2048$ layers per pixel contrary to the $2^8 = 256$ layers that provide the traditional images with 8 bits.

- A surveying diagram of the same area in scale 1:5000 of the year1978of suburban region of municipality Pylaia in scale 1:5000. The region was selected to be suburban for facilitation reasons with few buildings and soft slope for a better accuracy achievement. For the digitization of control points the above-mentioned map was used.

- The Digital Terrain Model (DTM), of which the digitalization step and accuracy were one meter (Ntokou K. - Theodorou M., 2001).

- Finally, the coordinates of 7 points, in Hatt projection, of the national network were used, in order to transform the measurement from the GPS, which were in the projection system WGS'84

3. IMAGE ORTHO RECTIFICATION

3.1. Image ortho rectification with control points digitized from surveying diagram

3.1.1. Rectification

For the image rectification 22 points were used (13 control points and 9 check points) the coordinates of which were received via digitization of map in scale 1:5000, which it was in Hatt projection. The polynomial model was selected and more concretely Afine transformation. (Erdas, 2001)

The RMS error for the control points was 0.4429 m, which was analyzed at X equal with 0.3508m and at Y equal with 0.2704m. Similarly the RMS error for the check points was 0.0920m, which was analyzed at X equal with 0.0713m and at Y equal with 0.0582m.

Considered these errors bearable, the next step was the image resampling with the Cubic Convolution method that resulted to a rectified image (Tsakiri –Strati M., 1998).

3.1.2. Ortho rectification

The image rectification was followed by ortho rectification with the use of Digital Terrain Model (DTM) of the region, the control points and the choice of model of satellite Spot. (Mpanta K., Xalkidou M., Xalkidis L., 2001)

22 points were used (13 control points and 9 check points). The RMS error for the control points was 0.4114m, which was analyzed at X equal with 0.2929m and at Y equal with 0.2888m. Similarly RMS error for the check points was 0.0549m that was analyzed at X equal with 0.0264m and at Y equal with 0.0481m. Finally the total vertical error of rectified image's adaptation in the DTM was estimated equal with 0.356 m.

With those errors considered bearable, the final step was the image resampling with the Cubic Convolution method of the rectified image and the production of the orthoimage (Figure 2).

3.2. Image ortho rectification with control points measured with GPS

3.2.1. Rectification

For the image rectification 20 points were used (12 control points and 8 check points) that were received from measurements, which were realized with the Global Positioning System (GPS).

The RMS error for the control points was 0.3685m, which was analyzed at X equal with 0.1822m and at Y equal with 0.3203m. Similarly the RMS error for the check points was 0.0920m, which was analyzed at X equal with 0.0497m and at Y equal with 0.0774m.

Considered these errors bearable, the next step was the image resampling with the Cubic Convolution method and the result was a rectified image.

3.2.2. Ortho rectification

The image rectification was followed by the ortho rectification with the use of digital terrain model (DTM) of the region, the control points and the choice of model of satellite Spot.

20 points were used (12 control points and 8 check points). The RMS error for the control points was 0.3243m, which was analyzed at X equal with 0.1640m and at Y equal with 0.2797m. Similarly RMS error for the check points was 0.0962m that was analyzed at X equal with 0.0810m and at Y equal with 0.0519m. Finally, the total vertical error of rectified image's adaptation in the DTM was estimated equal with 0.507 m.

With those errors considered bearable, the final step was the image resampling with the Cubic Convolution method of the rectified image and the production of the orthoimage. (Figure 3)

Figure 2. The panchromatic orthoimage using control points digitized from map.

Figure 3. The panchromatic orthoimage using control points measured with GPS.

4. ACCURACY ESTIMATION OF THE TWO ORTHOIMAGES

4.1. Required accuracy from the Hellenic Cadastre Project

As it is known the technical specifications of the Hellenic Cadastre fixes bearable limits for horizontal and vertical accuracy rise up to two (Technical specifications of Hellenic Cadastre Project, 1999) (Arvanitis A., 2000).

In order to achieve accuracy control the technical specifications demand the coordinates' comparison of certain characteristic points in the orthoimage with the coordinates that were received with any method (digitalization, GPS).

The map accuracy is expressed by variance σ^2, or the Root Mean Square error of the points' coordinates, that was calculated (Patias P., 2001):
- From the n points' horizontal coordinates

$$\sigma_{hor}^2 = \frac{1}{2n} \sum_{i=1}^{n} \left(\delta x_i^2 + \delta y_i^2 \right) \Rightarrow$$

$$\sigma_{hor}^2 = \frac{1}{2n} \sum_{i=1}^{n} \left[\left(x_i^\delta - x_i \right)^2 + \left(y_i^d - y_i \right)^2 \right] \tag{1}$$

- From the n points heights

$$\sigma_{ver}^2 = \frac{1}{n} \sum_{i=1}^{n} \left(z_i^\delta - z_i \right)^2 \tag{2}$$

Where

x_i^δ, y_i^δ, z_i^δ = the values of control points' coordinates in the orthoimage

x_i, y_i, z_i = the corresponding topographic control values.

δx_i^2, δy_i^2 = the coordinates' residuals

n = the number of points for the accuracy control

σ_{hor}^2, σ_{ver}^2 = the variances' estimation for the horizontal and vertical control

Before the value σ becomes acceptable, the values dxi, dyi are checked for probably gross errors applying data snooping control:

$$\delta x_i, \delta y_i \leq 1.96 \, \sigma_{hor} \tag{3}$$
$$\delta z_i \leq 2.16 \, \sigma_{ver} \tag{4}$$

The percentage of the rejected values resultant from the application of this control should not exceed the 5% of total values. After the rejection of the off limits deviations the root mean square error of the remaining points is calculated and the global test takes place. The value σ is checked with the help of the reference variance. The prices σ_o, which come in this case from the technical specifications of the Hellenic Cadastre (σ_{XY} και σ_Z), depending on the scale, are given for the coordinates x, y, z.

- For horizontal accuracy:

$$\sigma_{hor} \leq 0.92 \sigma_{XY} \cong 0.9 \, \sigma_{XY} \tag{5}$$

- For vertical accuracy:

$$\sigma_{ver} \leq 0.98 \sigma_Z \cong 0.9 \, \sigma_Z \tag{6}$$

Accordingly to the statistics if the inequalities are valid, the estimation of accuracy that was calculated is σ_{XY}=2m and σ_Z=2m by tacking into consideration the technical specifications of the Hellenic Cadastre about σ_o as well.

4.2. Orthoimage's accuracy estimation that was produced with the method of digitization

Nine points were used for the accuracy control, which were distributed in the total of region. The points' coordinates were received from ortoimage and they were compared with the coordinates that were received by the digitization of surveying diagram in scale 1:5000. After calculations it was calculated that σ_{hor}=1,245m and σ_{ver}=0.412m for the nine points.

The data snooping control for gross errors in the nine control points accomplished successfully. There was no necessity to reject any point because of the type:

$$\delta x_i, \delta y_i \leq 1.96 \sigma_{hor} = 2.44m \tag{7}$$

As well as the type:

$$\delta z_i \leq 2.16 \sigma_{ver} = 0.89m \tag{8}$$

Continuously a total accuracy control was applied, where the following type should be verified:

$$\sigma_{hor} \leq 0.92 \, \sigma_{XY} \cong 0.9 \, \sigma_{XY} \tag{9}$$

As well as the type

$$\sigma_{ver} \leq 0.98 \, \sigma_Z \cong 0.9 \, \sigma_Z \tag{10}$$

For the vertical accuracy the type was verified (0.412m<1.8m) and as it was expected. The type was also verified for the horizontal accuracy (1.245m>1.8m), a fact that indicates that the orthoimage's accuracy is bearable according to the technical specifications of Hellenic Cadastre.

4.3. Orthoimage's accuracy estimation of that was produced with the method of GPS

In this method eight points were used for the control precision, which were measured, as mentioned above, with GPS. In this method it was calculated that σ_{hor}=0.505m and σ_{ver}=0.370m for the eight points.

The reliability control for gross errors in the nine control points accomplished successfully. There was no necessity to reject any point because of the type below:

$$\delta x_i, \delta y_i \leq 1.96 \, \sigma_{hor} = 0.99m \tag{11}$$

As well as the type:

$$\delta z_i \leq 2.16 \, \sigma_{ver} = 0.779m \tag{12}$$

Continuously a total accuracy control was applied, where the following type should be verified:

$$\sigma_{hor} \leq 0.92\sigma_{XY} \cong 0.9 \, \sigma_{XY} \tag{13}$$

And the type

$$\sigma_{ver} 0.98\sigma_{Z} \cong 0.9\sigma_{Z} \tag{14}$$

The type for the vertical accuracy (0.370m<1.8m) was verified as well as the type for the horizontal accuracy (0.505m>1.8m), fact that indicates that the orthoimage's accuracy is bearable according to the technical specifications of Hellenic Cadastre.

5. CONCLUSION

Underlining the more important points of this research, in regard to the possibility of application of panchromatic image of satellite IKONOS -2 in the Hellenic Cadastre, judged necessary the report of the following conclusions and proposals:

5.1. First method

From the panchromatic orthoimage control resulted an estimation of total horizontal error equal to 1.245 m while the technical specifications of Hellenic Cadastre for suburban region (1:5000) is 2m. Obviously the accuracy from the orthoimage is acceptable from the Hellenic Cadastre.

The proposal that can be formulated for this method, in order to be the orthoimage production possible in Cadastral applications is the following: digitization of cartographic maps in bigger scale (for example 1:1000), with a recent syntax (ideal date 2000, for the particular application, because this is the chronology of image reception).

5.2. Second method

From the panchromatic orthoimage control resulted an estimation of total horizontal error equal to 0,505m while the tolerance given by the technical specifications of Hellenic Cadastre for this particular region (1:5000) is 2m. We lead to the conclusion that is possible to use this orthoimage in the Hellenic Cadastre.

Provided that this method became acceptable from the technical specifications of the Hellenic Cadastre, the only proposition that can be suggested is: Measurements of as many as possible characteristic points (for this region at least 100), aiming at the simultaneous production of digital terrain model (DTM), with the "stop and go" method. The method "stop and go" provides accuracy "unacceptable" for the GPS specifications (0.5m) but acceptable accuracy for the particular application with simultaneous production of digital terrain model (Pikridas C., 2001) (Christodoulou K., 2002).

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