

Integrated High Resolution Satellite Image, GPS and Cartographic Data in Urban Studies. Municipality of Thessaloniki.

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ABSTRACT:

Over the years, satellite based remote sensing data have been successfully utilized for mapping, monitoring, planning and development of urban sprawl, urban land use and urban environment. In the present investigation satellite images with GPS and cartographic data are integrated, in order to study the potentiality of creating a cartographic data of an urban area. For this aim the panchromatic image with spatial resolution 1 meter and the corresponding multi-spectral, with spatial resolution 4 meters and 4 spectrum bands, from IKONOS-2, and cartographic data were used. For the rectification of the images there were some ground control points used, measured with GPS. The urban region of study is the Municipality of Thessaloniki, in Central Macedonia, in Northern Greece. After mapping the two images and registering the multi-spectral image to the panchromatic image, fusion between them was attained. The product of fusion was a synthetic image with the advantages of the two initials. The estimation of spectral quality for the synthetic image was attained through statistical criteria. Special urban characteristics (for example: churches, monuments, hospitals, administration buildings, etc) were detected via visual interpretation and the use of a topographic map of the Municipality of Thessaloniki (scale 1:8000), obtained from the urban planning service. Also, there was an effort of modelling the urban environment of Thessaloniki, with the synthetic image, via classification. Special techniques for image classification in urban regions were used. The result was the creation of a thematic picture with a lot of urban characteristics, which can be used as a cartographic background in urban studies.

1. INTRODUCTION

Today Thessaloniki is more than just a city. It is a centre of national range, the biggest in northern Greece, with a population of about 1 million people. In greater Thessaloniki there are 45 administrative unities, 43 of which are municipalities and 2 are communities. The city's continuous development makes the effective supervision of its alterations extremely difficult, since the size of it and the land use keep on changing. Therefore, the necessity of creating a reliable cartographic background of the urban area, containing as more information as possible, arises. This will become the first step for the study of the allocation of surfaces and their use all over the city's area. Combining such backgrounds – images of different periods of time, describes the dynamic development of the city while detecting the drift of the urban extension. Of course this step is only part of the operations demanded for analyzing an area of study, which involves subjects such as:

- a. Natural Facts
- b. Socioeconomic Approach

- c. Decretive and Organizational Framework
- d. Land Use

The specific application regards in the procedure of composing data for the creation of a reliable cartographic background which covers the area taken up by the Municipality of Thessaloniki and where:

- a) There is an attempt to improve tracking down urban characteristics (e.g. hospitals, buildings of administration, monuments etc.) with the help of cartographic data, through visual interpretation and
- b) In order to separate the various classes of land use, special techniques for urban areas are applied for their classification.

2. METHODOLOGY AND DATA USED

2.1 Data

The data integrated for the creation of this cartographic background of the Municipality of Thessaloniki were two images taken by the IKONOS-2 satellite (in UTM projection, zone 34, ellipsoid WGS84, geodetic datum WGS84) in March 2000 showing the greater area of Thessaloniki and a topographic map of the same area, scale 1:8000, obtained from the Municipality's urban planning office. The two images were:

- A panchromatic image with a resolution of 1 meter (Fig. 1)
- A multispectral image with a resolution of 4 meters (Fig. 2)

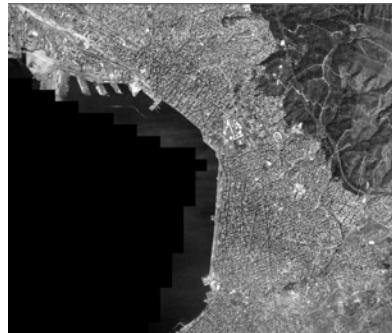


Figure 1. IKONOS PAN (1m)

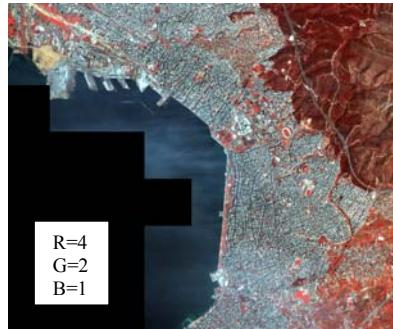


Figure 2. IKONOS MS (4m)

2.2 Methodology

2.2.1 Creating the synthetic images: The specific application through the process of the above data was completed in two stages. The first stage regarded to the preparation of the two satellite images, which would compose the image that constituted the cartographic background. The complete procedure is described in *Bussios N., Tsolakidis Y., 2003*. The creation of the synthetic image included:

- Mensurations of 34 ground control points (GCP'S), with good allocation in the Municipality of Thessaloniki with G.P.S.. The geometric model used for the transformation of the points from WGS84 to EGSA87, was a general affine transformation with 6 parameters. The equations of the affine transformation are the following:

$$\begin{aligned} x &= a_0 + a_1 X + a_2 Y \\ y &= b_0 + b_1 X + b_2 Y \end{aligned} \quad (1)$$

where $x, y =$ GCP'S coordinates (TM87)
 $X, Y =$ GCP'S coordinates (UTM)
 $a_i, b_i, i=0,1,2$ transformation parameters

- Geometric correction of each image, through a 2nd degree polynomial model. The total root mean square of the reduction was RMS = 0.6629m for the panchromatic image and RMS = 1.3404m for the multispectral. Resampling for both images was attained with the bicubic method. The equations of the transformation used are:

$$\begin{aligned} x &= a_0 + a_1 X + a_2 Y + a_3 X^2 + a_4 XY + a_5 Y^2 \\ y &= b_0 + b_1 X + b_2 Y + b_3 X^2 + b_4 XY + b_5 Y^2 \end{aligned} \quad (2)$$

where $x, y =$ GCP'S image coordinates (TM87)
 $X, Y =$ GCP'S image coordinates (UTM)
 $a_i, b_i, i=0,1,..,5$ transformation parameters

- Registration of the multispectral image in the panchromatic image with the help of a 2nd degree polynomial model and 22 control points. The registration presented a total root means square of 0.8376 m (RMS = 0.8376 m). Also there was a histogram matching of the multispectral's histogram to the panchromatic's histogram, in the first occasion, so that the two images would present the same radiometry, while in the second occasion there was no histogram matching between the two images. Finally, the exact same geographic region was cut off the two images, at the borders of the municipality. Hereafter, the merging of the two images with the principal components transformation (PCT) was applied. The result was the creation of two synthetic images.

The synthetic image in the first occasion where histogram matching between the two images was attained is the following (fig.3).

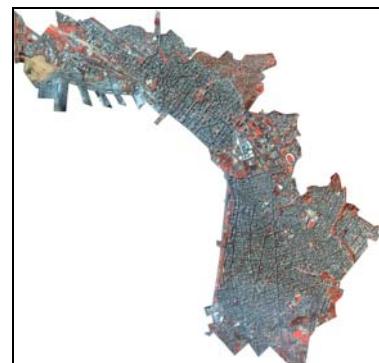


Figure 3. Synthetic image 1.Municipality of Thessaloniki.

In the second occasion where there was no histogram matching the image that came up is the following (fig.4).

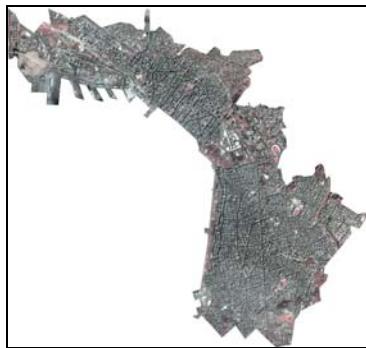


Figure 4. Synthetic image 2. Municipality of Thessaloniki.

The software *ERDAS IMAGINE 8.5* was used for the processing of the images while the GCP'S mensurations were actualized by the Leica 500 receiver (with the AT502 antenna) and their processing was actualized by the *LEICA SKI-PRO* and *ISTOS – 2000* programs.

2.2.2 Evaluation of spectral quality of the synthetic image: In a merging procedure it is extremely important to maintain the primitive spectral information in the final image as well. For this reason the synthetic images were studied for their spectral accuracy, through statistical criteria such as mean values, typical variations and coefficient correlation.

Analyzing the two synthetic images led to the following conclusions:

With a simple visual observation of the two synthetic images one can easily discover that the synthetic 1 image has better appearance. The results of the spectral examinations through statistical criteria clearly indicate as better method of merging the one where histogram matching between the layers of the multispectral and the layer of the panchromatic is attained, that is the synthetic 1 image (Tab. 5).

	Statistical criteria
Synthetic 1	✓
Synthetic 2	

Table 5. Evaluation of the two merging methods used after examining their spectral accuracy.

3. SYNTHETIC IMAGE - APPLICATIONS

The second stage regarded to the applications that took place in the synthetic image like:

a) Visual interpretation and

b) Classification

For the classification of the synthetic image and its estimation, the *ERDAS IMAGINE 8.5* software was used.

3.1 Visual interpretation of the synthetic 1 image

With the assistance of cartographic data an attempt to improve tracking down urban characteristics (e.g. hospitals, buildings of administration, monuments etc.) via visual interpretation takes place. Here are some examples (Fig.6,7,8)



Figure 6. Church of Agios Dimitrios



Figure 7. Hospital



Figure 8. Prefecture of Thessaloniki

Improvement of tracking down urban characteristics can be useful for creating city plans that communicate better with the user. It can also become a basis for a G.I.S. application.

3.2. Classification of the synthetic 1 and estimation of the classification

3.2.1 Classification: The type of classification selected for the synthetic 1 image was supervised and was accomplished with the maximum likelihood method. The selection and receipt of the samples was based on the V.I.S. model (Vegetation-Impervious surface-Soil),(Ridd 1995, Ming C. H. 2002). Estimation of the classification through close examination of the error matrix and the Kappa statistics followed. The selected classes were:

- Grassland, trees
 - healthy green grass vegetation and tree and/or shrub vegetation.
- Buildings
 - bright impervious surface, like rooftops, metals and tiles.
- Streets
 - medium impervious surface, like concrete and weathered asphalt.

- dark impervious surface, like asphalt and darkened concrete.
- Soil and/or dry vegetation.
- Shadow (*N. Haala, V. Walter, 1999*)

The selection of the samples was followed by the estimation of each class's samples by studying characteristics such as vectors of mean values intensions for each class (Fig. 9), histograms of each sample and the feature spaces of the samples.

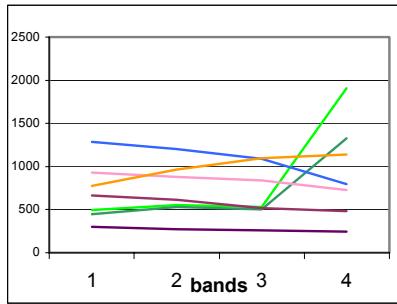


Figure 9. Vectors of mean values intensions in every layer

HEALTHY GREEN VEGETATION	
ROOFTOP/METAL /TILE	
ASHPALT/DARKENED CONCRETE	
CONCRETE/WEATHERED ASHPALT	
SHADOW	
SOIL	
TREES/SHRUB VEGETATION	

Table 10. Classified image legend

The next step was the classification of the synthetic 1 image (Fig. 11).

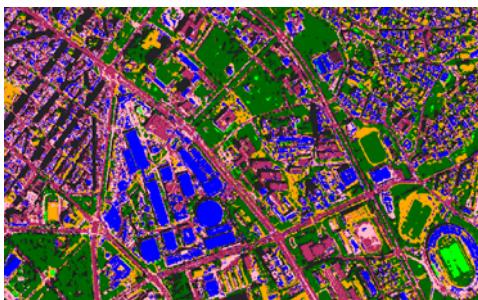


Figure 11 : Classified image of the Municipality of Thessaloniki



Figure 12: The synthetic image

3.2.2. Estimation of the classification: Urban regions, due to the heterogeneous nature they show concerning urban characteristics, are really hard to classify. Moreover, this problem is increased as the spatial resolution of the images increases, because of the upgrade of the details and the spectrum range of the pixels.

In this particular application the problem in the classification was detected in the difficulty of separating classes like streets and buildings. In their majority rooftops are consisted of different materials like metal, concrete, tile and others.

The materials that consist the rooftops have similar spectral behavior with the materials that consist the roads, like asphalt and concrete. The result of this fact is that the boundaries between roads and buildings are not distinct in the classified image (Fig. 13, 14)



Figure 13. Part of the synthetic 1 image

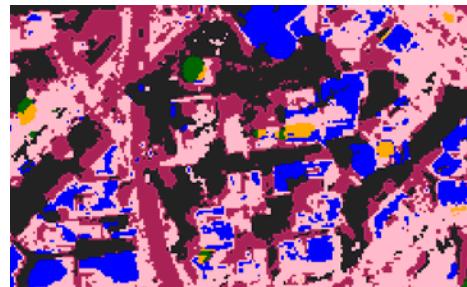


Figure 14. Classified image

Furthermore, materials like soil and tiles present the same phenomenon and as a result many tile rooftops are classified as soil (Fig. 15, 16).



Figure 15. Part of the synthetic 1 image

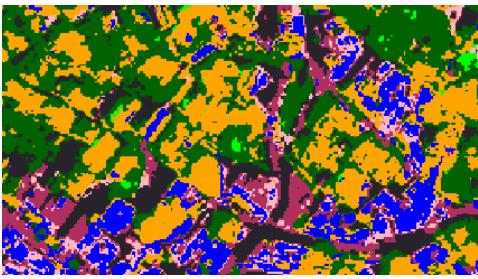


Figure 16. Classified image

Finally, the estimation of the classification was achieved using 84 points leveled for each class (12 points per class). This procedure provided the error matrix and the Kappa statistics. The accuracies attained are presented in table 17.

Classified image	Accuracy totals (%)	Kappa statistics (%)
SYNTHETIC 1	80,95	77,78

Table 17. Total results of the classification

3.2.3 Classification improvement: The traditional techniques of processing urban areas images, due to their high spatial frequency, when based only to the spectral observation of the objects, do not always provide the right result. In order to solve this problem the procedure of the classification can be supported, besides from some special techniques, by further data, which can be from a topographic or thematic map to extra layers. Also, a Digital Surface Model (DSM) can be an important help for separating the classes in the classified image. The hypsometric information can be combined in the classification, so as to achieve better results in separating classes with similar spectral behavior.

4. CONCLUSIONS

Remote sensing, with the continuously ongoing spatial resolution of modern satellites and the development of the processing methods for the

corresponding data, can offer irreplaceable cartographic products (*Tsakiri a.o. 1998*), like the synthetic multispectral image with a spatial resolution of 1 meter, which became the background for the applications described above. Specifically, we saw how useful can the synthetic image be, combined with cartographic data, in visual interpretation of urban characteristics. This could be applied for the creation of reliable maps of several themes, where the information, compared to a classic map, is more and is not represented by geometric schemes and colors, but by their actual characteristics (texture, color, relief etc.) Also, the classification of a synthetic image of an urban area can have as a result thematic maps related to land use, from which useful conclusions can be derived, about the land use, for a period of time, showing the tension of urban development. This way they contribute to the procedure of making serious decisions.

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