

# FROM THE AERIAL PHOTO TO HIGH RESOLUTION SATELLITE IMAGE. TOOLS FOR THE ARCHAEOLOGICAL RESEARCH

<sup>1</sup>O. Georgoula, <sup>2</sup>D. Kaimaris, <sup>3</sup>M. Tsakiri, <sup>4</sup>P. Patias

<sup>1</sup> Assistant Prof., <sup>2</sup> PhD Candidate, <sup>3</sup> Assistant Prof., <sup>4</sup> Professor

Department of Cadastre, Photogrammetry and Cartography, Aristotles University of Thessaloniki, Greece  
[olge@topo.auth.gr](mailto:olge@topo.auth.gr), [martsak@eng.topo.auth.gr](mailto:martsak@eng.topo.auth.gr)

ThS20

**KEY WORDS:** Remote Sensing, Quickbird, Archaeology, Ortho, Fusion, Interpretation

## ABSTRACT:

The aim of this project is to evaluate the possibilities that the high resolution satellite image offers in the field of archaeological research. More specific, the present study concerns the identification of buried archaeological remains with the aid of the Pan-sharpened (fused) image Quickbird-2. For this purpose, the fused image (spatial resolution 0.70m and spectral resolution 4 bands), that covers an extended area of the archaeological site of Philippoi in N. Greece, has been used. The new image has been produced from the fusion of two ortho images. The latest have been derived from the panchromatic image and the multispectral image as well. The generation of the above two ortho images has been based on a DTM of the area, photogrammetrically produced, and on the Quickbird sensor model. The fusion has been established with the PCA technique. The fused image has been evaluated with statistical criterions. Enhancement technique, as PCA was applied to facilitate the optical interpretation for the detection of the revealing traces. Comparing the interpretation results with the results coming out from previous research, based on photogrammetric data, has been found out that both of them converge. The advantage of the use of the fused image is that it offers additional valuable information to the archaeologists and/or to other technology oriented experts, as for example information about the land use etc. Additionally, the high spatial resolution of it offers the possibility for an accurate surveying of the detected traces.

## 1. INTRODUCTION

The use of the aerial photos for surveying and documentation of Archaeological sites is well known. The application of digital photogrammetric methods of processing, often of a large number of aerial photos, gives the necessary outputs as maps, DEMs, orthos, 3D models etc., for the monitoring of historical sites. Of special interest is the case, where the aerial photo is used for the detection of buried archaeological remains, which under the proper conditions, when viewed from the air are best identified. In this case the ortho, which combines the quantitative information of a map and the thematic information of a photo, plays a significant role in archaeological research.

At the archaeological site of Phillipoi in Northern Greece excavations take place for the last 90 years. During the excavations, a small part of the famous Via Egnatia of the Roman period has been uncovered. In 2003, a project has been carried out in the Department of Cadastre, Photogrammetry and Cartography in Aristotles University of Thessaloniki. (Georgoula et al, 2003). It concerned the processing of a block of 11 vertical aerial photos of the major area of the archaeological site of Philippoi. The photos was at 1:15,000 scale and they was captured in September 1994. The initial visual interpretation, via stereoscopic vision, led in the location of a lot of traces. The second stage was the digital photogrammetric process of the aerial photos and the production of a DTM and an orthomosaic at scale 1:5000. For this, the aerial photos were scanned at 1200dpi, that means the resolution of the digital images was approximately 0.3m. The visual interpretation of the orthomosaic of the entire area of interest, was of great help. Fifteen (15) traces were correlated

between them. The initial information, provided by the interpretation, was cross-evaluated with additional information coming from other sources, like cartographic data, historical sources and information from the archaeological excavations. Specially, the particular processing of old cadastral maps (1928, 1938, 1940, 1957, 1960) gave information about the old geomorphology (old streams, old ownership boundaries, etc), and thus, for many traces our initial estimations have been confirmed. They were traces of the old geomorphology of the region. This information, in principle of non archaeological interest, it has been very useful in two directions: firstly, in restricting our attention in a smaller number of traces and secondly, for the reconstruction of the ancient landscape. Thus, finally our attention was focused on 6 features. The final conclusion is that four (4) of these traces concern parts of Via Egnatia and the fifth feature is a part of a fortification wall. The last one is located on the top of a small hill and it concerns a buried construction approximately 53x47m, till now unknown, even for the archaeologists.

As the results of this research were very encouraging, it was decided to continue the efforts in the same direction with the aid of satellite images. In the past, there have been many studies using satellite imagery. These projects have been restricted mainly to geomorphological analyses using Landsat SPOT images or other data (Boehler, 1999, Comfort, 2001, <http://www.irex.org/programs/completed/blacksea/trelogan.pdf>, <http://www.geoinformatie.nl/cgi/projects/bcrs/multisensor/repor t1/10.htm>, [http://www.caa2002.gr/abstracts\\_papers/83.html](http://www.caa2002.gr/abstracts_papers/83.html), <http://www.culturalsite.com/petra/petrakaplan97.html>, <http://www.ghcc.msfc.nasa.gov/archeology/arenal.html>, <http://www.personal.rdg.ac.uk/~sgswitke/research.htm>).

The characteristics of the new digital remote sensed image, like IKONOS-2 become these data a valuable source of archaeological information (Campana, 2003). Today, the panchromatic (0.7m spatial resolution) and the multispectral (2.5m spatial resolution) images, offered by the satellite Quickbird-2, enable users to dispose and manipulate data of a large archaeological area, in a large portion of the optical spectrum, with a high spatial and radiometric resolution. In addition, the application of rigorous digital image analysis techniques in these data, can give valuable information to the archaeologists.

The aim of this project is to evaluate the possibilities that the high resolution satellite image Quickbird-2 offers for the detection of buried archaeological remains. The research is still in progress. Our interest is focused only on the features that have been already identified on the aerial photos and the orthomosaic, that means Via Egnatia, the defensive wall and the buried construction on the top of a hill, called today the hill of Alexander the Great.

## 2. STUDY AREA AND DATA SET

### 2.1 Study area

The site of study is the major area of the archaeological site of Philippoi in N. Greece (Fig. 1)



Fig. 1

It is a countryside landscape, with fields, villages and low height relief. The archaeological site of Philippoi, where the excavations are taken place, and the major area of it, where our attention is focused, are presented in Figure 2.

### 2.2 Data set and Pre-Processing

For this research a data set of Quick Bird (Q. B) satellite were used: a panchromatic image and a multispectral one. The Q.B. images were acquired in the 23th of May 2003. This time of capture offers two advantages: the images are recent and, in the

same time, near the year of the aerial images. Thus, no many transformations and changes in the area have been occurred in the period of 8 years. Secondly, in May the conditions for the detection of archaeological features are good. It is noticed that the aerial photos were captured in September. Thus, data of two different seasons were available. The Q. B. images were characterized by very good quality. The total absence of cloud and haze offered an excellent visibility. They covered an area of 8.5Km x 8.5Km.

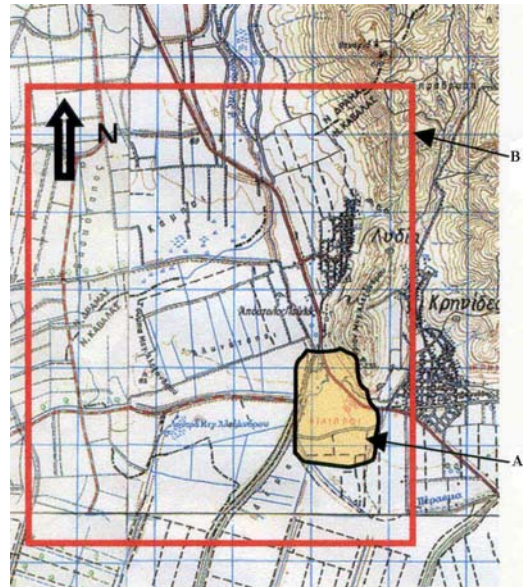


Fig. 2

- A. Archaeological site
- B. Area of study

The spatial ground resolution of 0.7m (PAN image) is approximately twice the resolution of the aerial photos already processed. The trace of Via Egnatia is of 6m width. That means that the spatial resolution of 0.7m of Quickbird-2 PAN image is adequate to distinguish the same trace. On the other hand the MS image has a spatial resolution of 2.5m but includes information that neither the aerial image nor the PAN image has. A fused image is characterized as the PAN image in four bands. Thus a new image, the fused, was necessary to be produced.

In order to proceed in generation of a fused image, the orthorectification of the Q.B images has been preceded. A DTM produced from aerial photos was available. Additionally six (6) Ground Control Points (GCPs) measured by GPS were available as well. The images were orthorectified with the aid of Leica Photogrammetry Suite software. The procedure was based the Quickbird sensor model. The orthorectification of PAN and MS images has been done with accuracy (RMS) of 0.66pixels and 0.5pixels respectively. Before the fusion process the ortho MS was registered to ortho PAN in order to fit better.

## 3. DATA FUSION AND INTERPRETATION

### 3.1 Data Fusion

In order to fuse the Panchromatic and Multispectral images, the PCA transformation was used. The spectral quality of fused image was evaluated by the correlation matrix and the NDVI

index. The correlation matrix between the bands of MS image and the fused image are presented in Table 1. This matrix indicates the correlation between the bands of each image and the correlation of the corresponding bands of the two images as well. Thus the spectral quality of the fused image can be evaluated.

	MS image				Fused image			
	B. 1	B. 2	B. 3	B. 4	B. 1	B. 2	B. 3	B. 4
B. 1	1	<b>0.98</b>	<b>0.93</b>	<b>0.17</b>	<b>0.92</b>	0.87	0.83	0.09
B. 2	0.98	1	<b>0.97</b>	<b>0.25</b>	0.93	<b>0.91</b>	0.90	0.17
B. 3	0.93	0.97	1	<b>0.17</b>	0.88	0.88	<b>0.92</b>	0.10
B. 4	0.17	0.25	0.17	1	0.39	0.48	0.41	<b>0.96</b>
B. 1	0.92	0.93	0.88	0.39	1	<b>0.98</b>	<b>0.93</b>	<b>0.36</b>
B. 2	0.87	0.91	0.88	0.48	0.98	1	<b>0.97</b>	<b>0.45</b>
B. 3	0.83	0.90	0.92	0.41	0.93	0.97	1	<b>0.38</b>
B. 4	0.09	0.17	0.10	0.96	0.36	0.45	0.38	1

Table 1. Correlation matrix between the bands (B) of MS image and fused image

The application of the NDVI index and the computation of the correlation matrix between the two NDVI images, gave the value of coefficient correlation 0.95.

Thus, safely we can conclude that the fused image preserve the spectral characteristics of the MS image (Tsakiri et al, 2002).

The assessment of the spatial accuracy of the fused image has been occurred via the registration of the new image into ortho Pan. This procedure has been done with an accuracy of RMS=0.4m. In Figure 3 an extract of the fused image is shown.



Fig. 3. An extract of the fused image

### 3.2 Interpretation

As is already mentioned, the interest of this study is focused on some traces that already have been identified on the orthomosaic. These features concern parts of Via Egnatia, a part of a defensive wall and the buried construction on the top of a hill.

The initial visual interpretation of the PAN and MS images gave a quasi total different appearance of the traces. The features were more intense. Additionally, while in the orthomosaic the traces have been appeared with discontinuities,

in the PAN image much more parts of the features have been located. This was valid for the fortification wall (Fig. 4, 5) and Via Egnatia (Fig. 8, 9). Totally different was the appearance of the buried construction (Fig. 10, 11).

In a second step the interpretation of the fused image has been done. The empirical method of combination of bands for color display was applied. Certainly, there is no single ideal combination. Likewise, many factors affect the result for the archaeological interpretation. In the Figure 6 the image of the fortification wall is presented, as result of the combination: R=1, G=2, B=4.

To facilitate the trace's identification and interpretation, the PCA transformation was applied on fused image. The three selected PC1, FMS1 and PC2 bands have been enhanced by applying the convolution filter 3x3 for edge enhancement. Finally a FCC image was produced by displaying respectively: R=PC1, G=FMS1 and B=PC2. In Figure 7, the image FCC of the fortification wall is presented. Via the interpretation of this display some additional details of the wall have been identified.

## 4. CONCLUSIONS

The aim of this project was the evaluation of the possibilities that the high resolution satellite image Quickbird-2 contributes to the detection of buried archaeological remains. The research is still in progress. Our interest is focused only on the features that have been already identified on the aerial photos. The first results are promising.

The initial visual interpretation of the PAN and MS images gave a clear and intense appearance of the traces. Additionally, while in the orthomosaic the traces have been appeared with discontinuities, in the Q.B. images much more parts of the features have been identified. It is already noticed that the data, orthomosaic and Q. B. images, was captured in different season. Thus the question is: season is the only parameter that affects the result?

Additionally, a preliminary application of image processing techniques on the fused image, revealed some additional details in the trace of the fortification wall. In this direction much more efforts will follow in the future. Others digital image analysis will be applied.

Ground truth reconnaissance about land use and land cover will be realized next month, May 2004. As Q.B. images were captured in May 2002, this work will help the research. Ground truth reconnaissance will be repeated in September, the same time aerial image has been taken.

The spatial ground resolution of Q.B. images allows: A) the identification of a large range of archaeological features. Till now, our interest is focused only on the features of Via Egnatia, the defensive wall and a buried construction. As is already noticed, a hundred of traces appear in the orthomosaic. Thus, the study and interpretation of the fused image for the identification of other archaeological traces will be done. B) the accurate surveying of the archaeological site. As the fused image is an orthorectified satellite image, all necessary information for the documentation of the archaeological site and the identified traces, is already here.





Fig 4. An extract of the orthomosaic, where a part of the fortification wall is located

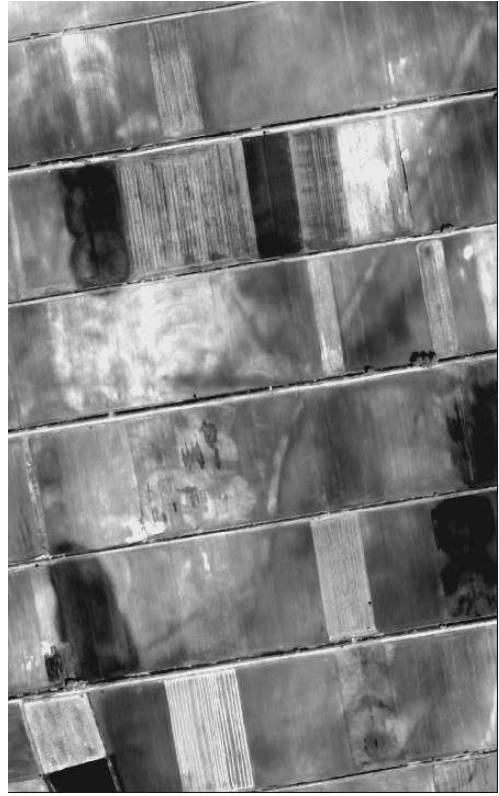


Fig. 5. The fortification wall on the PAN image

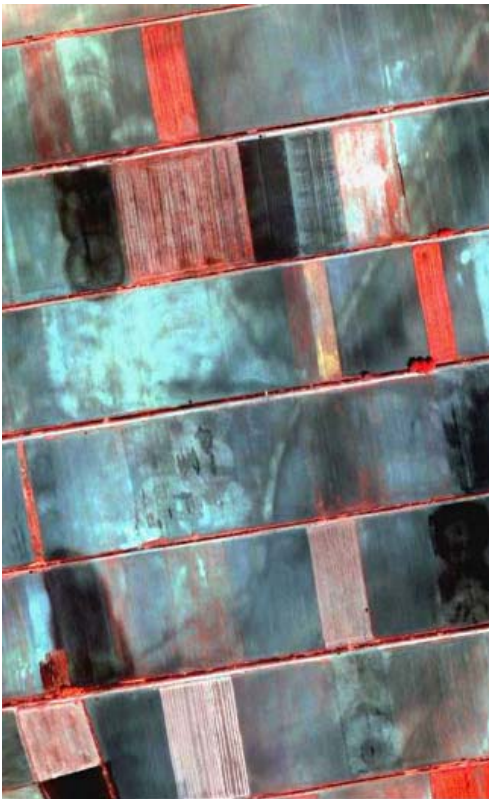


Fig. 6. The fortification wall on the fused image

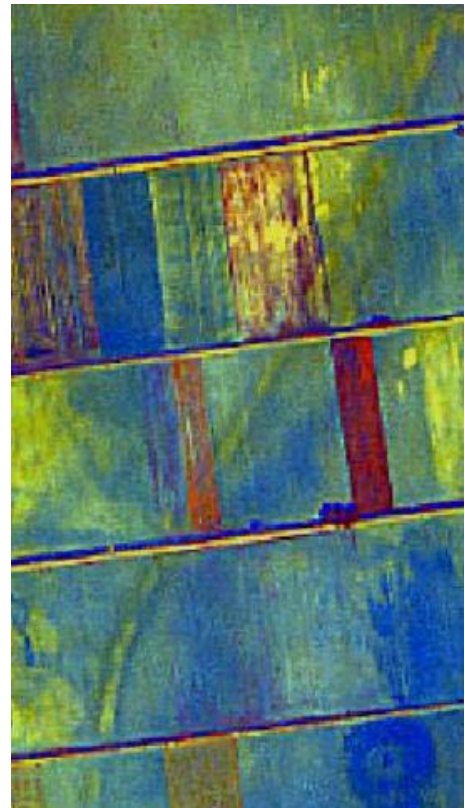


Fig.7. The fortification wall on the FCC image



Fig. 8. Via Egnatia on the orthomosaic



Fig. 9. Via Egnatia on the fused image



Fig. 10. The unknown construction on the orthomosaic



Fig. 11. The same construction on the fused image

#### 4. REFERENCES

Boehler, W., Heinz, G., 1999. Integration of high resolution satellite images into archaeological documentation. Report on the Joint ISPRS Working Group V/5, V/2 Workshop "Photogrammetric measurement, object modelling and documentation in Architecture and Industry, Thessaloniki, Greece.

Campana St., 2003. *Ikonos-2 Multispectral Satellite Imagery to the study of Archaeological Landscapes: an Integrated Multi-Sensor Approach in Combination with "Traditional" Methods.*

CAA, Heraklion, Greece 2002, Proceedings of the 30<sup>th</sup> Conference, pp. 219-225.

Comfort A., 2001. *Zeugma seen from space-archaeological survey work on the Euphrates using satellite imagery and GIS*, Report on the 4<sup>th</sup> International Conference on Archaeological Prospection, Austrian Academic of Sciences.

Georgoula, O., Kaimaris, D., Karadedos, G., Patias, P., 2003. *Photogrammetry and Archaeology: An integrated case study in the Archaeological Site of Philippi in N. Greece*. CAA, Vienna 2003, Proceedings of the 31<sup>th</sup> Conference, under publication

Tsakiri-Strati, M., Papadopoulou, M., Georgoula, O., 2002. *Fusion of XS SPOT4 and PAN SPOT2 images and assessment of the spectral quality of the products*. Scientific Journal of the Technical Chamber of Greece, Section A, Vol. 22, No. 3.

#### WEB SITES

<http://www.geoinformatie.nl/cgi/projects/bcrs/multisensor/repor t1/10.htm>

[http://www.caa2002.gr/abstracts\\_papers/83.html](http://www.caa2002.gr/abstracts_papers/83.html)

<http://www.culturalsite.com/petra/petrakaplan97.html>

<http://www.ghcc.msfc.nasa.gov/archeology/arenal.html>

<http://www.personal.rdg.ac.uk/~sgswitke/research.htm>