

# NOTES ABOUT SATELLITE IMAGES ORTHORECTIFICATION OF ARCHAEOLOGICAL SITES

C. Sena<sup>1\*</sup>, C.A. Birocco<sup>2</sup>

<sup>1</sup>Polytechnic of Turin, C.so Duca degli Abruzzi 24, Turin (Italy)- [carmelo.sena@polito.it](mailto:carmelo.sena@polito.it), <sup>2</sup>ARTGeomatica, corso Bramante 91, Turin (Italy) - [ca.birocco@jumpy.it](mailto:ca.birocco@jumpy.it)

## *Commission V, PS WG V/4*

**KEY WORDS:** Cartography-Archaeology- Ortho-rectification-High resolution-Experience

### **ABSTRACT:**

The comparison between aerial photographs and satellite images, with regard to their performance, is strongly actual: in fact, advantages and defects of both are well known. In the past, low spatial resolution of satellite images was a limit in cartographical applications: now, the recent orbital platforms are improving the data quality and, at the same time, make very large ground coverage possible.

This feature, in digital orthorectification, is most interesting. It can reduce (and, in some cases, eliminate) the need of image mosaicking, which is difficult or not possible using aerial photographs.

Some experiences in our archaeological research unit have shown the capabilities of IKONOS images in Cartography on a large scale, related to land study on extended archaeological sites. The intent is to experience the differential rectification applied to a satellite image (SPOT V, IKONOS, etc.), comparing the obtained digital product with reference maps (as far as the scale 1:2000).

### **1. INTRODUCTION**

The aim of this paper is to investigate the potentialities for archaeological research teams to utilise high resolution satellite images (Ikonos, etc).

Archaeologists have shown an interest in high resolution satellite images, from the initial first successful satellite launch in September '99.

We would like to remind that the aerial photographs, and most recently the satellite images, represent one of the available tools for archaeologist researchers who study the territory.

The main aim of this study is the reconstruction of the settlements' framework through an analysis of the land's organisation, the localisation of natural resources and the morphological characteristics.

This study would also require the cartography at a medium-large scale (1:5.000/1:2.000): these scales define the level of planimetric accuracy of maps which this information has to guarantee.

### **2. MAIN EXPERIENCES**

Our experiences in utilising the satellite images in archaeology have been mainly carried out in the '90s.

SPOT images (P and XS) have been utilised for many years, before the last SPOT V generation, and they offered a geometric maximum resolution of 10 meters on the ground.(Fig.1).

The control ground points (GCP) have been often defined through direct topographic measures (e.g. GPS) and, in the georeferencing polynomial models have been applied (since the affine transformation to the fourth grade).

As mentioned before, the study of the land for archaeological objectives focuses on some aspects which we could define 'macroscopics': the observed structures have relevant dimensions.

The permanent divisions of the cultivated extensions, the shape of the roads and hydrological framework, the landscape and morphological peculiarities could be often recognised on the images characterised by a medium geometric resolution.

The above mentioned context is, of course, quite relevant: for example we could obtain more interesting information from low resolution images in desert areas, rarely urbanised, in comparison to images with high resolution more suitable for urbanised areas where the human planning actions are more present.

Three analyses could be at least carried out on the georeferential image:

- Geometric analysis: it refers to some regular structures linked to the anthropic land organisation. On the basis of the geometric resolution it will be possible to identify only the biggest structures and therefore the main divisions (walls, cultivation, big communication paths, settlements etc ... ) or with highest resolutions it will be possible to also identify subjects with a minor dimension until to identify the perimeter of small constructions not visible but present underground. This analysis highlights the direction of anthropic signs recognised by the image as 'traces' with also the support of the bibliographic data, surveys and excavations.



Figure 1. Image SPOT V – Iraq, Assur ruins  
(Copyright SPOT Image, CNES 2002)

- Radiometric analysis: with the available tools the multi-spectral image, which is aimed at drawing the land's use map and identifying the old construction material present on the surface, is classified. Actually some agricultural works (with plough) crumble the superficial part of the buried structures, and consequently the surrounding land has some traces of construction materials which could be recognised through the different spectral firma.
- Interpretative analysis: it is a process developed by the researcher on the basis of his/her own knowledge of the historical and human settlements context of the area. The working platform is the GIS/SIT one, and a wide database with information collected from a bibliography and a survey is available. In this phase the data received from the satellite image could be positioned both on the spatial and temporal dimension.

How relevant is the geometric accuracy of this analysis ? It is surely quite relevant, but not so much as we could actually imagine. Let's analyse the reasons of this assertion.

The study of land is normally carried out at a medium-large scale. On 1:5.000 scale, for example, the attended map's accuracy in cartography is 1 meter, therefore it could be compared with the pixel of the panchromatic Ikonos band. (Fig. 2).



Figure 2. Image Ikonos: ancient human evidence (wall)  
(Copyright Space Imaging 2001)

However if we work with multi-spectral data, the pixel on the ground measures 4 metres, therefore the localisation of each pixel overcomes the defined planimetric tolerance.

In our applications we have verified the validity of the pan-sharpening between the panchromatic band and the multispectral ones, both from a metric and radiometric side. Actually it has been applied in the surveys at 1:5.000 scale, and also 1:2.000 scale with results that we consider interesting.

Even if we are aware of the possibility of some errors, it is often necessary the use of the satellite image over the limit of its own resolution: therefore the georeferentation, which is acceptable for a working scale 1:5.000, could not be acceptable for a larger working scale.

Which data (historical and not) could be considered for the comparison with information received from the study of the satellite image?

In many cases these data are characterised by a relevant topographic imprecision, due to direct measurements carried out with a large approximation and often without a cartographic framework of reference.

Information collected more recently is more reliable, even if most of the available material is characterised by a position data rather imprecise.

Therefore our question is: how has to be the level of accuracy of the GIS/SIT system which includes all this information ?

Most probably the medium planimetric error could not only referred to the working scale (with the often used criteria of error due to graphicism), but it will be compared by the accuracy which is specific for each group of information.

In this perspective the georeferentation of the satellite image maintains a relevant role, but the accepted tolerance could be

higher than other cases in the field of conventional cartography. Following these considerations we have justified a product which could present some metric characteristics out of standards: actually in difficult situations, as often it could happen in archaeological areas (e.g. Ancient territories of Mesopotamia, Medium East), the topographic operations for the survey of control points and the cartographic framework of reference have to be reduced as much as possible.

The available updated cartography with a large scale is really rare: therefore we have the need to carry out the DEM, necessary for the ortho-projection, directly from topographic measurements (logistical problems) or through the stereo-restitution. In the latter case the inconvenient is due to the need to acquire the couples of satellite images.

Considered that many settlements which are subject of our studies are luckily located in flat lands or in territories with slight levels' variations, we often have used the most simple georeferencing models without using the differential rectification / DEM. In fact we have noted that the accuracy of the localisation of information on the images, related to the dimension of pixel, is compatible with the precision of these studies. (Fig. 3)

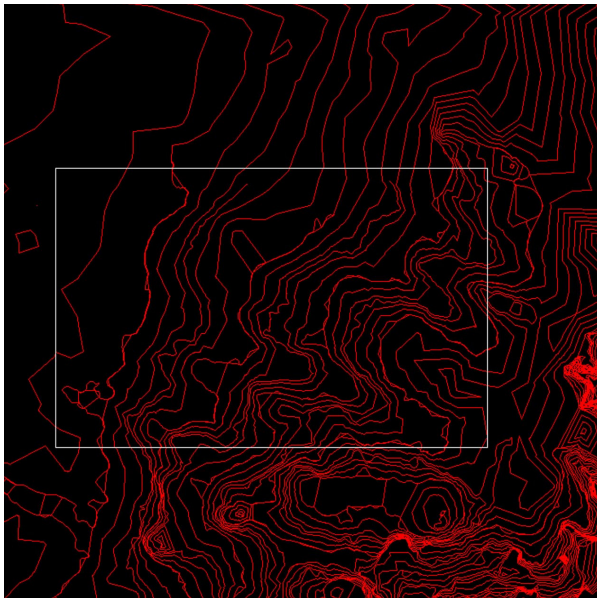


Figure 3. Cartagine's archaeological site (Tunisia): altimetric survey

Information carried out from the satellite image's study is verified, in cases considered relevant, by the archaeologists directly on site. This check is made through GPS hand type ("navigators") in which the option of differential correction is often absent.

The precision of these instruments is well known and in the best cases the error of location on the ground overcomes the error of information location on the image simply geo-referred and not ortho-projected.

It is understood that this consideration could be valid if the parameters of the applied transformation have been carried out on a solid basis, without errors and using a relevant number of control points.

In a recent application we have tried what we have described before. We used a GPS receiver (Garmin) for localising the archaeological data to be compared with information of a panchromatic/multi-spectral Ikonos image georeferred through

15 control points (established through GPS observations with a Leica SR530 system-double frequency).

The differences of levels noted in the working area doesn't overcome 30 meters and, considered the altitude of flight of the Ikonos satellite, a similar transformation applied to the panchromatic image has shown an average error of 0,68 meter (on the control points): the error is inferior to the pixel dimension.

We have verified the error of localisation of information on the image by comparing the co-ordinates of some archaeological subjects with the topographic data acquired on site through the SR530 receiver in stop&go modality: the differences have normally been of 1-2 pixel, therefore maximum 1,60 meters. (table 1)

	Number of points	$\epsilon_{\text{mean}}$
Control points (GCP)	12	0.68 m $\pm$ 0.18 m
Test points	9	0.82 m $\pm$ 0.20 m

Table 1. Control points, s.e.m. planimetric (survey Cartagine, November 2003)

The data of the archaeological survey, with the GPS hand receiver, are obviously less precise and accurate: the localisation error has been generally bigger than 6-7 pixel.

In the information system some maps have been integrated by digital treatment.. These maps, carried out with a 1:10.000 scale in some surveys in the '80s, are characterised by generic cartographic frameworks. The comparison with current topographic data has highlighted differences of 2-3 meters, in line with the attended planimetric error.

Therefore, the basic data of the georeferred satellite data present acceptable metric characteristics if compared with the remaining available data.

### 3. CONCLUSIONS

In the survey's applications the metric contents have a relevant role, and this is well known to professionals, as we are, who have been working since many years on the development of the use of topographic and photogrammetric methods.

However, we have also to take into consideration that the use of resources and tools have to be dimensioned according to the results we would like to achieve.

In the specific area of archaeological research, aimed at studying the territory, we have analysed, for the georeferentation of the satellite image, the advantages of the approach that we have defined - maybe improperly - 'simplified', if compared to the redefined techniques which foresee more complex mathematical models.

This proposal has been made because it is not possible to think that we could extend the use of satellite images to neighbouring areas, as the one we have considered, which require for a proper use some complex procedures.

If we wish that the satellite images, in particular the ones with a high definition, are more useful in the field of archaeological research we have to be aware that their use, availability need to be improved and simplified from their source.

Actually we can not think that for using these images we have to utilise redefined operations of them, operations which actually require the use of complex programmes allowing different corrections.

Furthermore the use of these programmes is only for qualified personnel and equipped centres. This process could be done only when it is required an appreciable use of the images' data

and for redefined aims.

However, if the image has to be used for the above mentioned reasons or, for example, in substitution of unavailable or unsuitable cartography (e.g. inaccessible areas), or as a preliminary document for the context's knowledge, it has to support the problems' resolution rather than be a source of further problems.

The starting point, as mentioned before, is the working scale.

The archaeological researcher, according to the growing scale, leaves the study of the territory and focuses on its specific data until the excavation: then the established limit of accuracy changes, and it refers to the standards of the topographic survey. With reference to the general studies, we could avoid big resources' investments for the search of results that, often, are too much expensive if compared to the real advantages given to the research itself.

## REFERENCES

Sena, C. – Birocco, C. A., 2003. Confronti di tipo topografico-fotogrammetrico sui metodi di georeferenziazione di immagini telerilevate ad alta risoluzione metrica. Report "Progetto di Ricerca COFIN 2001"

Holland, D. – Guilford, B. – Murray, K., 2002. Oeepe-Project on Topographic Mapping from High Resolution Space Sensors, Official publication no. 44