SATELLITE-BASED IDENTIFICATION OF ARCHAEOLOGICAL FEATURES

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ABSTRACT

This paper deals with the use of QuickBird images for the identification of features linked to ancient transformations the landscape induced by human activities. The investigation was performed on Metaponto, one of the most important archaeological sites in the South of Italy. The analysis was focused on the identification of ancient land divisions related to the Greek colonization age. The obtained results showed that the use of QuickBird images enables the detection of the archaeological features linked to buried remains with a high level of detail.

INTRODUCTION

The importance of applying space technology to cultural heritage and archaeological research has been paid great attention worldwide, mainly because, nowadays, high resolution satellite data such as, IKONOS (1999) and QuickBird (2001), are able to match with aerial photogrammetric surveying images. Actually, QuickBird is the commercial satellite that provides the highest spatial resolution images from both panchromatic and multispectral sensors with resolutions of 61-72cm and 2.44-2.88m (depending upon the off-nadir viewing angle) respectively. Satellite QuickBird imagery could open new perspective in the field of archaeological investigations (i,ii,iii).

One of the main advantages of satellite QuickBird data compared to aerial photos, is the possibility of exploiting the multispectral properties of the data. The spectral capability coupled with high spatial resolution can make the VHR satellite images a valuable data source for archaeological investigation ranging from synoptic view (i.e. from landscape archaeology) to small details (i.e. single subsurface building).

However, the high spatial resolution poses a serious challenge in the feature extraction. To obtain maximum benefit from the recently available satellite data sources extensive researches are needed to improve data analysis and tools for the extraction of spatial and spectral information. In particular, feature extraction and analysis steps are of particular importance in the field of archaeological remote sensing since buried archaeological remains as well as traces of ancient transformation of landscape tend to induce small spatial anomalies characterized by small spectral signals. These small spatial and spectral anomalies can be easily obscured by stronger signals emitted by earth materials (vegetation, soil, rocks, asphalts, concrete).

This paper deals with the use of QuickBird images for the identification of features linked to ancient human changes of the landscape. In particular, the object of the investigation is the reconnaissance of ancient land divisions. The study case is located in the Metaponto territory in the South of Italy. The analysis was focused on the land divisions related to both ancient Greek colonization and the Roman age.

METHODS

The Quickbird -based analysis adopted for the identification of superficial anomalies is shown in figure 1.
Both panchromatic and multispectral data were first investigated individually and then combined by using a data fusion algorithm. Data fusion technique integrates the geometric detail of a high-resolution panchromatic image and the spectral information of a low-resolution image to produce a high-resolution multispectral image.

As in the previous works of the same author group, the methodological approach used for analyzing the satellite Quickbird data is mainly based on data fusion and edge detection algorithms that are applied in order to better enhance and detect the superficial anomalies. Additionally, the satellite-based analysis is here enriched by edge thresholding and thinning algorithms that allow a refinement identification of the target.

1) Data fusion

Image fusion refers to the process of combining multiple images of a scene to obtain a single composite image. The different images to be fused can come from different sensors of the same basic type or they may come from different types of sensors. The composite image should contain a more useful description of the scene than provided by any of the individual source images. In the current cases under investigation, the QuickBird panchromatic and multispectral images were fused by using a data fusion algorithm that was specifically developed for VHR satellite images (iv). This algorithm exploits a method based on least squares for founding the best approximation between the fused image bands and the original data. This obtains the maximum increase in detail coupled with a minimum distortion. This algorithm has been adopted by Digital Globe and it is also available in a PCI-Geomatica routine.

2) Edge detection

In order to emphasize the marks arising from the presence of buried structures, an edge detection algorithm was applied to data fusion products. The edge detection was performed (v) by applying a multiscale approach based on the scale-space theory that uses Gaussian smoothing kernels. The selection of scale was undertaken keeping in mind that, in our case it was necessary to focus on structures having small sizes and signal amplitudes as expected in the case of surface anomalies due to buried walls, buildings and roads.

3) Edge thresholding

In this study, histogram-based thresholding was used to produce a binary image, in that all edge elements have value one. The threshold is not an absolute one, but an upper percentage from the cumulative distribution function of the edge detection filtered image.

4) Edge thinning

Thinning algorithms are used on binary images to generate skeletons that preserve the same connectivity structures as the objects in the original images. Thinning is a pre-processing operation of pattern recognition since a thinned object is easier to trace and hence is easier to recognize. Generally, a thinning algorithm is used to erode an object, layer by layer until only a unit-width skeleton is left.

In the present study case, the fast parallel thinning algorithm by (vi) was used. Such an algorithm was selected because it preserves the merits of the original, such as the edge noise immunity and good effect in thinning crossed lines. It also overcomes weaknesses such as the serious shrinking and line connectivity problems. A 3x 3 pixel window size, shown in table is used, as previously, in the edge detection step.

5) Line extraction

Using visual inspection, we only considered regular pattern anomalies because the presence of geometric features, being quite rare in nature, generally provides useful information for the identification of signs indicating ancient human activities.
Finally, the last step of the adopted procedure is the reconnaissance and interpretation of marks. This is a very important task that is performed also using additional information, such as the traditional cartography and/or field survey etc. This facilitates the elimination or at least reduction of the potential coarse errors linked to the presence of road networks, bridges, pipeline etc. that can also be detected by the edge identification procedure.

Figure 1 flow chart of the procedure adopted for the identification of archaeological marks.

RESULTS & DISCUSSION
The study area is the archaeological site of Metaponto. It is located between the Basento and Bradano rivers, near the Ionian sea, in the Southeast of the Basilicata Region (see figure 2). It is one of the most important archaeological areas in the South of Italy.

The several archaeological campaigns (vii, viii, ix, x, xi) stated that human presence since mid 8th century B.C. was when Metaponto was founded by Greeks coming from the Acaia region. Between the Greek colonization (700 BC-200 BC) and the Roman age (200 BC – 400 AD) the territory was characterized by an intensive use of the soil as revealed by the several rural sites that can be observed by surface surveys and excavations, and also by the presence of an extensive system of parallel land divisions. In particular, these lines are thought to have been a network of country lanes or drainage canals. The satellite-based detection of these land divisions is the main objective of our analysis.

The detected land divisions are close to the Archaeological Park of Metaponto that includes (see A in figure 3a-b) four temples built between the 6th and 4th century BC, the agora (namely market place) and a theatre dating back to the second half of the 4th century (see, respectively 1, 2 and 3 in figure 3a). The areas under investigation were mainly covered by weeds, such as Eruca sativa, Cichorium intybus, Agropyron repens.

The satellite analysis was carried out by using QuickBird images (Catalog ID 1010010003314001) acquired on August 22nd 2004 with an off nadir view angle of 2 degrees (see table 1). The reconnaissance of land divisions was performed by analyzing the results obtained from the edge detection algorithm applied to both single channels and data fusion products. The best results were obtained from panchromatic, NIR channel images, and NDVI (obtained from the following formula: NIR-RED/NIR+RED) maps. However, the Blue, Green and Red channels did not show any regular features of archaeological interest. The results obtained from the edge detection algorithm applied to data fusion products substantially...
The detected anomalies are the typical marks induced by the presence of vegetation that, in this case, is mainly composed by weeds. Such anomalies, indicated respectively as B and C in figure 3a-b, are evident in the east and southeast parts of the Archaeological Park. In particular, for the B area, the weed-marks related to land divisions are not visible by using the panchromatic image. They are only delineated (see, figure 3b,d) by using NIR channel images (both single channel and NIR data fusion product). The use of NDVI map (figure 4) makes such marks more evident. There are seven rectilinear features: six of these features have an orientation of 55°-60° West of North (that are distanced from each other by about 35 to 54 m) and one is orthogonal to them.

For the C area, the weed-marks are visible using only panchromatic and NIR images (figure 3a-d). Here, there are 6 rectilinear features with an orientation of 50°-55° West of North that are distant each other approximately 46 to 48 m.

The fact that the same kind of archaeological mark exhibits different spectral features, can be linked to the different surface characteristics observed for the two investigated areas. Both of them were covered by weeds (such as Eruca sativa, Cichorium intybus, Agropyron repens), that were dry at the end of summer when the satellite images were acquired (August, 22nd 2004). However, area B (see Figure 3) had a more packed weed cover compared to that present over area C. Therefore, for area B the reflectance variations induced by the presence of buried archaeological deposits are stronger than those observed for area C. These variations are remarkably emphasized by the NIR band and NDVI map (see figure 3b,d and 4); thus, showing the high potential of multispectral Quickbird data. This makes them ideal for investigations on a regional scale as well as for research performed in areas where aerial photography is restricted because of military or political reasons.
Figure 3. QuickBird images. (a) Panchromatic image: letter A denotes the Archaeological Park, B and C indicate the areas in which crop marks were detected; (b) NIR data fusion product; (c) panchromatic image with survey of weed-marks related to land divisions in area C; (d) NIR data fusion product with survey of weed-marks related to land divisions in area B and C.

Figure 4. QuickBird NDVI map (a) and the archaeological features detected (b).

REFERENCE


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