Journal of Archaeological Science 40 (2013) 3604–3613

Contents lists available at SciVerse ScienceDirect

Journal of Archaeological Science

journal homepage: http://www.elsevier.com/locate/jas

Combined application of pansharpening and enhancement methods to improve archaeological cropmark visibility and identification in QuickBird imagery: two case studies from Apulia, Southern Italy

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ARTICLE INFO

Article history:
Received 25 September 2012
Received in revised form
28 March 2013
Accepted 18 April 2013

Keywords:
VHR satellite imagery
QuickBird
Pansharpening
Spatial Enhancement
Archaeological applications
Magnetic survey
Southern Italy

ABSTRACT

Launch of Very High Resolution (VHR) satellite sensors meant a significant evolution for Remote Sensing archaeological applications since data with high spatial resolution may be used to identify signals related to buried archaeological remains (e.g. cropmarks, soilmarks, dampmarks) in very extended territories. The aim of this work is to develop a suitable image processing workflow to improve the cropmark visibility in the VHR satellite images. The workflow implemented consists of two steps: first the panchromatic and multispectral images have been pansharpened in order to merge the two images, then some Enhancement methods have been applied on the pansharpened image. As a result of the several tested pansharpening techniques, the Principal Component Resolution Merge yields images of very good quality useful not only for visualization but also as input for further processing. Among the different enhancement methods taken into consideration, the Spatial Enhancement, carried out by applying the Wallis Adaptive filter further improve the visibility and recognition of the archaeological signals.

All methods were evaluated on QuickBird imagery acquired in the Tavoliere plain (Apulia, Southern Italy) on May 27th, 2006. In particular, cropmarks generated by two buried ancient settlements were considered. For one of these test sites, results of a high resolution ground magnetic survey, carried out for other aims, were also employed to further assess the validity of information extracted by the proposed workflow.

1. Introduction

Satellite images have been used for archaeological applications since the '70s when they started to be available for civil purposes. In particular, terrestrial and ocean monitoring from space started with the launch of Landsat satellites (1972–1999) provided with the sensor Enhanced Thematic Mapper Plus (ETM+). Since ETM+ acquired data with spatial resolution of 30 m and 15 m (multispectral images, MS and panchromatic images, PAN respectively), only large archaeological features detections were possible. Over the years other satellites with rising spectral and spatial resolutions have been launched: for instance, since the '80s, French SPOT series has improved pixel dimensions from 20 m and 10 m (SPOT 1) to 10 m and 5/2.5 m (SPOT 5), respectively for MS and PAN images. However, the usefulness of satellite data for archaeological studies remarkably increased when VHR satellites were launched starting from the end of '90s. In fact their advanced sensors are able to locate and recognize also small landscape features (e.g. archaeological features), thanks to their very high PAN-spatial resolution (Table 1).

As a consequence, VHR satellites can produce very useful results in detecting signals such as cropmarks or soilmarks, related to buried archaeological remains. Up to now, there are no standard and univocal procedures to process satellite data for the detection of these signals (Lasaponara and Masini, 2011). This is due mainly to two reasons: i) the use of the Remote Sensing in this field is a developing application; ii) signals generated in vegetation and soil depend on the typical environmental characteristics of the considered site.

Pansharpening and Enhancement can be considered as two suitable operations to improve the visibility of cropmarks on satellite data both on a small and large scale. Several studies present

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http://dx.doi.org/10.1016/j.jas.2013.04.013

Table 1
Very High Resolution satellites; launch year and PAN-MS spatial resolution.

VHR satellite	Launch year	PAN-Spatial resolution (at nadir)	MS-Spatial resolution (at nadir)
IKONOS	1999	0.82 m	4.00 m
QuickBird	2001	0.67 m	2.69 m
EROS B	2006	0.70 m	–
Cartosat – 2	2007	0.80 m	–
WorldView – 1	2007	0.50 m	–
GeoEye – 1	2008	0.41 m	1.65 m
WorldView – 2	2009	0.46 m	1.84 m

results of applying these methods for a better identification of the buried structures (e.g. Beck et al., 2007; De Laet et al., 2007; Lasaponara and Masini, 2007).

Starting from this scientific background different algorithms of Pansharpening and of spatial/spectral Enhancement were applied to VHR QuickBird data to understand those useful in archaeological applications among algorithms mentioned in literature.

Moreover, it is known that, the pansharpening procedure introduce an alteration in spectral values. For this reason, some authors indicate pansharpened data as useful only for visual inspection (e.g. Traviglia and Cottica, 2011) whereas others consider them as a possible input for further processing (e.g. Lasaponara et al., 2011). The amount of this spectral degradation might change depending on the type of algorithm applied. Therefore, several pansharpening methods have been examined and results evaluated in order to obtain convenient indications about the choice of the algorithm capable to produce an appropriate dataset as input to enhancement processing.

Two recognized buried archaeological sites located in the Tavoliere lowland (Apulia, Southern Italy) were chosen for this study which fits into a greater Research Project of National Interest (PRIN). Carried out during the last years, the project aims at locating and identifying buried archaeological features and reconstructing ancient landscapes via both geophysical and remote sensing methods. High resolution geophysical magnetic data, acquired in one of the two test sites, were also employed as reference image of ground truth information.

2. Study area

Characterized by a long term human presence since the Neolithic, Tavoliere plain is one of the most important archaeological areas in Southern Italy. Over the years, archaeologists have carried out several studies in this part of Apulia (e.g. Jones, 1987; Volpe, 2002; Radcliffe, 2006; Gliozzo et al., 2013). Today this territory is marked by an intensive cultivation of cereals in which both negative and positive cropmarks are often considerably and clearly visible (e.g. Ciminale et al., 2007; Ciminale et al. 2009).

In this context an area between the towns of Ascoli Satriano, Orta Nova and Cerignola, where, 44 sites were already identified by aerial photo interpretation, was taken into consideration (Fig. 1).

The particular archaeological interest, supported by historical studies and methodical fieldwalking, as well as the good quality of the remotely sensed data suggested focusing the attention on two sites: Corleto (COR) and Tre Casette (TRC).

Corleto is a vast site (about 16 ha) characterized by several linear signals and by two relevant curve shaped cropmarks. Both kind of signals probably go back mainly to the Middle Ages. The TRC site is located at approximately 5 km in NE direction. This extends over quite a large area (about 10 ha). In this case, the archaeological signals visible on the satellite image correspond to buried remains which date back to different ages. The roughly circular cropmarks are generated by the external ditches of a large Neolithic settlement, while the other linear signals could be related to the remains of a Roman farmstead.

Methods and procedures examined in this study have always been applied to both the test sites; for a more fluent presentation of the research, figures sometimes refer to the COR site, sometimes to the TRC site.

3. Data and methods

Satellite QuickBird (QB) images (MS, PAN) were used for this study. Pansharpening was the first operation carried out in order to combine both very high spatial resolution of PAN image and high spectral resolution of MS. Several methods were employed and the relative outputs compared.

After this step, two well known methods of spectral enhancement were considered (Principal component analysis and Tasseled cap) and the Wallis Adaptive filter was applied to carry out Spatial Enhancement: this filter was tested to increase detail visibility and to improve luminance regulation.

The software used to accomplish all the computation procedures is ERDAS Imagine 2011.

As regards the TRC site, a supplementary dataset was taken into consideration because of the opportunity to carry out a high-resolution ground based magnetic survey.

The comparison between satellite and magnetic processed data was an assessment procedure of the enhancement effect.

3.1. Data

3.1.1. Satellite data

The QB dataset (Fig. 1) was acquired on 27th of May 2006, in a period of the year generally characterized by the best cropmark visibility. It covers an area of about 37 km^2 and is composed of two types of images: a multispectral and a panchromatic one. The MS image has 4 bands with a spectral width of 430–545 nm for Blue, 466–620 nm for Green, 590–710 nm for Red, 715–918 nm for Near Infra Red. The PAN image has 1band with a spectral width of 405–1053 nm. The spatial resolution is 2.69 m and 0.67 m at nadir for MS and PAN respectively.

3.1.2. Magnetic data

Magnetometry is one of the most largely employed geophysical technique for archaeological research in open country. Thanks to the natural and/or thermo-remanent magnetization as well as to the magnetic susceptibility variation of both structures and soil materials, magnetometry allows to detect buried structures via the analysis of the anomalies in the Earth magnetic field. Anthropogenic features such as kilns, walls, roads, pits, ditches, tiles, etc., have often different magnetic properties from the surrounding soil, therefore this method can be used to detect them (e.g. Becker, 1995; Johnson, 2006; Aspinall et al., 2008; Caggiani et al., 2012). At present, modern instruments and appropriate procedures for data acquisition, processing and visualization enable to detect also very subtle anomalies (e.g. down to hundredths of nT in presence of buried post-holes).

Measurements in the TRC site were carried out with a high sensitivity (0.05 nT) Geometrics G858 optical pumping magnetometer in duo-sensor configuration (e.g. Becker, 1999). Several 40×40 m^2 square areas were surveyed covering an overall surface of 9.12 ha. Data were acquired in bi-directional mode along profiles 0.5 m apart with a sampling rate of 10 data/s. In total, more than 1,460,000 measurement points were acquired with a mean spatial resolution of 0.5 m $\times$ 0.125 m.