AIRBORNE MULTISPECTRAL REMOTE SENSING APPLICATION IN ARCHAEOLOGICAL AREAS

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ABSTRACT

This project has been applied in the archaeological site of Recopolis and in its surroundings. This area is located in Guadalajara, Spain. The Recópolis visigotic site has been largely investigated with several field surveys and laboratory analysis. As a support to these campaigns, interest area has been oveflown at July and at November 2002, including the deposit and a nearby arab castell, operating simultaneously with two airborne remote sensing instruments, a multispectral scanner Daedalus 1268 and a digital camera AMDC integrated whit a positioning and orientation system (GPS/IMU).

The aim of this collaboration between INTA and UPM is to provide high spectral and spatial resolution images to support the archaeological study. The acquired images have been used to make a preliminary site cartography, to extract current land cover and to test detecting and/or confirming models of possible buried archaeological structures. We describe in this paper the flight configurations, the data processing and the first results and conclusions.
Key Words: Multispectral scanner, digital camera, GPS/INS, archaeological site mapping.

INTRODUCTION

Since their early stages, remote sensing techniques have been applied to archaeological studies. A remote sensing instrument measures (usually covering a 2-D area and so rendering an image) the electromagnetic radiation coming from the study target; this radiation being either reflected sunlight, thermally emitted radiance or (in so-called active systems) energy sent by the instrument itself (microwaves in a RADAR or a laser beam in a LIDAR). Classical remote sensing is represented by aerial photography, while nowadays most applications benefit from digital data. A remote sensing system is labelled multispectral if the registered radiation is splitted in different, discrete wavelengths intervals ("bands"), and so different measurements on the same target are available.

The early works from the 60's (Donoghue 1999) showed that multispectral airborne remote sensing data were well suited to archaeological sites studies. The high spatial resolution, well suited to the scale required, coupled with the discriminant power of multi-wavelength information, make it potentially valuable for detection of buried or semi-buried features. However, technology and cost limited for many years the use of remote sensing images other than aerial photography, and few works have been published using aerial digital multispectral data as a support to archaeology.

In 2002, we have applied multispectral digital images to the exploration of the Recópolis archaeological site. Recópolis, dated 350-450 d.C., is the most important visigotic village found in Iberia. The *Cartografía en Patrimonio y Arqueología* (CARPA) U.P.M. group has been working since 90's in this site. This paper presents the characteristics of the flight campaign and the data processing applied, in order to show how to use this type of data to retrieve valuable archaeological information.

INTA AIRBORNE REMOTE SENSING SYSTEM

The *Laboratorio de Teledeteccion* at INTA owns a remote sensing aircraft and a number of remote sensing instruments, which are available to scientific or operational users. A usual set-up is to operate simultaneously two complementary cameras, a multispectral line scanner (DS-1268 "ATM") with wide spectral coverage and a multispectral digital camera (AMDC) with high geometrical quality but limited multispectrality (Fig.[1]).

DS-1268 is an opto-mechanical radiometer with image formation through the combination of a spinning mirror and the aircraft motion (a *whiskbroom scanner* in the remote sensing jergoon). It split the incoming radiation in 11 spectral bands, from visible through near infrared up to thermal infrared: in a typical spectral configuration the radiometer includes the same bands as the well-known earth observation satellite LANDSAT-TM. The total Field of View (FOV) is 85º and the Instantaneous FOV is 2.5 miliradians, corresponding to a spatial resolution in the range 1 to 7 meters and a swath width from 600 m to 5,000 m depending on the flight height.

The AMDC is a frame camera, i.e. an optical system imaging instantaneously a bidimensional area. The focal plane holds for that purpose a CCD array with 2.024 x 2.041 detectors. By the use of a filter wheel the CCD records sequentially 4 spectral images + a panchromatic one: there is a small shift between each exposure, but the imaged area is roughly the same for all 5 images. The total Field of View (FOV) is 36 x 36º and the Instantaneous FOV is 0.32 miliradians, corresponding to a spatial resolution in the range 0.5 to 1 meter and a image size from 1,000 x 1,000 m to 2,000 x 2,000 m depending on the flight height.

Both cameras are supported by a Inertial Navigation System Applanix POS/AV 410, specifically designed and installed to provide position and attitude information for the direct georeferencing of airborne images with the required resolution and accuracy (Rejas et al. 2003).

STUDY SITE AND ACQUISITION CAMPAIGNS CONFIGURATION

The study site of Recopolis is located in central Spain in a small elevation facing the mid-course of River Tajo. Targets of interest are not only the visigotic city but also an Arab castle located in the same hill. The estimated area covered by the archaelogic targets is around 25 Ha, from which only 1 Ha. are currently excavated while the rest extends mostly under crop fields (mainly cereals).

Flight campaigns were performed in July and November 2002, with both DS-1268 and AMDC installed in the INTA aircraft. The flight height was 2400 m, in order to obtain a pixel size of 3.5 m for DS-1268 and 0.5 m for AMDC. Due to the resulting image width, the study area was covered by 5 different flight lines, with enough overlapping to ensure no gaps in the area coverage (Fig.[2]).

Supporting the image acquisition, INTA performed on site ground measurements with a field spectroradiometer GER-1500. The output of such measurements are spectral reflectances for characterization of the surface spectral features and for eventual correction of noise or bias in the images due to atmospheric effect.

Detailed topographic information (1:500 map) is available from the UPM team.

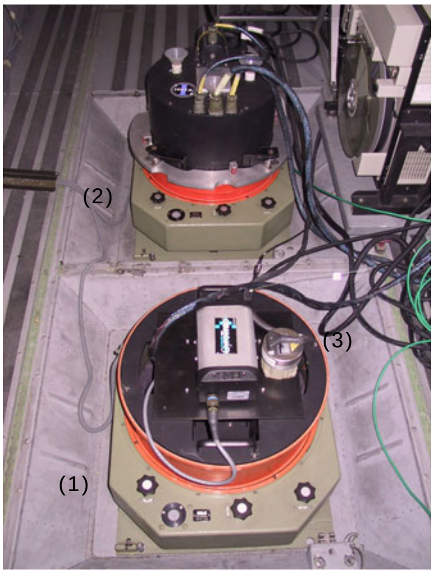


Figure [1]. Airborne remote sensing system of INTA, AMDC (1) , Daedalus 1268 (2) and IMU (3).

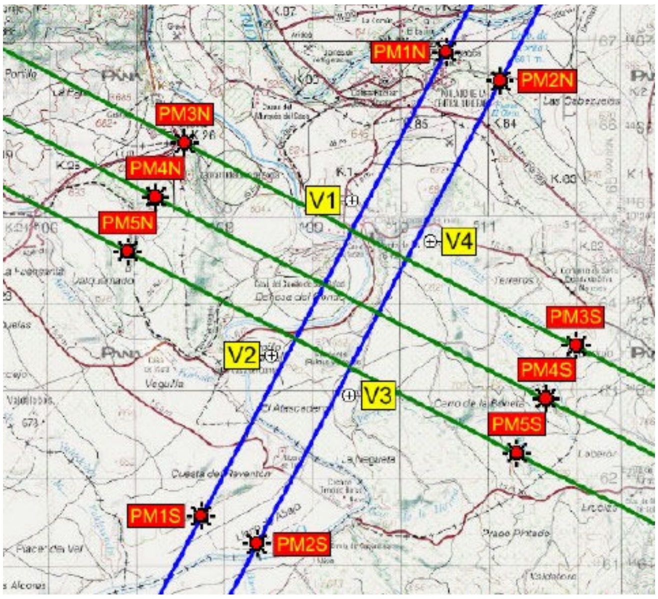


Figure [2]. Study site and fligth lines.

DATA PROCESING

Data processing techniques are used to retrieve information from remote sensing data. They usually include geometric correction, radiometric correction, and a number of analysis (image enhancement, image arithmetics and statistical analysis). The choice of techniques depends on image quality and in the required output. We present here the techniques we have used: all of them are available within the image processing package *Geomatica* from PCI Geomatics (also available from other packages as ERDAS-Imagine or ENVI).

In the AMDC images, two radiometric distortions were observed. One is a darkening of the image to the edges. The second is a local defocusing in some bands. Both effects were caused by problems in the instrument during the campaign, and require a specific solution. For the darkening, and under the assumption that all camera detectors shall give in average the same value (200,000 image lines), a normalization function was built estimating the mean value of each image column through all the study area (Fig.[3]). The defocusing has been minimised using a standard high pass filter. For the geometric correction, we applied the POS/AV data to the radiometrically corrected AMDC images using the commercial software Orthoengine (a module of the *Geomatica* package).

The same tool was used to build a single image per band mosaicking the individual frames. No atmospheric correction was applied. As a final step, we applied a textural analysis using well-known filters designed for enhancing image structures (for example a Sobel filter).

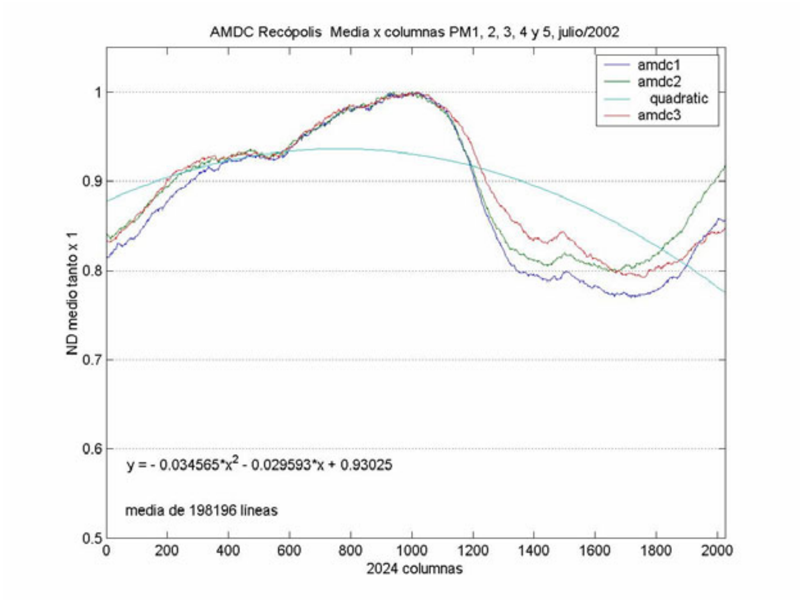
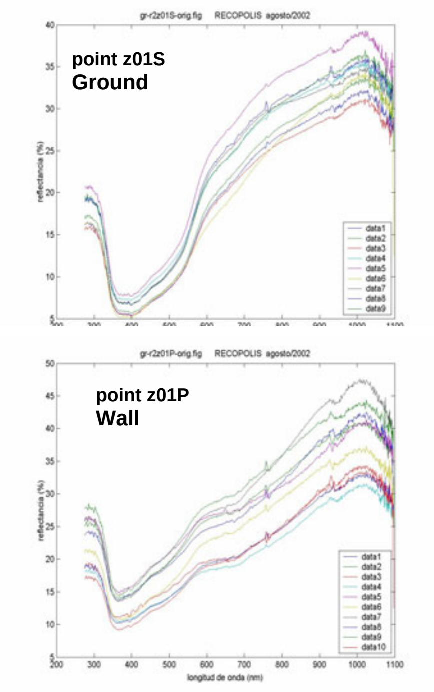


Figure [3]. AMDC image radiometric adjust and two spectral signatures examples.

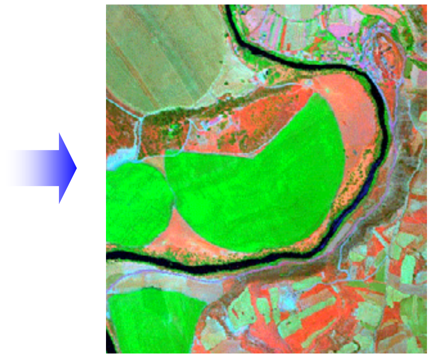


No radiometric correction was applied to the ATM images. For geometric correction we selected ground control points from the orthorectified AMDC images. A thin plate spline (i.e. a set of interpolating bi-dimensional polynomials) was applied to the ground control points to map the original image onto a orthophotomap.

Finally, we combined both instruments by using an image fusion algorithm implemented in *Geomatica*: the 11 bands from DS-1268, at 3.5 m resolution, were merged with the 0.5 m panchromatic band from AMDC resulting in 11 different 0.5 m images (Fig.[4]). The image fusion algorithms currently in use are intelligent tools that preserve multiespectral variability while introducing spatial variability from the high resolution data (Yun Zhang 2002); however, it has to be noted that the procedure relies in data statistics and so no "new" information is created, but simply the existing one is revealed.

Figure [4]. AMDC res. 0.5 m

DS-1268 12 channels, res. 3.7 m



DS-1268, 12 channels, res. 0.5 m Jul./2002

The combined images have been used for a statistical classification using the standard clustering algorithm ISODATA.

The GER 1500 measurements were processed using MATLAB in order to produce reflectances in bands similar to the airborne instruments bands, and then are archived to be used in case the future work requires it.

FIRST RESULTS

The remote sensing images are currently in use as a graphic document displaying the status of the works and the actual land use through the site (Fig.[5]). Either direct visual inspection or integration on a dedicated Geographical Information System is possible.

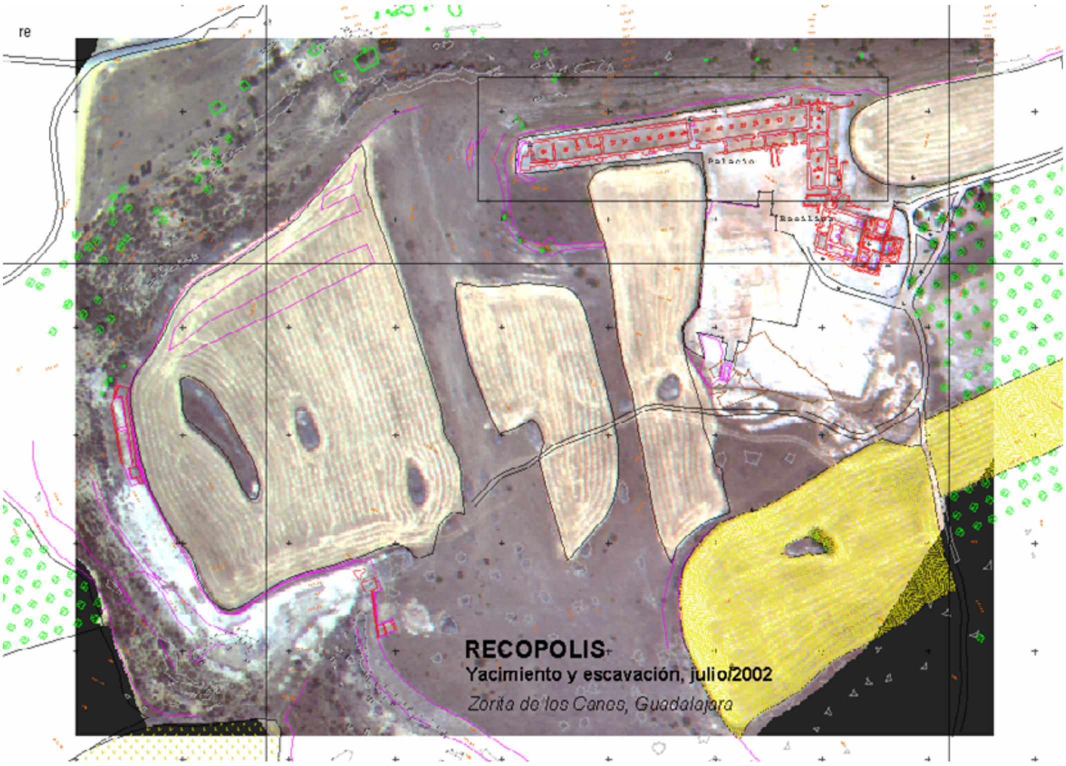


Figure [5]. 1:500 map and AMDC orthoimage, RGB 321.

The AMDC images processed with the Sobel filter have revealed some patterns which are likely to represent buried structures (Fig.[6]); this is the type of help that one expects from the remote sensing tools.

After different trials, the output of ISODATA classification using the bands ATM11 and ATM12 (both combined with the AMDC) was selected as the most useful. In this classified image patterns similar to the ones observed in the filtered AMDC images were apparent, patterns that are consistent with signals of man-made structures (Fig.[7]).

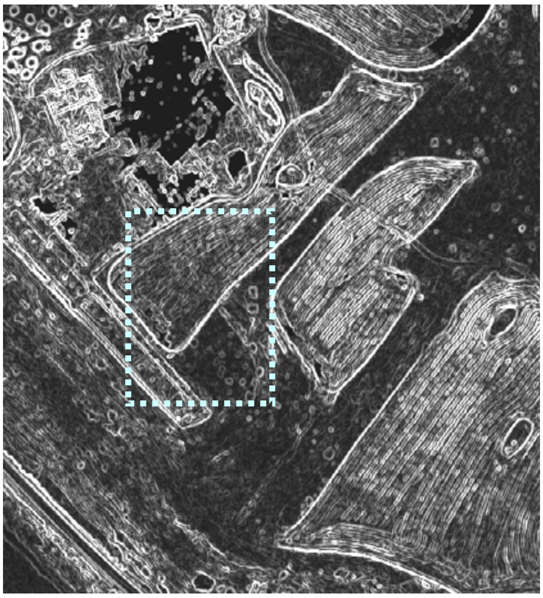


Figure [6]. Sobel filter with AMDC red channel.

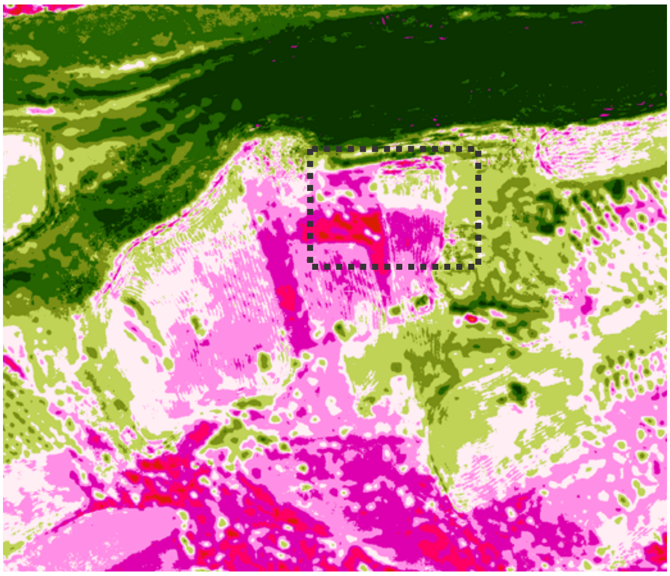


Figure [7]. ISODATA classification using ATM11 and ATM12 with possible buried archaeological structures.

OPEN WORK

INTA and UPM groups are working to complete the analysis of the existing images using techniques as image texture, airborne thermography, segmentation, classification and pattern recognition.

Moreover, it is planned to acquire new hyperspectral data with an instrument AHS (Airborne Hiperspectral Scanner) which can offer very interesting information.

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