FUSION OF CULTURES

Abstracts of the XXXVIII Annual Conference on Computer Applications and Quantitative Methods in Archaeology,

CAA 2010

F. Javier Melero · Pedro Cano · Jorge Revelles

Editors

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Fco. Javier Melero, Pedro Cano & Jorge Revelles (Editors)

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Remote Sensing Image Processing for Archaeology: Effectiveness, Issues, Prospects. A State of the Art.

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1. Introduction

Since the introduction of multispectral and hyperspectral remotely sensed data in archaeological investigation, the significance and the implications of the image processing activity have been clear to archaeologists employing remote sensing in their research activity.

Image processing, by improving the quality or the contrast of the image or transforming it in a new set of images where relevant information can be more easily detected, often produces results far more useful than the ones that visual analysis of the original, raw data guarantee, providing an enhanced visualization of the studied landscapes and promoting the recognition of not yet identified ephemeral archaeological marks.

In the past 20 years a consistent part of the projects involving the use of multispectral and hyperspectral data have included image processing as part of their routines activities in preparatory steps before under-taking visual analysis and interpretation.

The extensive use of a vast range of techniques, however, does not translate yet into a coherent methodological strategy for the application of this important set of practices to particular archaeological situations and environments and their application is often left more to attempts than being planned and targeted. Consequently, despite the high potential offered by the enhancement and transformation of digital images, the adopted approach subsides often to a series of well-established, routine techniques that often do not consider fully the characteristics of a territory or the peculiarities of each portion of it.

The present paper will cover the use of both the most commonly adopted image processing methods and the ones that, although not frequent, have produced relevant outcomes, and it will try to analyse the strength of the different techniques, the bias and issues encountered in their implementation, the ambits and the physical environments in which they can be better used and exploited.

2. Defining a work strategy

It is unquestionable -and long accepted- that it is impossible to define a priori what type of image processing will provide the best results for archaeological research. It is also well recognized and quite obvious that the results that have been reached in a specific landscape context are peculiar to that ambit only and to such a determinate spatio-temporal situation and that different outcomes could be achieved applying similar processes to other areas (even similar ones).

Nevertheless this does not prevent researchers from planning accurately a strategy for implementing the best and most suitable image processing techniques that apply to specific factors like, for example but not limited to, type of environment (crop land, bush land, bare soil, sandy soil etc), morphologic characteristics of the landscape, specific goals of the research (e.g. identification of quarries by searching for the concentration of a rock type) etc.

Thus, for example, in a territory that is mainly devoted to agriculture a large application of Vegetation Indices (VI) should be necessarily planned, but these should be selected on the basis of the defining characteristics of the fields, which are often not homogeneous: next to fields where the crops are dense and thick, where DVI or NDVI can work effectively, there could be fields less productive with a different, looser plant density, where the reflectance of the soil introduces a significant bias on the overall pixel reflectance. Consequently, in those situations it be-comes necessary to apply Vegetation Indices that take this factor into consideration (e.g. SAVI or MSAVI2).

Like the density of crops and vegetation, it is necessary to tackle beforehand many other aspects of the target landscapes, like the morphological, ecological, seasonal ones or even particular situations related, for example, to the presence of shades on imagery: all these conditions in fact can alter significantly the spectral content of the pixels.

Consequently the recognition of a targeted set of procedures should become the gateway of a remote sensing analysis rather than applying the same image processing as standard practise on vast territories with no real connection with the investigated land-scape.

It is sometime hard to judge, based on the current literature devoted to the topic, the level of improvement of the features visibility given by image processing. This is mainly related to the fact that we mostly tend to speak about our successful research, forgetting that even information on the failure of a technique or of an approach can be really valuable in the advance of the archaeological application of the discipline. Thus, in perusing the by now vast bibliography on the subject, one gains often the impression that all the applied image processing techniques multiply exponentially the capacity of features identification, but this is not always reflected in the exponential growth of number of identified and recorded features.

That the application of image processing techniques is always successful is not possible or credible. There is doubtless a bias introduced by the fact that most of the articles on the subject (frequently restrained to a short number of pages allowed by Proceedings) deal more with technical aspects illustrated by few examples than with overall statistics on the number of detected features, so the real impact of image processing is simply not described. Nonetheless, a lack of quantification of the obtained results makes it hard to judge in the right perspective the adequacy of an application, its effectiveness and the level of improvement it can guarantee if compared to the raw data or other similar procedures.

3. Image processing: a brief resume of common and less common techniques

Among the most common procedures adopted in archaeological remote sensing Vegetation Indices, Classifications, Ratios, Principal Component Analysis (PCA) and Tasselled cap Transformation (TCT) are to be included. These methods of processing have been adopted since the 80's (or in few sporadic cases even before) and exerted to different types of remotely sensed data, including Landsat, ARIES, ASTER and more recently Quickbird and Ikonos, among the most common.

3.1. Assessing vegetation quality: Vegetation Indices

Vegetation Indices find wide application in the archaeological research, since studies about the quality of the vegetation, monitoring deviations in its vigour, can enable the detection of subterranean archaeological deposits that promote or, on the contrary, reduce the development of the vegetation.

The largest part of the archaeological researches involving the use of VIs has entailed primarily the use of the Normalized Vegetation Index (NDVI) (CHALLIS, HOWARD 2006, ESTRADA-BELLI, KOCH 2007, LASAPONARA, MASINI 2006), especially when using hyperspectral data (EMMOLO et al. 2004, MEROLA et al. 2005).

Such use, however, appears in certain cases to be more dictated by conventions than from the conviction that it represents the most appropriate process in the given circumstances, based, for example, on the particular environmental and morphological characteristics of the target site. In spite of its common adoption over every type of environmental conditions, other VIs (namely RVI, DVI, MSAVI2, to cite some) have demonstrated better results for archaeological purposes (MEROLA et al. 2006, TRAVIGLIA 2005). In those cases the vegetation coverage type, the density of the canopy or other more complex factors have been preliminarily taken in consideration when selecting them as the most appropriate processes to evaluate the biomass of a certain area. Such factors in fact can strongly affect the results of the process itself.

This process selection activity tailored to the land-scape cannot always ensure by default successful results (TRAVIGLIA 2005) but can support avoiding inevitably incorrect outcomes delivered by mistaken assumptions.

3.2. Classifications

Another largely applied image processing technique is classification, in the forms of supervised and unsupervised. Since the beginning of the image processing activity related to archaeology, researchers have tried to automatically extract meaningful information from the imagery by correlating spectral con-tent with distinctive archaeological features through the clustering of sets of pixel with similar spectral characteristics (one of the first examples dates back to the 70's. HAMLIN 1977).

Classification devoted to recognise a specific spectral response characterising archaeological features, however, seems to fail to fulfill completely the expectations and to deliver invalid and questionable results in archaeological applications, (BECK 2007, TRAVIGLIA 2006), largely less rewarding than the successful results for other classes of materials in different disciplines (geology, for example). Where classification can instead support effectively the archaeological research is in locating environmental settings with similar characteristics, e.g. types of soil or other environmental variables, whose presence can be correlated to archaeological sites (CUSTER et al. 1986).

3.3. Principal Component Analysis

Principal Component Analysis is another highly implemented image processing techniques (ALTAWEEL 2005, ESTRADA-BELLI et al. 2007, GIARDINO, HALEY 2006, to mention a few). This is due to the fact that the application of the PCA to archaeological study can be of great utility since it may provide in many cases supplementary information compared to the original bands and allows a better discrimination of different surfaces that become more distinguishable in visual analysis.

Despite the recognizable advantages obtainable applying the PCA, it is rarely stressed that many details that are visible analysing singularly the original bands cannot always be recognized in the PCs -single components or composites- because they are covered by the overlaying information from other bands. Consequently in specific cases, e.g. when dealing with hyperspectral data, improved outcomes in terms of detectable features can be achieved through the computation of spectral subsets, referred as SPCs (Selective Principal Components): these are obtained through a PCA computed for groups of bands, detected by a single spectrometer of the sensor or belonging the same spectral region (MEROLA 2005, TRAVIGLIA 2005).

3.4. Tasselled cap Transformation

Quite considerable potential has been shown by the recourse to the Tasselled Cap Transformation. The TCT is a linear transformation of bands that defines a new coordinate system in terms of which the soil line and the spectral region of vegetation are more clearly represented. After performing TCT, the majority of information is contained in few components or “features”, directly related to physical scene characteristics. Brightness axis is associated with changes in the soil background reflectance. Another “feature”, the Greenness, is closely orthogonal to brightness and is a contrast between NIR and visible bands: this means that it is correlated with variations in the vigour of green vegetation and related to the amount present in the scene. The Wetness axis provides information about the level of humidity of the soil.

The implications of the use of the Tasselled Cap in archaeological research appear clear: contributing in identify humid areas, ancient riverbeds, artificial and natural canalisations etc. this transformation concurs to reproduce the hydro-morphologic conditions of the ancient landscape (BRIVIO, et al. 2000, RICHASON, HRITZ 2007, WILLIAMSON et al. 2002).

3.5. Even more processes...

Filters and Stretches are common methods to high-light and enhance tonal variations between neighbouring pixels and have found vast application over a variety of spectral data. Edge enhancement filters have been lately quite efficiently used (DE LAET 2007, LEUCCI et al. 2002) in several projects.

Among others of the first types of processing adopted (MARCOLONGO, MASCELLARI 1977, MORAIN 1981) band ratios are still used a lot (CARLA 1998, SEVER 1998, PAVLIDIS et al 2002) although their strength is somehow outmoded by more refine procedures.

The list of other image processing techniques includes more methods (IHS transform, Brovery and Fourier transformations, data fusion etc), bringing the total amount to several tens of applied techniques. This fact is sufficient to understand that due to the high number of possible applicable methods some sort of pre-selection must be applied in advance. The choice can be affected by several factors embedded with the research program and has to be driven by landscape characteristics and the goals of the project.

References

ALTAWEEL M., 2005. The use of ASTER satellite imagery in archaeological contexts. Archaeological Prospection, 12, 3, pp: 151-166.

BRIVIO P.A., PEPE M., TOMASONI R., 2000. Multispectral and multiscale remote sensing data for archaeological prospecting in an alpine alluvial plain. Journal of Cultural Heritage, 1, 2, pp: 155–164.

CARLA R., CARRARA A., JACOLI M., ALESSANDRO V., BARONTI S., 1998. Analysis of multispectral imagery for archaeological investigation. In Proceedings of 1st International Congress on "Science and Technology for the Safeguard of Cultural Heritage in the Mediterranean Basin”, I, pp: 349-353. Luxograph, Palermo.

CHALLIS K., HOWARD A. J., 2006. A review of trends within archaeological remote sensing in alluvial environments. Archaeological Prospection, 13, 4, pp: 231-240.

CUSTER J.F., EVELEIGH T., KLEMAS V., WELLS I., 1986. Application of LANDSAT data and synoptic

Remote Sensing to predictive models for prehistoric archaeological sites: an example from the Delaware Coastal Plain. American Antiquity, 51, 3, (Jul.1986), pp: 572-588.

DE LAET, V., PAULISSEN E., WAELKENS M., 2007. Methods for the extraction of archaeological features from very high-resolution Ikonos-2 remote sensing imagery, Hisar (southwest Turkey). Journal of Archaeological Science, 34, 5, pp: 830-841.

EMMOLO D., FRANCO V., LO BRUTTO M., ORLANDO P., VILLA B., 2004. Hyperspectral techniques and GIS for archaeological investigation. In ISPRS, Proceeding of the ISPRS Commission VII Symposium. Geo-Imagery Bridging Continents, vol. XXXV, part B7, pp: 492-497.

ESTRADA-BELLI F., KOCH M., 2007. Remote Sensing and GIS Analysis of a Maya City and Its Landscape: Holmul, Guatemala. In Wiseman, J., El-Baz, F. (eds.) Remote Sensing in Archaeology, pp: 263-281. Springer, New York.

GIARDINO M. J., HALEY B.S., 2006. Airborne remote sensing and geospatial analysis. In Johnson, J.K. (ed.) Remote Sensing in Archaeology. An Explicitly North American Perspective, pp.47-77. University Alabama Press, Tuscaloosa, AL.

HAMLIN C., 1977. Machine processing of Landsat data: an introduction for anthropologists and archaeologists. MASCA Newsletter, 13, 1/2, pp: 1-11.

LASAPONARA R., MASINI N., 2006. Identification of archaeological buried remains based on the Normalized Difference Vegetation Index (NDVI) from Quickbird satellite data. IEEE Geoscience and Remote Sensing Letters, 3, 3 pp: 325- 328.

LEUCCI G., NEGRI S., RICCHETTI E., 2002. Integration of high resolution optical satellite imagery and geophysical survey for archaeological prospection in Hierapolis (Turkey). In 2002 IEEE 24th Canadian Symposium on Remote Sensing, 4, pp: 1991-1993.

MARCOLONGO B., MASCELLARI M., 1977. Satellite images and their treatments applied to the identification of the "Roman Reticulum" in the Venetian plan. Photogrammetrische Woche, 4, pp: 281-293.

MEROLA P., ALLEGRINI A., BAJOCCO S., 2005. Hyperspectral MIVIS data to investigate the Lilybaeum (Marsala) Archaeological Park. In Remote Sensing for Environmental Monitoring, GIS Applications and Geology. Proceedings of SPIE, 5983, pp: 212-222.

MEROLA P., ALLEGRINI A., GUGLIETTA D., SAMPIETRI S., 2006. Using Vegetation Indices to study archaeological areas. In Campana, S., Forte, M. (eds.) From Space to Place. 2nd International Conference on Remote Sensing in Archaeology, pp: 303-309. Oxford, Archaeopress

MORAIN S., BUDGE T., KOMAREK A., 1981. An Airborne Spectral Analysis of Settlement Sites in Chaco Canyon. In Lyons, T. (ed.) Remote Sensing Multispectral Analysis of Cultural Resources: Chaco Canyon and Bandelier National Monument. Supplement No.5, pp: 1-35.CRMD, Washington.

PAVLIDIS L., FRASER C. S., OGLEBY C. 2002. The application of high-resolution satellite imagery for the detection of ancient Minoan features on Crete. In Burenhult, G. (ed) Archaeological Informatics: Pushing the Envelope CAA 2001, pp: 393-400. BAR International Series, Oxford.

RICHASON B.F., HRITZ C. 2007. Remote Sensing and GIS Use in the Archaeological Analysis of the Central Mesopotamian Plain. In Wiseman, J., El-Baz, F. (eds.) Remote Sensing in Archaeology, pp: 283-325. Springer, New York.

SEVER T.L., 1998. Validating Prehistoric and Current Social Phenomena upon the Landscape of the Peten, Guatemala. In Liverman et al. (eds) People and Pixels. Linking Remote Sensing and Social Science, pp: 145-163.

TRAVIGLIA A., 2005. Integration of MIVIS Hyperspectral remotely sensed data and Geographical Information Systems to study ancient landscape: the Aquileia case study, Agri Centuriati, 2, pp: 139-170.

TRAVIGLIA A., 2006. Archaeological usability of Hyperspectral images: successes and failures of image processing techniques. In Campana, S., Forte, M. (eds.) From Space to Place. 2nd International Conference on Remote Sensing in Archaeology, pp: 123-130. Archaeopress, Oxford.

WILLIAMSON R. A., HURST W., JEFFE M. 2002. Satellite remote sensing for archaeology and historic preservation: Mapping the ancient trails of Southeast Utah (ESA SP-515). In Warmbein, B. (ed) Proceedings of the Conference Space Applications for Heritage Conservation, 5-8 November 2002 Strasbourg, S2_7.