ARCHAEOLOGICAL LAND USE CHARACTERIZATION USING MULTISPECTRAL REMOTE SENSING DATA

Ivan E. Villalon-Turrubiates[1], *Member*, *IEEE*, and Maria J. Llovera-Torres[2]

[1]Universidad de Guadalajara, Centro Universitario de los Valles, México, villalon@ieee.org
[2]Universidad Autónoma de San Luis Potosí, México, llovera_torres@alumnos.uaslp.edu.mx

ABSTRACT

Much of human history can be traced through the impacts of human actions upon the environment. The use of remote sensing technology offers the archeologist the opportunity to detect these impacts which are often invisible to the naked eye. The extraction of remote sensing signatures from a particular geographical region allows the generation of geophysical signature maps; this can be achieved using an accurate and recently developed multispectral image classification approach based on pixel statistics for the class description, which is referred to as the Weighted Pixel Statistics method. This paper presents the prospective study for archaeological land use characterization using multispectral remote sensing data provided by SPOT-5 imagery. The results obtained with this study probe the efficiency of the classification technique.

1. INTRODUCTION

Generations of archaeologists have longed for some way of learning from archaeological sites without actually having to dig them. The prominent archaeologist Lewis Roberts Binford, Ph.D., once said "*ideally, we should have an X-ray machine which would allow us to locate and formally evaluate the range of variation manifest in cultural features*" [1]. Recently, Binford's elusive X-ray machine has been actualized in a series of increasingly and highly sophisticated remote sensing contrivances. These new techniques can (prior to excavation) provide information of where the archeological sites are and what they contain. Surface studies are necessary to obtain data that excavations cannot provide. Some examples are the applications of aerial and satellite photography, which shows a wide panorama of the archaeological site, allows examining ground marks, find walls from former occupations, etc. [2]. In some cases is possible to identify in the ground the necessary elements to study the materials and establish a chronology (even a tentative one), shows the environmental relationship with the site, important aspects as space dimension and distances to another related sites [3]. The extension and complexity of the site are necessary elements for planning and managing the archaeological research site.

The geophysical techniques employed in prospecting studies are important because provides information to the researcher to help solving difficulties, to act within large terrain extensions, to detect archaeological contexts and maximize the excavation efficiency [4].

Considerable progress has been made generally in the application of remote sensing (RS) techniques to both research and operational problems for urban assessment, urban planning and natural resources management. Modern applied theory of signal and image processing for land cover and land use analysis is now a mature and well developed research field, presented and detailed in many works ([5] thru [8] and the references therein are only some indicative examples).

Although the existing theory offers a manifold of statistical techniques to tackle with the particular geophysical monitoring problems, in many applications areas there still remain some unresolved crucial theoretical and data processing problems.

One of the most important problems to be solved is particularly related to the extraction of physical characteristics for applications in archaeological land use characterization.

Modern digital signal and image processing techniques are currently used by archaeologist to detect the impacts of human actions upon the environment. This information can be used to address issues in human settlement, environmental interaction, and climate change [9].

Archeologists want to know how ancient people successfully adapted to their environment and what factors may have led to their collapse or disappearance.

Remote sensing can be used as a methodological procedure for detecting, inventorying, and prioritizing surface and shallow-depth archeological information in a rapid, accurate, and quantified manner [10].

The application of an accurate tool recently developed in [11] for supervised segmentation, classification and quantification of archaeological land use (ALU) using multispectral remote sensing (MRS) imagery is based on the analysis of pixel statistics, and is referred to as the weighted pixel statistics (WPS) method.

2. MULTISPECTRAL IMAGING

Multispectral imaging is a technology originally developed for space-based imaging, are the main type of images acquired by RS radiometers. Usually, MRS systems have from 3 to 7 radiometers; each one acquires one digital image (called scene) in a small band of visible spectra, ranging 450 nm to 690 nm, called red-green-blue (RGB) regions [12].

For different purposes, combinations of spectral bands can be used. They are usually represented with red (R), green (G) and blue (B) channels. This is referred to as True-Color RS imagery [12].

The wavelengths for the spectral bands are 450-520 nm for Blue, 520-600 nm for Green, and 600-690 nm for Red (the values are approximated, exact values depends on the particular MRS instruments [13]).

3. WEIGHTED PIXEL STATISTICS METHOD

The weighted pixel statistics (WPS) classification rule is computationally simple. An extensive study was performed in [11] to probe that the accuracy obtained with this classification process is more efficient (both qualitatively and quantitatively) compared with other more computationally intensive algorithm (as the weighted order statistics method [8]).

The WPS algorithm is characterized by the mean and variance values of the sensed archaeological signatures (SAS) to be classified (defined as classes) and the Euclidean distances based on the Pythagorean Theorem.

The training data for class segmentation requires the number of SAS to be classified (c); the means matrix **M** ($c \times c$ size) that contains the mean values μ_{cc}: ($0 \leq \mu_{cc} \leq 255$, gray-level) of the SAS classes for each RGB bands; and the variances matrix **V** ($c \times c$ size) that contains the variances of the SAS classes for each RGB bands. The matrix **M** and **V** represents the weights of the classification process.

Next, the image is separated in the spectral bands (R, G and B) and each (i, j)-*th* pixel is statistically analyzed calculating the means and variances from a neighborhood set of *5x5* pixels for each RGB band, respectively.

To compute the output of the classifier, the distances between the pixel statistics and the training data is calculated using Euclidean distances based on the Pythagorean Theorem for means and variances, respectively.

The decision rule used by the WPS method is based on the minimum distances gained between the weighted training data and the pixel statistics.

The WPS techniques provide a high level of SAS segmentation and classification.

Figure 1 shows the detailed processing structure of the WPS classifier.

4. SPOT-5 IMAGERY

SPOT Image is the worldwide distributor of geographic information products and services derived from the SPOT Earth observation satellites. A SPOT satellite image is a view of the Earth seen through one of the satellite's high-resolution imaging instruments. The technical characteristics of each instrument determine the resolution and spectral mode of the image. The acquired image is then processed to suit users' requirements in terms of geographic information. It is delivered in a standard format able to be integrated directly in current geographic information software packages [14].

5. ALU SIMULATION EXPERIMENT

The image used for this study was obtained from SPOT-5 satellite and corresponds to the archaeological site called "Guachimontones" located in the city of Teuchitlán, state of Jalisco Mexico. This is the mayor site of the so-called "Teuchitlan tradition", a complex society that existed from as early as 300 BCE until 900 CE. The image was provided by the Mexican NAVY (SEMAR Secretaría de Marina/Armada de México) under the ERMEXS program (Estación de Recepción México de la Constelación SPOT) [15]. The spatial resolution is 10m (spectral mode Hi) and the spectral resolution corresponds to 3 bands:

- B1: green band (0.50 – 0.59 μm).
- B2: red band (0.61 – 0.68 μm).
- B3: near infrared band (0.78 – 0.89 μm).

In the reported results, an ALU electronic map is extracted from the MRS high-resolution image using the WPS method.

Figure 1 shows a picture of the Archaeological Site.

Figure 2 shows the multispectral high-resolution (*1024x1024*-pixels) MRS image in TIFF format [14].

Figure 3 shows the ALU map extracted from Figure 2 and obtained applying the WPS method for the adopted ordered weight vector.

The WPS method employs the three defined bands from the original image; therefore, using the statistical pixel-based information the ALU map obtained shows a high-accurate classification without unclassified zones.

Figure 1 – Picture of the Archaeological Site ”Guachimontones”.

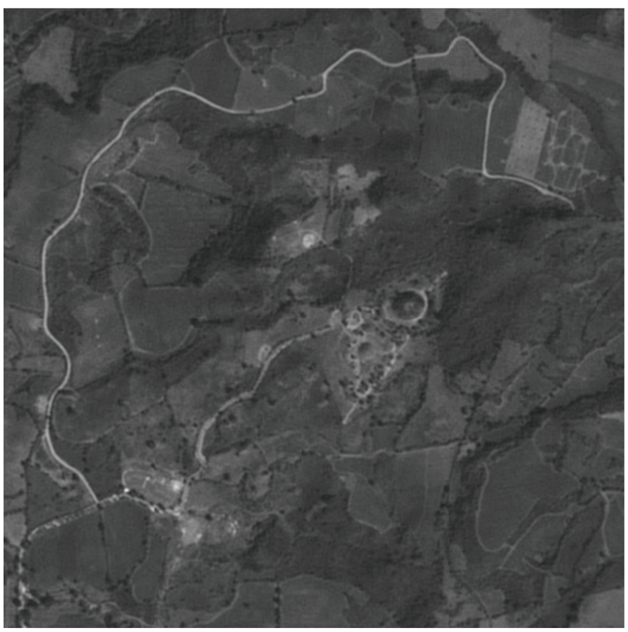

Figure 2 – Multispectral RS scene (courtesy of ERMEXS).

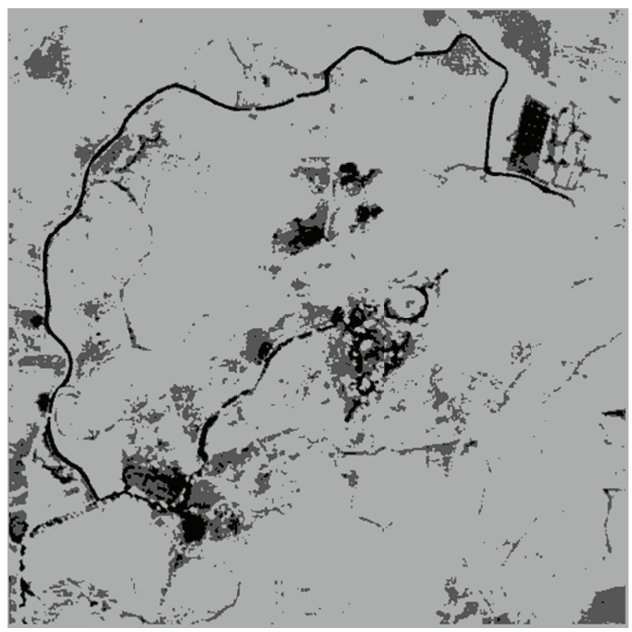

Figure 3 – ALU map extracted using the WPS method.

Three level of ALU signatures are selected for this particular simulation process, moreover, unclassified zones must be also considered (2-bit classification) as

– ALU relative to archaeological land use zones.
– ALU relative to modern land use zones.
– ALU relative to natural land cover zones.
– Unclassified zones of the SAS map.

6. CONCLUDING REMARKS

From the simulation results one may deduce that the applied WPS classifier provides a high-accurate classification without unclassified zones because it uses more robust information in the processing (several image spectral bands). The reported here simulation results shows the qualitative analysis of the overall performance of the WPS method for land use characterization as an auxiliary tool in archaeological information retrieval.

This paper presents the prospective study of the effectiveness that this approach provides for supervised segmentation and classification of sensed archaeological signatures for land use characterization. Data interpretation is a matter of further studies.

7. ACKNOWLEDGMENT

The authors would like to thank the "Programa de Mejoramiento del Profesorado PROMEP" of the Public Education Secretary (SEP) of Mexico and the University of Guadalajara for the resources provided for this research under the research project number PROMEP/103.5/08/2919 and titled "Agregación de métodos para el mapeo y caracterización del medio ambiente mediante técnicas de percepción remota", and to the Department of Humanities and Social Sciences of the Autonomous University of San Luis Potosi. Also to the Mexican ERMEXS (Estación de Recepción México de la Constelación SPOT, Secretaría de Marina/Armada de México) for the SPOT-5 images provided for this research.

7. REFERENCES

[1] L.R. Binford, "A Consideration of Archaeological Research Design", in American Antiquity, pp. 425-441, 1964.

[2] C. Gamble, *Arqueología Básica*, Ariel, Spain, 2001.

[3] J. Litvak-King, *Introducción a la arqueología, todas las piedras tienen 2000 años*, Trillas, Mexico, 1986.

[4] L. Barba-Pingarron, *The ordered aplication of geophysical, chemical and sedimentological thechniques study of archaelogocal sites: the case of san José Ixtapa*, Thesis of the University of Georgia, U.S.A., 1984.

[5] S.W. Perry, H.S. Wong, and L. Guan, *Adaptive Image Processing: A Computational Intelligence Perspective*, CRC Press, U.S.A., 2002.

[6] Y. Shkvarko, and I. Villalon-Turrubiates, "Remote sensing imagery and signature fields reconstruction via aggregation of robust regularization with neural computing", in *Advanced Concepts for Intelligent Vision Systems*, J. Blanc-Talon, W. Philips, D. Popescu and P. Scheunders, Springer-Verlag, Germany, pp. 865-876, 2007.

[7] R. Porter, D. Eads, D. Hush, and J. Theiler, "Weighted order statistics classifiers with large rank-order margin", in *Proceedings of the 20th International Conference on Machine Learning*, Washington U.S.A., 2003.

[8] P.M. Mather, *Computer Processing of Remotely-Sensed Images,* John Wiley & Sons, U.S.A., 2004.

[9] R. Williamson, "Remote Sensing Methods", *Advances in Science and Technology for Historic Preservation*, Plenum Press, U.S.A., 2008.

[10] F. Miller, and D. Lee, "Applications of Ecological Concepts and Remote Sensing Technologies in Archeological Site Reconnaissance", *Applications of Space-Age Technology in Anthropology*, C. Behrens, and T. Sever, NASA Press, U.S.A., 1991.

[11] I.E. Villalon-Turrubiates, "Weighted Pixel Statistics for Multispectral Image Classification of Remote Sensing Signatures: Performance Study", *Proceedings of the 5rd IEEE International Conference on Electrical Engineering, Computing Science and Automatic Control (CCE),* Mexico City, pp. 534-539, 2008.

[12] H. Hough, *Satellite Surveillance*. U.S.A.: Loompanics Unlimited, U.S.A., 1992.

[13] J. R. Jensen, *Introductory Digital Image Processing: A Remote Sensing Perspective,* Prentice-Hall, U.S.A., 2005.

[14] Satellite Imagery and Smart Mapping Solutions, http://www.spotimage.com, 2010.

[15] Estación de Recepción México de la Constelación SPOT – Secretaría de Marina SEMAR / Armada de México, http://www.ermexs.siap.gob.mx, 2010.