Evolutionary Approach for Detection of Buried Remains Using Hyperspectral Images

León Dozal, José L. Silván-Cárdenas, Daniela Moctezuma, Oscar S. Siordia, and Enrique Naredo

Abstract

Hyperspectral imaging has been successfully utilized to locate clandestine graves. This study applied a Genetic Programming technique called Brain Programming (BP) for automating the design of Hyperspectral Visual Attention Models (H-VAM.), which is proposed as a new method for the detection of buried remains. Four graves were simulated and monitored during six months by taking in situ spectral measurements of the ground. Two experiments were implemented using Kappa and weighted Kappa coefficients as classification accuracy measures for guiding the BP search of the best H-VAM. Experimental results demonstrate that the proposed BP method improves classification accuracy compared to a previous approach. A better detection performance was observed for the image acquired after three months from burial. Moreover, results suggest that the use of spectral bands that respond to vegetation and water content of the plants and provide evidence that the number of buried bodies plays a crucial role on a successful detection.

Introduction

Locating unmarked graves represents a complicated and time-consuming forensic problem because their locations are often remote and the burial time is generally unknown (Siegel and Saukko, 2013). The research on the detection of clandestine graves through multi and hyperspectral images is incipient, yet has proven to be one of the most challenging forensic problems. This is an important area of work, since airborne hyperspectral data enable searching over a large area that is otherwise inaccessible by foot; especially because, in principle, any area of the Earth can be mapped by hyperspectral imaging, be it with aircraft or satellites (Ross *et al.*, 2005).

Several studies have tested the potential of multispectral and hyperspectral images with varying results. Kalacska and Bell (2006) were among the first that demonstrated the potential of remote sensing as a tool for locating heretofore unknown mass graves. Afterwards, Kalacska *et al.* (2009) analyzed the *in situ* and airborne spectral reflectance of a set of animal mass graves and identically constructed false graves. Their results indicated that the reflectance spectra of grave are readily distinguishable from false grave at both scales. In addition, they observed that vegetation regeneration was severely inhibited by cattle carcasses for up to a period of 16 months. Caccianiga *et al.* (2012) studied the effects of decomposition of buried swine carcasses on soil and vegetation structure and composition as a tool for detecting clandestine graves. They found that soil disturbance was the main factor affecting plant cover, while the role of decomposition seemed to be much less critical. Leblanc *et al.* (2014) performed a blind-test of the potential for airborne hyperspectral imaging technology to locate buried remains of pig carcasses. They were able to predict two single graves, within GPS error (10 m), whose location they did not know. Recently, Silván-Cárdenas *et al.* (2017) studied some methods for detecting clandestine graves using hyperspectral data collected on ground. Through a controlled experiment using buried carcasses of pigs, demonstrated that hyperspectral data have potential for detecting buried remains only after three months from burial. Furthermore, that the critical spectral regions for graves detection are the NIR and SWIR1[1] spectral regions, some of which were so narrow (10 nm) that stressed the need for hyperspectral sensing.

The method of acquisition of hyperspectral images is equally important than the process of pattern recognition for detection of graves based on such information. In this sense, some techniques of evolutionary computation have been successfully applied for selection and combination of spectral bands aiming at different applications such as classification of vegetation species, soil mineral identification, synthesizing spectral indices, estimate pasture mass and quality, and precision farming, to mention just a few (Ross *et al.*, 2005; Chion *et al.*, 2008; Albarracín *et al.*, 2016; Zhuo *et al.*, 2008; Li *et al.*, 2011, Kawamura *et al.*, 2010, Puente *et al.*, 2011, Ullah *et al.*, 2012, Davis *et al.*, 2006, Landry *et al.*, 2006; Kawamura *et al.*, 2010; Awuley and Ross, 2016). On the other hand, currently, visual attention models have been designed for the spatial and spectral analysis of hyperspectral images with applications such as detection of prominence, visualization and interpretation, and detection of objects (Le Moan *et al.*, 2011and 2013; Wang, 2013; Liang *et al.*, 2013; Cao *et al.*, 2015; Zhang *et al.*, 2017).

In this study an evolutionary technique is proposed based on genetic programming, known as Brain Programming (BP), for optimizing a so-called Hyperspectral Visual Attention Models (H-VAM) for graves detection.

Problem Statement

The present work addresses the problem of detection of clandestine graves as a problem of classification of hyperspectral images. The image classification problem can be stated in formal terms as follows. Suppose we want to classify each pixel in an image into one of N classes, let say $C_1, C_2, \ldots, C_N$. Then, decision rules must be established to enable assignment of any given pixel to these classes (Varshney and Arora, 2004).

When working with hyperspectral images, some issues arise due to the high dimensionality of this type of images, e.g., Hughes phenomenon, high information redundancy in spectral and spatial domains, need for finding features that increase discrimination between classes and high computational resources required in the classification process.

For this reason, a compelling need to reduce the dimension of data exists. The methods for reduction of dimensionality can be roughly divided into two categories: feature extraction

Centro de Investigación en Ciencias de Información Geoespacial, A.C., Circuito Tecnopolo Norte No. 117, Fracc. Tecnopolo II, Pocitos, Aguascalientes, CP 20313, Mexico (leon.dozal@gmail.com).

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1. The abbreviations used in this paper are summarized in Table 1.