A Vector Agent Approach to Extract the Boundaries of Real-World Phenomena from Satellite Images

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Abstract

This paper explores the application of vector agents (VA), a geometry-led type of computational agent, to extract the boundaries and classify real-world objects from satellite images. This method has been successfully implemented and tested on a multi-spectral satellite image to extract a set of objects with real-world counterparts. Comparison to the outcome of an Object-Based Image Analysis at a single scale of segmentation has also been made. The results of the presented approach enables real-world phenomena to be modelled with geographical objects derived intelligently from images. These objects have geometric, state and neighbourhood behaviours allowing them to iterate towards realistic output boundaries and robust classification in the simulation process.

1 Introduction

In the process of determining real world phenomena in remotely sensed images (e.g. an agricultural parcel or a building), the object boundaries are often interpreted as a set of irregular polygons. These boundaries enclose homogeneous areas and are collectively able to convert a spatial phenomenon, defined in a continuous environment (e.g. the remotely sensed image), into a set of objects in a discrete space (e.g. the classified image). However, from a geographic object-based image analysis (GOBIA) perspective, it may not be easy to determine these regions precisely. For one, they are extracted without a direct relationship with real-world objects (Benz et al., 2004) in a sequential process of segmentation and subsequent classification. Hence, segmented objects cannot adjust their geometry once they are classified. They are also extracted based on a set of crisp experimental parameters such as scale, colour, and shape (Hay et al., 2005). In turn, existing approaches are not capable of modeling vague/fuzzy/diffuse boundaries and/or complex geometric behaviours of such boundaries in a dynamic manner on the basis of the real-world phenomena that such boundaries are meant to represent.

To tackle these limitations, a vector agent (VA) approach that encapsulates spatial reasoning capabilities (e.g. use of orientation and size knowledge), will be investigated in order to extract the boundary of real-world phenomena from a satellite image. Each image object in the model can be interpreted as a level of abstraction of a real-world object in subsequent iterations of an evolving process from pixel to real-world object. In this regard, this VA implementation moves toward a classification solution. Hence, the modelled objects are a set of vector agents that evolve dynamically in a spatio-temporal environment (Figure 1), and once evolved are subject to a single scale. These VAs provide a dynamic geometry and impose the properties of real-world and simulation environment for the modelled objects. This is in contrast to previous VA implementations (Hammam et al., 2007; Moore, 2011) in which VAs manipulated their own geometry according to fractals. All VA realisations can be placed within the Geographic Automata (GA) framework of Torrens and Benenson (2005).

2 Implementation and Outcome

The initial scenario is formed based on three different classes: agriculture, bare soil and water, found in a subset of an IKONOS image (Figure 2a). First, each desired object is automatically initialized in space. This is done by using the feature space defined by the reflectance information from each of the four spectral bands of the sample image. The feature space exhibits sets of pixels as contiguous clusters with similar spectral reflectance properties. A candidate pixel, which has a minimum spectral distance from the mean of each cluster, is extracted for each class. In addition, a spectral threshold is defined for each class as the maximum Euclidean distance for candidate pixel to belong to the modelled class object. This is equivalent to a minimum Euclidean distance classifier. After initializing, the desired object repeatedly seeks to find such candidate pixels in image space, in an effort to define the full extent of its VA boundary. Also, the other agents are automatically initialized in space, in the same way. Once an agent finds a neighbor pixel that meets the class criteria, this triggers the evolving process of the VA controlled by a set of rules. These rules are defined by structure and geometry primitives to adjust the boundaries of the modelled objects.

An example of the result of this process is shown in Figure 2(b), while Figure 2(c) illustrates the outcome of a single-scale segmentation of the same subset completed with the Trimble eCognition OBIA classification software. The results are promising and indicate that the VA object classification method is capable of evolving towards a modelling of the image in readily classified objects, while traditional OBIA requires the successive and somewhat independents process of segmentation then classification.

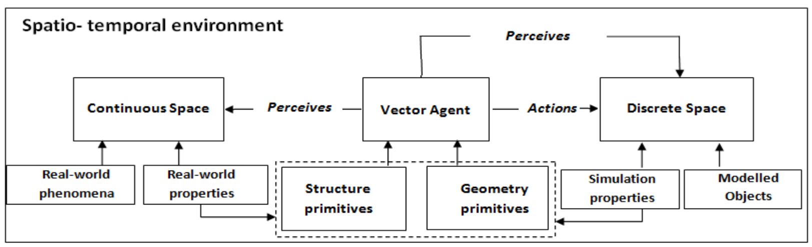

Figure 1: Schematic of the processes involved by the proposed approach.

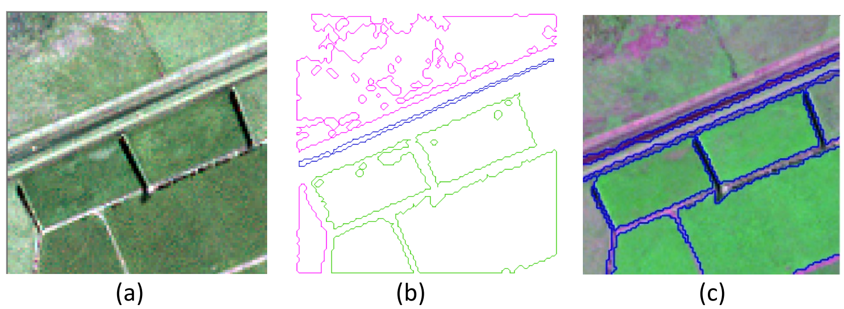

Figure 2: (a). Multispectral IKONOS image (Dunedin, 2005), (b). The boundaries of the modelled objects based on VA classification, (c). OBIA segmentation (scale = 45, colour = 0.4) for agriculture, bare soil and water classes.

3 Conclusions

This study proposes a new intelligent vector agent approach to extract the boundaries of real-world objects in the image space through spatial reasoning. This approach enables the desired objects to extract their own boundaries based on the existing information for a great variety and complexity of real-world objects. In this study, the different behaviours of desired objects, such as initialising, expanding and shrinking, have been individually investigated. For future development, the full scope of the geometry, state and neighbourhood interactions rules will be explored.

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