Advancing in Spatial Object Recognition: GEOBIA approach

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Abstract

GEOgraphic Object Based Image Analysis (GEOBIA) is an emerging approach in remote sensing and GI Science. This approach provides a knowledge-base framework to delineate, manage and manipulate objects in multiple scales. The central aspect of this approach is to extract a meaningful object. In this paper, we present a simple method to contribute in the meaningfulness of objects within a framework of robustness. The extracted patch in multiple scales is observed for geometric variability and distribution. The result shows that such variability once captured in a form of index it would be useful in determining the robustness of objects.

Keywords: GEOBIA, reliability, robustness, ecology, patch.

1 Introduction

GEOgraphic Object Based Image Analysis (GEOBIA) is an emerging approach in remote sensing and GI Science. This approach provides a knowledge-base framework to delineate, manage and manipulate objects in multiple scales. The fundamental objective of this approach is the extraction of pertinent and robust entities from a given data source usually a raster image. The accepted paradigm for doing this is through perception, recognition and interpretation of the real world features as objects [1, 2, 3, 11, 12, 13].

The body of knowledge on GEOBIA is increasing for many application areas [3]. One of the application areas is Landscape ecology [7, 8]. We observe that although the application of GEOBIA is very useful in preparing GIS ready vector maps [2], there is an urgent need of research in testing the robustness of extracted objects and making a recommendation to measure it.

In particular, the ecological patches characterized by their exploratory statistics are being used in determining the abundance of flora and fauna. Hence, assessing the robustness issue of the ecological patches which are building blocks of any ecological study is of vital importance. In this on-going research work, the robustness issue is assessed by observing the variation in exploratory statistics of the patch attributes in multiple scales within a GEOBIA framework. The scalar data analysis approach is used for different geometrical attributes. It is perceived that there is a strong need and a challenge of understanding the identifiability of objects in objectification of segments from the remote sensing images. Preliminary results show that the robustness can be included as a general term in the GEOBIA framework to further ascertain the validity of extracted objects. We aim to integrate the theoretical aspect of robustness and contribute in the advancement of object recognition in our on-going project work. As a prototype study, in this paper, we present a test case of an ecological patch that is extracted in five different multiple scales. Our results show that geometrical attributes of patches in multiple scales when characterized by exploratory statistical measures are useful for informed decision making in analysing the abundance of ecological communities. In this study, we pose a simple question of information loss/gain with the disaggregation / aggregation of objects in multiple levels. In answering this question, we pick up a representative heterogeneous segmented object what we called a patch and observe the change in geometrical attributes (extent and shape) in multiple scales. We limited ourselves for area attributes only in this study.

This paper is organized into 6 parts. In the 2nd part we present the state of the art of GEOBIA including technical advancement, methodological initiatives and theoretical aspects where we focus on overarching research questions to be addressed for GEOBIA as an approach, in the 3rd part we describe relationship of robustness and ‘objectification’ of real world features, in the 4th part we present a test case of the prototype research of an ecological patch and associated geometric attributes. In the 5th part we present preliminary visualization results. The 6th part provides discussion, conclusion and future outlook.

2 State of the art

Practically, GEOBIA is a cognitive approach. More than 800 publications using this approach for diverse fields ranging from environmental mapping and monitoring to medical image analysis are reported [3]. There are few theoretical advancement such as quantifying semantic accuracy in segmented images [16], quantifying the robustness of fuzzy rule sets [10], object specific analysis and upscaling [7], accuracy assessment in object based image analysis [4] and studies on perception and syntax [15] are reported.

Biennial GEOIBA conferences are helping to advance this approach in spatial object extraction, interpretation and knowledge creation since 2006. From technological side, open source initiatives in object based image analysis have begun with the introduction of orfeo toolbox, InterIMAGE and GeoDMA, and spring software. An overview of free and open source geographic information tools for landscape ecology is presented in [17]. However, many applications rely on eCognition by Trimble which is a powerful commercial package for object based image analysis [18].

Recent workshop on Geographic object based multi-scale analysis; developing a methodological framework for GIScience in September 2012 at Columbus, Ohio in USA is the latest initiative for GEOBIA advancement [5]. During the workshop, interesting overarching research questions to be addressed were discussed. The questions covered from concepts, methods and applications. Main focus was to define and discuss a methodology for bridging the remote sensing centred GEOBIA approach and GIScience concepts to delineate, manage and manipulate objects.

Taking the above mentioned overarching questions in the perspective, we ask number of complimentary questions in our project, such as: How can we conceive the geographical objects in multiple scales? Is it possible to perceive, recognize, interpret and represent the geographical objects in better reflecting our conception? Is it possible to quantify the robustness of delineated objects? If so, can we quantify locally for an object and globally for a scene? Can robustness of an object be understood by observing its aggregation / disaggregation in terms of geometrical attributes? Can geometric attributes serve as a necessary condition in describing a robust object? Can this make any contribution in advancing the spatial object recognition for GIS and remote sensing community?

In answering above questions, we take this as an opportunity for research with great potential in a wider applications including urban green space mapping with a particular focus on tree crown mapping / change detection and native grasslands monitoring in the local Australian context. We are pursuing this project which is in its initial phase.

3 Robustness and 'objectification' in GEOBIA

The term Robustness is encountered in very different scientific fields, from engineering and control theory to dynamical systems to biology [14, 6]. Intuitively the question comes for robustness of what and with respect to what? In the case of GEOBIA, what do we mean by a robust object? After adapting the specific segmentation technique to delineate the objects in multiple scales, we would like to observe how the state of such objects are changing in terms of simple topological features described by geometrical shape and extent. When we perceive real world objects in multiple scales how can we be assured that such objects in multiple scales are resilient and stable although these have to go for aggregation / disaggregation process. There will be definitely other scientific avenues to be tackled in this framework but we can think of robustness as a convergence of these uncertainties and there is a greater need to develop robustness index in objectification of the real world objects.

Within the GEOBIA framework robustness issue has been studied for fuzzy rule sets in classifying the segmented objects [10]. It is recommended that the first and most obvious criterion for success of any OBIA approach is an appropriate image segmentation method that is able to create adequate image objects [10]. However, the objects after segmentation were not tested for robustness. Thus, we argue here that objects after segmentation should be tested for robustness which could give us a certainty to some extent in the classification process. To do so, we could start with a simple observation of change in topology described by geometric attributes for the objects in multiple scales. This approach could be useful primarily in interpreting the abundance of flora and fauna in ecological applications. As a preliminary study we tested this approach for an ecologically diverse patch in a hope to generalise this later for other applications.

4 Data and patch

A very high resolution aerial photograph was used in this study as a test case data. For the project, we are in the process of acquiring World View-2 imagery and hyperspectral sensor images using Micro-Hyperspec imaging sensors (With the capacity of Near Infra-Red and visible and near infra-red) from an Unmanned Aerial Vehicle system.

The aerial photograph was used to generate the patches (image objects) in multiple scales using eCognition software [18]. The aerial photo was acquired for Hobart City, Tasmania, Australia considering the heterogeneous land cover / land use of the city (Figure 1). The greenness of the city and native trees were the main motivation for this research. Five different levels were conceived in objectification after the segmentation in five different scales. The number of objects for different levels of segmentations for whole scene and selected patch are presented in Table 1. It is observed that coarser the segmentation scale fewer are the objects and finer the segmentation scale more are the objects (Table 1).The skeleton of the selected patch is included in the inset (Fig 1). To develop a focused and specific analysis, we have selected a heterogeneous patch (Fig. 2). Its dis-aggregation was observed from top down approach from coarse to finer segmentation scales (Figure 2 and Table 2).

Figure 1: Study area showing the heterogeneous land cover/land uses in an urban setting of Hobart city, Tasmania, Australia.

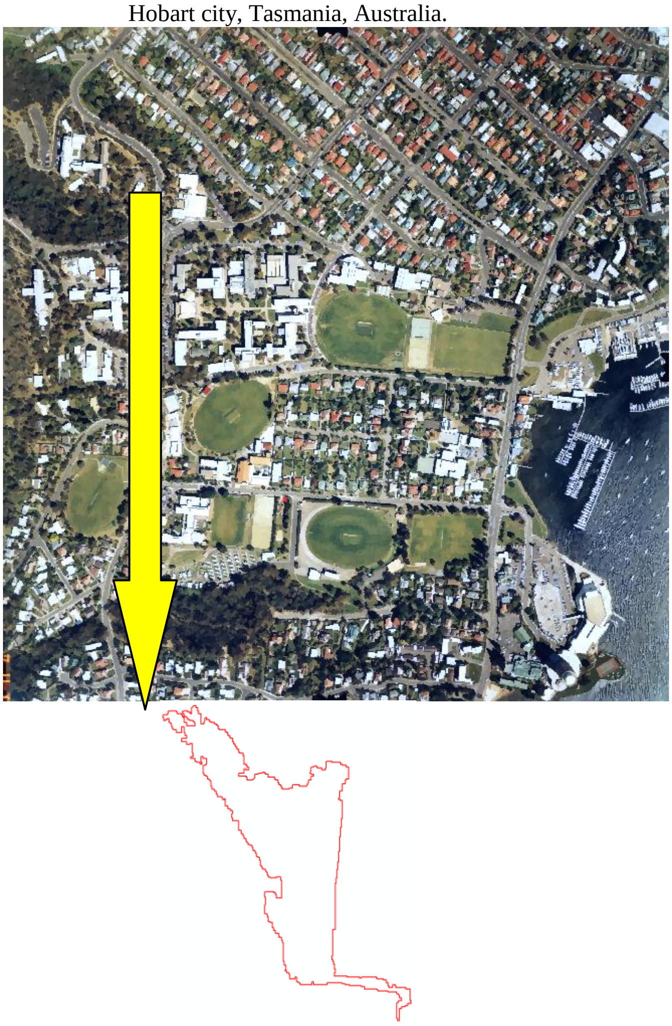


Table 1: Number of segmented objects in multiple scales for different levels

Level	Scale	Number of objects	
		Whole scene	**Selected patch**
5	250	1894	1
4	200	2822	3
3	100	9535	10
2	50	23977	26
1	20	58771	54

We present area attributes and successive changes during the disaggregation process (Table 2) with respect to original patch area in a top level. This shows that the inherited areas are decreasing with finer level objects. Visualization of this information is made by plotting means and their confidence intervals. Further, distribution patterns of areas are visualized using time series plot. As we are seeking for information loss / gain in the disaggregation process these visualization tool are suitable to capture the information.

Figure 2: Multi-scale representation of segmented objects in objectification for a selected patch with red boarder. Top left 250- scale, top right 200-scale, middle left 100-scale, middle right 50-scale and bottom one 20-scale segmentation results showing the disaggregration of objects (a top down approach).

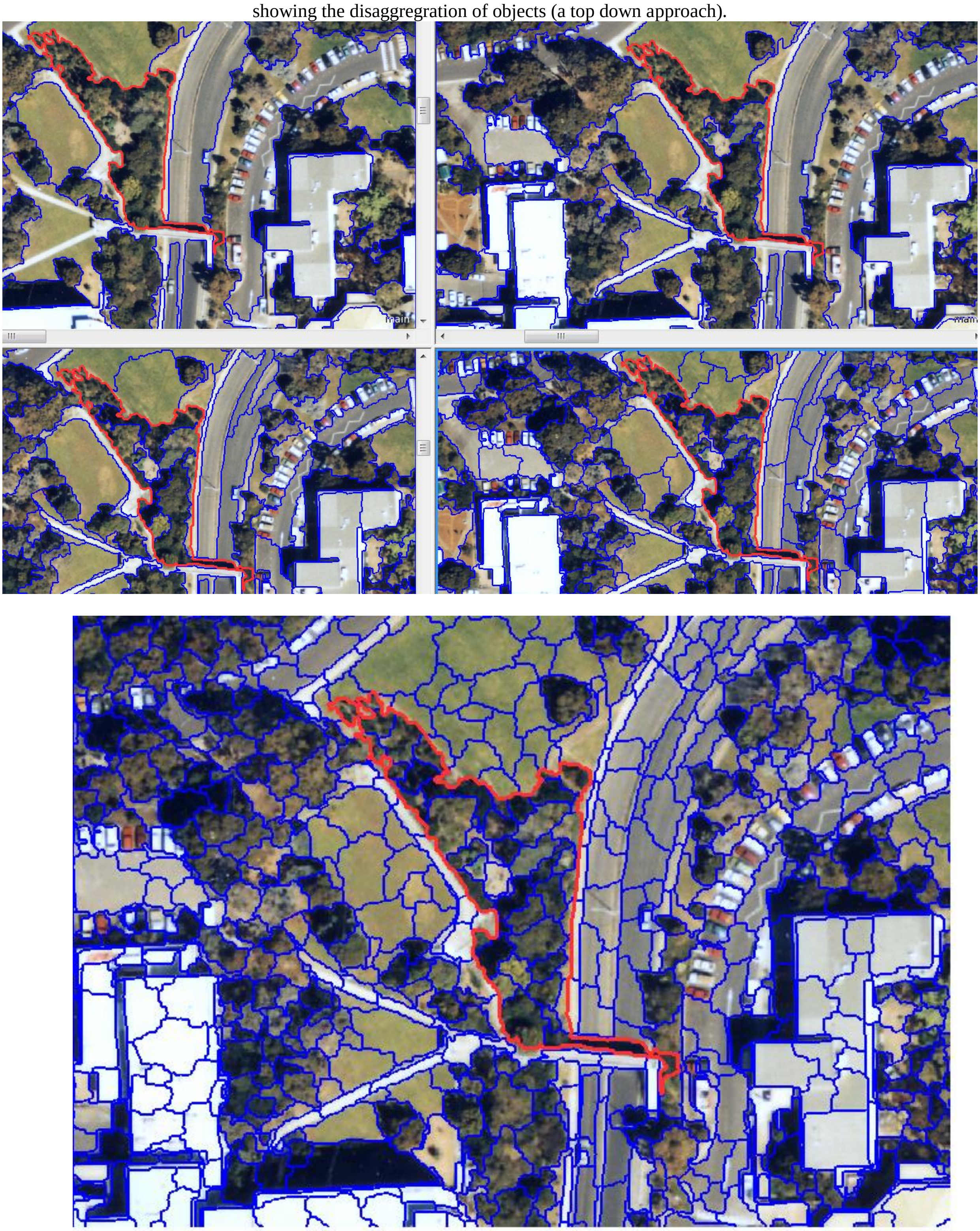


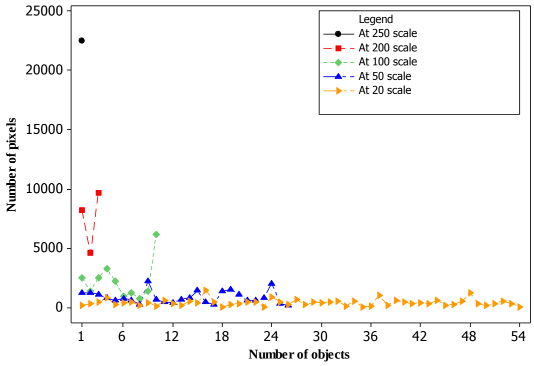
Table 2: Disaggregation of the selected patch from 1 to 3 to 10 to 26 to 54 across the scales and the retained areas with respect to its original area.

% Area in 250 Scale	% Area in 200 Scale	% Area in 100 Scale	% Area in 50 Scale	% Area in 20 Scale
100	36.5	11.1	5.4	0.8
	20.4	6.1	5.5	1.4
	43.1	11.2	4.9	2.0
		14.6	3.6	3.7
		9.9	2.7	1.2
		4.3	3.5	1.9
		5.6	2.7	2.2
		3.5	1.2	0.9
		6.3	9.8	1.8
		27.4	2.9	0.4
			2.0	2.5
			1.7	1.4
			3.1	0.9
			3.5	2.3
			6.3	1.6
			1.9	6.4
			1.4	2.2
			6.4	0.3
			6.7	1.2
			4.9	1.6
			2.5	1.9
			2.7	2.2
			3.5	0.3
			8.8	3.8
			1.6	2.1
			0.8	1.2
				3.1
				1.1
				2.1
				1.7
				2.0
				2.5
				0.4
				2.5
				0.3
				0.4
				4.7
				0.9
				2.7
				1.9
				1.4
				1.8
				1.4
				2.7
				0.9
				1.1
				2.3
				5.5
				1.5
				0.8
				1.4
				2.4
				1.5
				0.3

5 Visulaization of Information loss/gain in the attributes

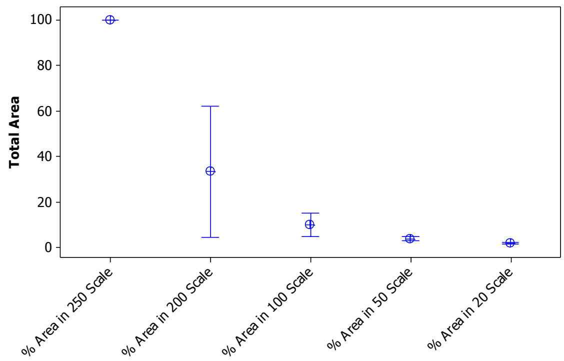
The distribution pattern of pixels in forming the image objects are visualised across the five scales (Fig. 3). It is observed that bigger the image objects more are the pixels and smaller the image objects less is the contained pixels. In very fine scale, in our case at 20-scale, the objects contain uniform pixel numbers whereas in intermediate scales there is variability in pixel numbers.

Fig. 3 Distribution pattern of pixels in forming the objects from 1 to 54 across the five different scales.



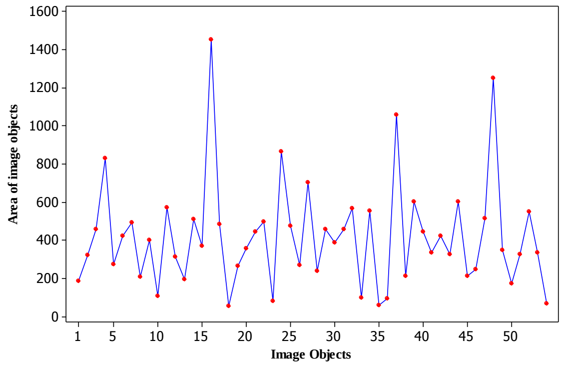
The variability measure is observed for the change in geometry of the patches by taking the area of a selected patch as 100 per cent and calculating the retaining areas with respect to the original patch. The variability of disaggregated patches in multiple scales (Fig 4) shows that finer the scale less is the variability.

Fig. 4 Variability of disaggregated patches in multiple scales



Further, at the very finer level the distribution pattern of areas corresponding to the objects are observed (Fig 5). The descriptive statistics as well as the figure show that fewer image objects are not uniform. Majority of the image objects are uniform.

Fig 5 Distribution pattern of areas and corresponding image objects in a finer scale-20.



6 Discussion, Conclusion, Future work and Outlook

We presented a simple approach of detecting pattern of information loss/gain in observing the real world feature in a geographic disaggregation process. We are able to visualize distribution pattern and variability of the patches. Multi-scale modeling and robustness test of the ecologically important patches for urban green space mapping and native grassland monitoring is planned for the study site in the city of Hobart and in the Tasmanian Midlands respectively. World-view 2 and hyperspectral imagery will be acquired for a summer season to monitor and map the native grasslands where the physical data will be used in doing the segmentation of the patches in different scales. Physical data will be incorporated in defining the rule set while doing the segmentation and classification. Experts' knowledge will be used to ascertain the depicted patches with the consultation to the ecologists working in the area.

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