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Association of Spatial Object Recognition and GEOBIA: an Experimental Approach

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Abstract

Spatial object recognition is an important facet of spatial information system. Psychological and mathematical basis are two important factors in forming spatial object. In recent years, Geographic Object Based Image Analysis (GEOBIA) is extensively used in extracting the information from remotely sensed images. The extracted information is being used by incorporating the experts' knowledge. With these developments, in this paper, we conducted an experiment for the human subjects in an image of an area of natural importance. The image along with eight different sets of segmented images of the same area were provided to the human subjects, such that they can improve their understanding using their perception, cognition and decision for the Geographic object recognition. The results of two stages were collated and a relation to mathematical and psychological basis is made. The results showed that there exists different ways to comprehend the geographical objects according to background experience of human subjects, despite the use of similar automatic spatial partitions at different scales. But, also that there exists a certain association of pertinent scale to the human perception in recognising the spatial objects.

Keywords: Spatial object, GEOBIA, Human subject, Geography, Recognition

1 Introduction

Spatial object formation and their recognition by human subjects are of prime importance in spatial information science. Object recognition has been studied from different perspectives for example using shape context [1], spatial relationship model [10] and using spatial and functional compatibility [3]. However, a precise recognition of spatial objects in remotely sensed imagery in interpretation and analysis of real world features still need a lot of improvement on the methods developed so far considering the complexity of imaging applications [5]. Geospatial analysts, geographers and experts related to spatial science try their best in delineating such objects. A priori knowledge on the psychological basis, mathematical basis and the concepts on the basis of spatial object formation will help for an accurate interpretation of such spatial image objects. In practical terms, with the intensive application of Geographic Object Based Image Analysis (GEOBIA) in extracting image objects in multiple scales [2], there is a greater need of understanding of the image object formation [6]. In this article, our focus is to contribute in spatial object recognition in satellite images taking into account the psychological and mathematical basis of object formation and recognition. In particular, among many aspects of spatial object formation, we present Boundary Contour System (BCS) and Feature Contour System (FCS). BCS activates a boundary completion process taking texture into account whereas FCS activate a diffusion filling-in process that spreads featural qualities like colour across the perceptual domain [8]. The role of colour and texture in forming spatial objects in satellite images is extremely important. With this realisation, in this paper, we developed a protocol on spatial object delineation and performed an experiment on a high resolution image segmented in multiple scales taking colour and texture into account. The segmented images in multiple scales were given to human subjects along with protocol in two stages.

The main goals of this experiment were to extract the information from human subjects on their ability to delineate the spatial objects in very high resolution image and compare their results with the software generated results in multiple scales. Further, they were asked to suggest optimal scales corresponding to the spatial objects in the real world. Image object recognition is based on the objective and subjective dimensions where the objectivity is guided by the parameters like colour, texture, shape, size and scale whereas the subjectivity is guided by the perception and cognition of the image interpreters. In this paper, we aim to answer to the following questions:

Do the automatic partitionings correspond to the subjective delineations of the real world features in the image? Are there relevant scales to be used to depict certain types of geographical objects? In general, what kind of methodology could be designed to address these issues? In answering these questions, we limited ourselves in evaluating the results in the following aspects: a priori knowledge of geographical objects in the study area in terms of semantic and geometric features, object interpretation and object analysis.

The organisation of the paper is as follows: in section 2, we present a brief background on spatial object formation taking into account psychological and mathematical basis. Section 3 presents an overview of data, GEOBIA along with a test example using GEOBIA. Section 4 presents the results from the experiment. Section 5 presents discussions and conclusions and section 6 presents the future work.

2 Spatial object recognition

Geographically speaking, a spatial object inherits the characters for example shape, size, colour, texture, form, etc. these are realised after perception, recognition and then interpretation. The process of perceiving, recognising and interpreting are related to psychological and topological-geometrical framework.

2.1 Psychological basis of image recognition

There were many developments in psychology in perception, recognition and interpretation of any system or object. The associated theories like Hierarchy, Catastrophe, Chaos and Fractal contributed in this domain of defining, perceiving and realising the things. We focus on hierarchy theory and human perception and cognition in realising the discontinuity of spatial objects. We suggest readers to refer the works by Gestalt, Husserl and Petitot for details [4]. In realising an object, we perceive the characters such as shape, size, colour, texture and process these cognitively for formalism. Then we interpret the object as a thing, which usually belongs to a common shared knowledge. While processing all these and separating the objects the above characters help us to segment the object and differentiate it from other similar objects in a particular scale. Thus segmentation and scaling have key roles in object recognition. We present these two (segmentation and scaling) in the framework of qualitative discontinuities in the natural world after [7]. The mathematical basis takes into account topological-geometrical description and their physical explanation. This formalism is directly adapted from [4] and [7] works.

2.2 Mathematical basis of image recognition

Phenomenologically speaking, a material system S occupying a spatial domain W establishes its form through a set of observable and measurable qualities $\{q_1(w),.......,q_n(w)\}$ that are characteristics of its actual internal state A_w at every point $w \in W$, and take their values in typical quality spaces $Q_1,......,Q_n$ (colour, texture, etc.). When the spatial control w differs smoothly in W, A_w differs smoothly, too. If A_w exists as the actual state, then the q_i functions also differes smoothly. But if the actual state A_w bifurcates towards another actual state B_w when w crosses some critical value, then some of the q_i functions must present a discontinuity. [7] called regular the points $w \in W$, where locally all the qualities q_i vary smoothly and singular the points $w \in W$, where locally some of the q_i present a qualitative discontinuity. The set R of regular points is by definition an open set of W and its complementary set $K = W - R$, the set of singular points, is therefore a closed set. By definition, K is the morphology produced by the internal dynamical behaviour of the system S. It decomposes W into homogeneous regions.

From the morphodynamical perspective, to explain the observable morphology of any substance or feature the efficient way is to generate a segmentation (W, K) from its underlying physics where K is controlled by the critical values of the control W i.e. by the values for which the internal dynamics X_w displays a catastrophe or a bifurcation, one internal state being replaced by another internal state. To do the segmentation, first we observe some level or scale of observation and we have to make visual perception. There exist two fundamental systems in visual perception namely Boundary Contour System (BCS) and Feature Contour System (FCS). BCS controls the emergence of the segmentation of the visual scene. It detects, sharpens, enhances and completes edges, especially boundaries, by means of a “spatially long-range cooperative process”. It groups textures and generates a boundary web of form-sensitive compartments that simultaneously encode smooth shading, discrete boundary and textural elements. The boundaries organise the image geometrically (morphologically). On the other hand, FCS performs featural filling-in (lateral spreading), i.e. diffusion. It establishes qualities such as colour or brightness. The diffusion process is triggered and limited by the virtual boundaries provided by the BCS.

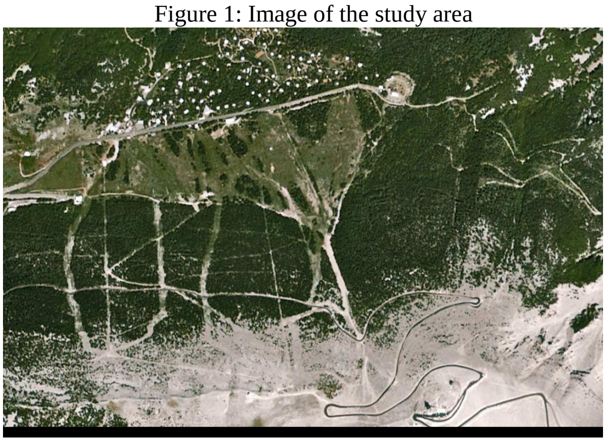
With this mathematical and conceptual note we argue that BCS delineates the boundaries taking textural information whereas FCS delineates the boundaries taking colour information into account in forming the spatial objects. In this mathematical ground we formulated our experiment for texture and colour in GEOBIA.

3 Data and Methodology

3.1 Data

An image of Mont Ventoux (Mont Serin), South of France was obtained from Google and georeferenced to projected coordinate system of local area. The study area is a nature reserve and consists of different land use types from ski field, camping to residential houses in touristic areas (Figure 1). The image was processed to generate meaningful image objects using eCognition software version 8.7 [9] in a framework of Geographic Object Based Image Analysis (GEOBIA). To test the framework we develop “candidate objects” in five different scales as presented below (Table 1).

Figure 1: Image of the study area



3.2 GEOBIA

The image segmentation or partitioning is in practice from 1970s and is a basic building block for GEOBIA [2]. The

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partitioning is basically made taking into account the homogeneity and heterogeneity criterion in image analysis [5]. However, with geographic features we take into account the context as well in making the partitioning [6]. Such partitioning or segmentation is based on the defined algorithm for example edge detection, multi-resolution, chessboard etc. Among the available segmentation methods, multi-resolution segmentation is chosen to generate the image objects in multiple scales [9]. The optimum segmentation parameters were determined using a systematic trial and error approach validated by the visual inspection of the image objects. In this study, the colour criterion was assigned a weight of 0.9 and the shape received the remaining 0.1 (compactness 0.5 and smoothness 0.5) as these two are complementary. The weight 0.9 for colour refers to the emphasis on object's colour in delineating the objects. Five levels were generated in hierarchy namely for scale indexed by scale factors 20, 40, 80, 150 and 250 to extract the meaningful image objects. The same scaling parameters were chosen for a weight of 0.1 to colour meaning that the more emphasis on object's texture in delineating the objects. The map of these image objects were provided to the human subjects for a test experiment along with the developed protocol.

Table 1: Parameters used in developing candidate objects.

Scale	Colour	Texture
20	0.1	0.9
40	0.9	0.1
40	0.1	0.9
80	0.9	0.1
80	0.1	0.9
150	0.9	0.1
150	0.1	0.9
250	0.9	0.1
250	0.1	0.9

3.3 An experiment with human subjects

We developed a protocol in two stages for a group of human subjects. The human subjects were chosen in a way such that we can differentiate the effect of priori knowledge in spatial object recognition. The group of human subjects comprised 4 geographers (G), 2 ecologists (E), 2 economists (Ec), 2 computer scientists (I) and a child (C) of 12 years old. The test was performed in two stages. In the first stage of the protocol, we provided the map of the study area to human subjects who are familiar with it. We asked to identify and characterise several land-uses or land-covers the human subjects can find. We further asked to complete the task within 20 minutes. We provided the table to list the land use-cover types, the representative contouring colour and to justify there choice. A question was asked to provide the information in the difficulty of recognising the geographical objects in the provided map. The results from the first stage were collated, analysed and summarised.

In the same day, after the first stage we handed in the second stage protocol to the human subjects along with original map of the study area (the one given in the first stage) and nine other segmented maps in multiple scales (see Table 1). We asked to observe these maps carefully mentioning that they are drawn at different scales, and that they show many objects of different shapes, sizes, textures, which are more or less homogeneous and present different contour accuracy. The targeted land-uses or land-covers were provided with their assigned colours: camping (brown), houses (red), residential area (orange), ski run and area (pink), forest (green), copse (purple), grassland (blue), rocky ravines (black). We asked to draw the contours of relevant objects using the relevant colour in the "pertinent" map they could find for this purpose. We have asked to complete the task in about 30 minutes. We collated the result, analysed and summarised.

4 Results

4.1 Results of stage 1

The response result of the first stage of the experiment shows that ecologists focused on the land cover and land use of the real world while geographer focused on the classification of whole landscape. In general, geographers identified many real world objects accurately than other human subjects. They also draw the complete image.

Independently from their professional background, most of the human subjects delineated 4 or 5 groups of geographical objects. Only the young girl found 3 classes, and a geographer who knew very well the Mont Ventoux, designed 9 accurate classes. This choice clearly has dependent on the spatial granularity considered. Indeed, we identified two main strategies in object recognition. About half of the participants designed aggregated objects: the houses were contoured, as well the copse and the camping (when it was found). The other people applied a multi-scale analysis, including delineated areas (generally forest, grassland, residential area), and drawn hot spots (houses, camping, few copses). It is also noticeable that the accuracy of the exercise varies a lot with the individuals. Geographers or ecologists, often explicitly handling pattern geometries, use to draw precise contours in our experiment. As ecologist depicted the land cover and the land use considering shape, size, colour and texture, the representative sample of the result of an ecologist is provided for the map and justification (Fig. 2 and Fig. 3).

4.2 Results of stage 2

The second stage of the experimental protocol provided interesting complementary results. We proposed to the subjects a series of maps delineating the spatial objects in terms of land cover / uses at different scales. The results are presented in the Table 2 for corresponding maps represented in numbers for example 150-0.1 is for the map with scale 150, colour criterion 0.1 and texture criterion 0.9.

First of all, when we look at the scales, it does not clearly appear some dominant choice for a given land use or land cover. But when we decompose the information of the Table 2, even with a small sample of subjects for this experiment, we notice that there exists a link between the 'pertinent' scale and the type of object.

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Table 2: Results from stage 2 (X means not found by participants)

Human subjects	Camping	Houses	Residential area	Ski run and area	Forest	Copse	Grassland	Rocky ravines
E1	150-0.1	20-0.1	40-0.1	250-0.1	40-0.9	X	40-0.9	X
G1	150-0.1	20-0.1	250-0.9	250-0.9	250-0.9	80-0.9	80-0.9	250-0.1
G2	X	20-0.1	250-0.9	150-0.9	250-0.1	150-0.9	150-0.9	250-0.1
G3	150-0.9	150-0.9	150-0.9	150-0.9	150-0.9	150-0.9	150-0.9	150-0.9
G4	150-0.9	150-0.9	150-0.9	150-0.9	150-0.9	150-0.9	150-0.9	150-0.9
E2	150-0.9	40-0.9	250-0.9	80-0.9	250-0.9	80-0.9	80-0.9	X
I1	X	20-0.1	80-0.1	20-0.1	80-0.1	20-0.1	150-0.1	250-0.1
Ec1	X	20-0.1	250-0.9	250-0.9	250-0.1	X	150-0.1	250-0.1
Ec2	X	80-0.9	80-0.9	250-0.1	250-0.1	20-0.1	250-0.1	250-0.1
C1	150-0.9	80-0.9	250-0.9	250-0.1	250-0.1	40-0.1	80-0.1	250-0.9
I2	X	250-0.9	150-0.1	80-0.1	80-0.1	80-0.1	250-0.9	X

The camping and the rocky ravines (Fig. 4), which are typical, rather homogeneous and distinct objects, seem to be delicate to find, although when people succeeded in that mission, they mostly agree on same or close scale (respectively 150 for the camping and 250 for the rocky ravines).

Figure 2: A representative result for stage 1 of the experiment

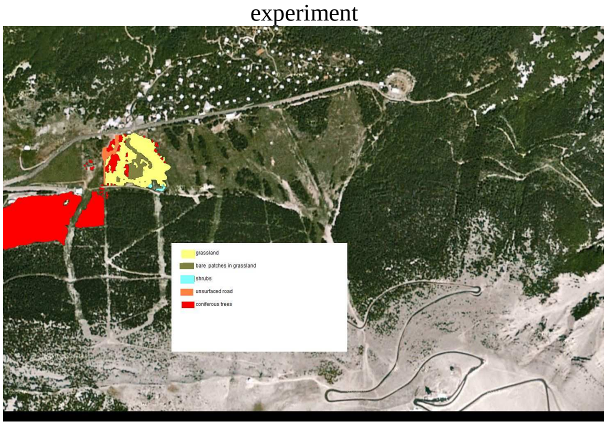


Figure 3: A representative result for stage 2 of the experiment (Houses)

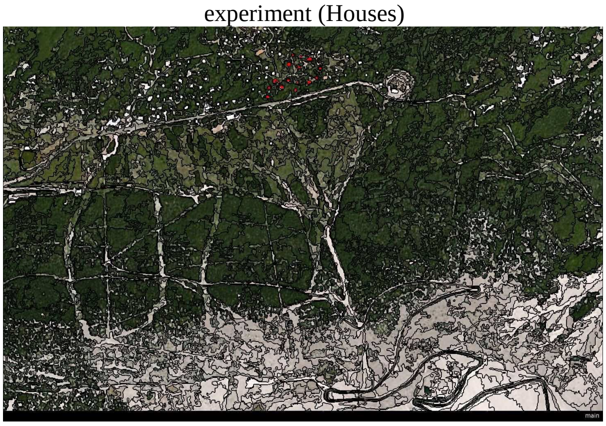
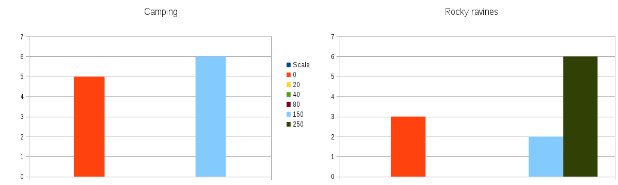
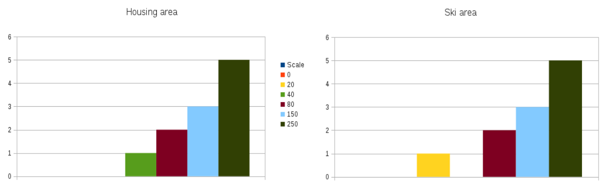


Figure 4: Results for camping and rocky ravines



When the question mentioned the term 'area' (for housing and ski areas for instance), the scale distributions look like each others, with a neat peak in the highest scale (Fig. 5). It seems here that a useful scale sets beyond 80.

Figure 5: Results for housing area and ski area



This distribution shape is then a little degraded for forest and grassland (Fig. 6), though there still exists a peak for each of them. It is noticeable that grassland seems easier to delineate at the scale 80-150, because it is indeed interspersed by many copses and forest patches and does not look really homogeneous.

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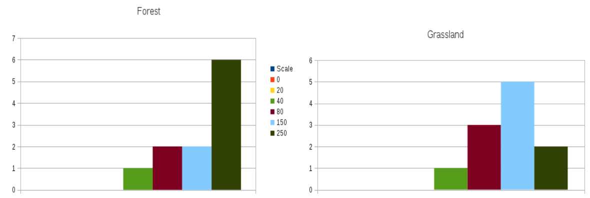
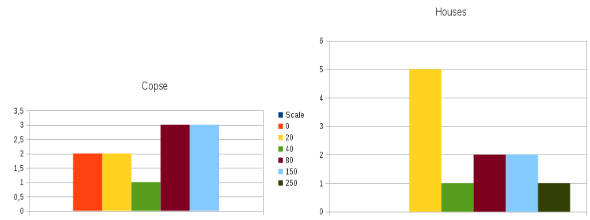
Figure 6: Results for forest and grassland



We find in the last two graphs (Fig. 7) very different geographical objects. The first one is the houses. Their strong homogeneity in (light) colour, (squared) shape, (small) size and (regular) density enabled all the participants to recognise them, with a coherent peak in the smallest scale (20). However, some participants still considered them as an 'area of houses', that explains the choice of higher scales (80 and 150, notably).

Copse has been introduced in the protocol due to a certain definition ambiguity and also because it sets as a kind of composed object. Indeed, copse is closer to morphology than the other tested land uses and covers, at least in the way the participants perceive it. What is the composition of a copse? What is its size? This fuzziness leads to a larger variety in the choice of scale, with no clear peak.

Figure 7: Results for copse and houses



We analysed in details the comments provided by the participants. Although it seems impossible to compare them due to their textual peculiarities, it is however possible to make a hierarchy from the different cited terms to justify their choice. Here is a ranking of the 4 main arguments, except the scale which was the targeted explicit objective:

colour: the fact the colour is important is explicit or the real observed colours are written for the main spatial objects

shape: often associated to 'zoning', 'area', 'set', 'coverage', 'form', the shape is a combination of object perimeter geometry and content of this perimeter; we were satisfied as some of the participants gave very precise descriptions of these shapes ;

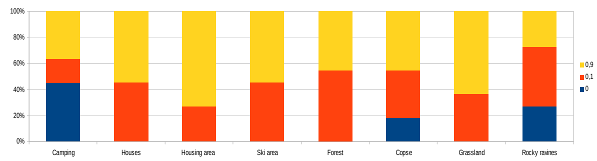
texture: relating to 'segmentation', '(de)composition', 'patches', texture is somewhat more difficult to handle because it involves the spatial granularity, while the participants had to deal with objects to recognise;

confidence: several participants focused on remarks that comment their success (or not) to find the objects; this is a dual information which can be used to make relative the object detection.

The above results showed us that, as expected, there is a clear association between object recognition and pertinent scale of candidate objects.

Figure 8 illustrates the dominance (or not) of the colour as a criterion in object recognition. A value of 0.9 corresponds to objects that eCognition has drawn mainly following the colour characteristic. When this value is 0.1, this means the image with objects depicted by their texture has been favoured in the anaysis. For instance, the houses and their area seem to be recognised using their light colour, whereas forest and rocky ravines, corresponding to very large areas, involved rather homogeneous textures in object determination. However, these trends cannot be generalised and it is interesting to notice that both colour and textures have been taken into account by participants.

Figure 8: Colour *versus* Texture



5 Discussion and Conclusions

The results we got from different human subjects showed that there are similarities in some of the land cover types for example houses and dissimilarity in ski fields. This revealed that there is an agreement among the subjects for finer scale objects which suggests us that the perception of the subjects is matching in finer scales [5] for example in recognising the houses whereas it is not in the coarser scale such as for the ski fields.

We are conscious that our sample is tight and not representative of the variety of possible human perception. Nevertheless, these experiments tend to show that possibly there exists a pertinent scale for which a certain type of spatial objects may be recognised. Most of the participants succeeded in finding this scale useful for a given object. None of them argued they would like to keep all maps to draw their findings. The comparison between the two stages, unsupervised followed by supervised, shows that the participants applied the same method (areal *versus* multi-scale) in both stages. But, on the other hand, most of them did not feel bothered to search from a defined list of objects.

Regarding the different results obtained about the choice of scales to identify certain kinds of objects, it seems that there is fortunately a relationship between what human subjects perceive about the real world and some of the partitioning levels proposed by the software (eCognition). Then, we propose to introduce a process of « relevant scale » in object recognition, in a third stage. This process will lay on a set of priori knowledge established by experts, in a supervised way. This will permit to join the multi-scale approach with the expert knowledge. These spatial signatures can then be fed into eCognition to find relevant object at a given 'pertinent scale'. This approach will be tested later.

6 Future Work

This study indicates possible future research topics as well as refinements and extension to the current framework. The refinements could be made in selecting the human subjects by incorporating experts of the local area to have precise cognitive information in recognising the spatial objects. The extension of the work will be made by incorporating the topographical features and their role in creating spatial objects. Such objects would be given to the human subjects and the difference in object recognition will be analysed. The role of topographical features like road network and digital elevation model of the territory will be added to develop the spatial objects. Such objects will be given to the human subjects in making recognition. We will compare the difference of object recognition ability of human subjects of different portfolios in different scenarios with and without topographical features. With the inclusion of such topographical features we do hope that we will be able to characterise the spatial object recognition ability of human subjects having different portfolios. The semantics of spatial aspect will be added with the inclusion of topographical features.

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