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Automatic generation of land use maps from land cover maps

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Abstract

Land cover is the observed (bio)physical cover on the earth's surface. Land use is characterized by the arrangements, activities and inputs that people undertake in a certain land cover type to produce, change or maintain it. The overall aim of the research described in this study is to formalize a methodology that automates land use mapping process for urban areas. The assumption underlying this approach is that land use objects can be distinguished on the basis of semantic and spatial information of land cover objects.
Keywords: Earth Observation, Land Cover, Land Use, Topology Information.

1 Introduction

Nowadays, many public and private agencies, like the Environmental Protection Agency of Austria in the LISA (Land Information System Austria) project [7], use a manual approach, based on classic photo-interpretation techniques, to derive land use information from land cover maps. These methodologies are expensive, time consuming and subjective. In some cases, semi-automatic procedures are applied: for instance, to produce GMES Urban Atlas maps [5], image analysis packages such as eCognition [4] are utilized. Automatic processing techniques may reduce the time employed for manual interpretation, satisfying current demands for continuous and precise data that accurately describes the territory.

While land cover is related to the physical characteristics of the earth's surface, land use is related to the socio-economic occupation of the earth's surface: hence, the classification process to obtain it is more problematic [3]. Land use is primarily defined in terms of human activities but it can be inferred from the structure of physical components. Spatial patterns and relations (among land cover objects) must be taken in consideration to derive the land use.

The field of Object-Based Image Analysis (OBIA) is mainly devoted to object-based classification of satellite image to obtain land cover maps and in fewer cases land use maps [9, 10, 12]. Such object-based techniques could be further extended to identify more complex land use objects starting from the basic knowledge of land cover objects in the classified images. Complex structures (e.g., a nuclear plant or road network) can be identified as the result of the combination of different objects or of groups of objects [1]. This requires the study of the spatial and semantic relations among the objects and their definition in computer language [8].

Early work in this area is described, e.g., in [2], where authors define a Structural Analysis and Mapping System (SAMS) that is able to understand urban land use in terms of structural composition of the land cover objects. More recently, in [6], authors describe a pattern recognition methodology to automatically classify urban structure by using their morphological properties and topological spatial relations. While previous methods explicitly search for spatial relations and try to understand the spatial structure among land cover objects, in [13], authors propose a more black-box oriented method that statistically examines the land cover information to determine the land use of the parcel.

The overall aim of the research described in this study is to formalize a methodology that automates the land use mapping process for urban areas. The assumption underlying our approach is that land use objects can be distinguished on the basis of semantic and spatial information about land cover objects. A distinguishing aspect of the proposed methodology is that land cover maps and the output land use maps are stored in a vector data model. We suppose to use OGC Geometry Object Model [11] to describe the objects' geometry. Various computational geometry algorithms are used for checking geometric properties and relations between land cover objects and for transforming geometries.

This paper is organized as follows: the proposed methodology that automates land use mapping process for urban areas is outlined in section 2. In section 3 the methodology is applied to a LISA data set to identify residential areas. A summary concludes the paper.

2 Methodology

We suppose to consider as input a pre-classified map containing only simple features belonging to land cover classes (Figure 1). The expected result of the automatic procedure to generate land use from land cover is shown in Figure 2.

To clarify the proposed methodology we apply it to the "Urban Settlement" use case, which aims at identifying residential areas. Land cover maps used for testing our methodology are based on the LISA data model. LISA defines a set of land cover classes ("building", "other constructed area", "tree", "surface water", ...) and land use classes ("urban settlement", "agricultural block", "forest block", ...) to classify features belonging to land cover and features belonging to land use. In the land cover of Figure 1, "other constructed area" is a polygon with holes represented in light yellow, "building" objects are polygons represented in red, and "tree", "bushes" and "shrub" objects are polygons represented with various shades of green.

Figure 1: Extract of land cover map

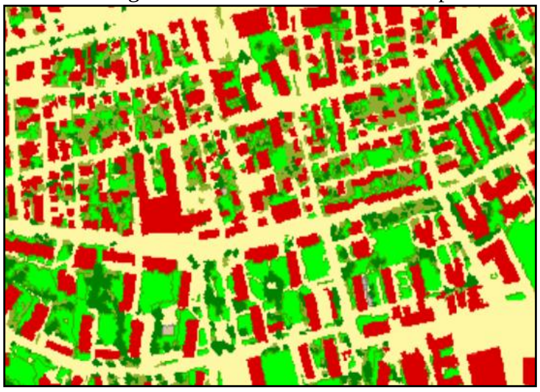
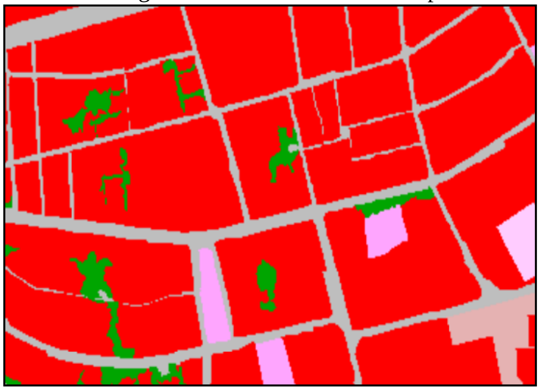


Figure 2: Extract of land use map



The proposed methodology consists of four phases. The first phase aims at defining geometric properties and semantic relations that characterize land use objects. Specifically, for each land use object we need to define a set of land cover objects with their geometric attributes and the semantic and geometrically relations among them: for example, the reference distance between land cover objects, the reference size for land cover objects, their reference shapes, and the occurring topological relations.

The second phase aims to define the geometric operators (via computational geometry algorithms) that allow us to compute and/or verify geometric properties and spatial relations identified in the previous phase. The third phase aims to define a set of parameterized functions that performed in a given sequence permit to identify land use objects. Typically, the first functions to apply aggregate and group land cover objects into intermediate categories; subsequent functions refine land use object geometry with cartographic generalization operators. Finally, the fourth phase aims at testing functions formalized in the previous steps on real data. The assumptions underlying the last phase are that input maps are vector layers containing only land cover objects and that land cover objects form a planar subdivision.

3 Urban Settlement use case

The Urban Settlement use case aims at defining urban land use objects such as residential areas. Residential areas can be recognized by analysing the shape and size of buildings and the spatial relations among them. In order to implement the Urban Settlement use case, the sequence of functions that must be carried out are the following: (1) Object Aggregation; (2) Object Grouping; (3) Object Refinement; (4) Object Check Size.

The Object Aggregation function aims at creating the urban settlement aggregates putting together the land cover objects that semantically belong to specific land cover classes (such as "building", "tree", "bushes" and "herbaceous"), that are dimensionally comparable and not too big or small with respect to a reference size, and that satisfy the topological relation "touch" (Figure 3).

The Object Grouping function groups together the identified urban settlement aggregates. Clustering algorithms, based on boundary or centroid distance, are used to identify urban settlement aggregates to group in a single cluster (Figure 4).

Figure 3: Urban settlement aggregate identified by Object Aggregation function (object geometry is a Polygon)

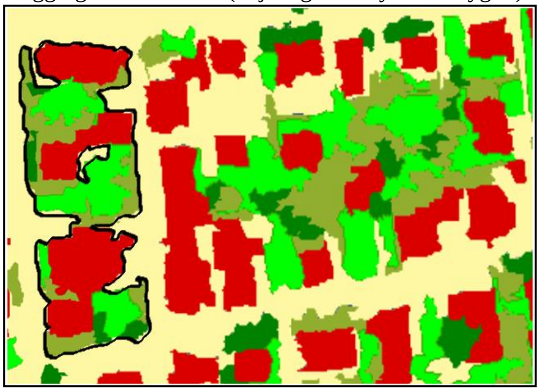


Figure 4: In this example the Object Grouping function constructs one cluster (object geometry is a MultiPolygon)

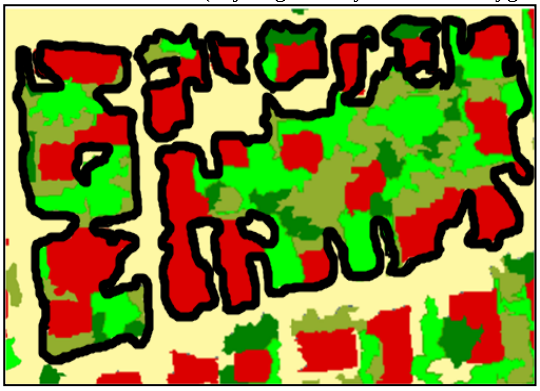


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Figure 5: The Object Refinement function. Fusion transforms a MultiPolygon in a Polygon

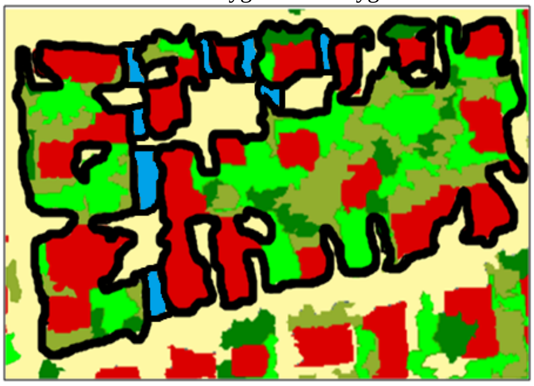
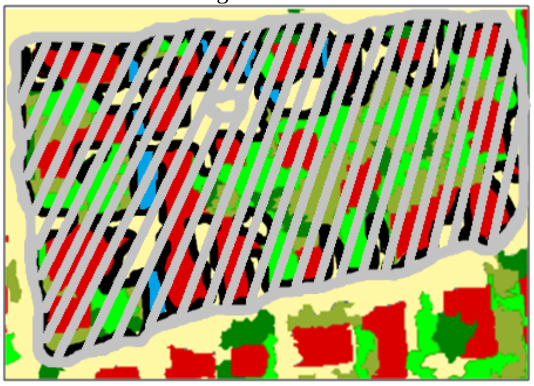


Figure 6: The Object Refinement function. Shape regularization



The Object Refinement function involves two steps. The first step consists in fusing the objects that are closer than the identified distance, by making the convex hull of neighboring parts of boundaries (Figure 5). The second step performs a regularization of the object shape, by filtering small irregularities and by replacing irregular sides with straight edges (Figure 6).

Finally, the Object Check Size function carries out a validation of the land use objects constructed so far. Only land use objects that have an area greater than the minimum mapping unit (MMU) of the output data set are considered valid.

4 Conclusions

In this study, we outlined a new methodology to automate the identification of land use objects from land cover maps. As a use case, we applied it to the identification of residential areas. As a further development of this work, we will apply the methodology in other use cases, such as the identification of industrial and commercial areas or agricultural land use. We plan to integrate the methodology in a web-based GIS architecture and validate the approach with LISA end-users.

Acknowledgements

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