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Land cover class extraction in GEOBIA using environmental spatial temporal ontology

Jagannath Aryal[a,*], Ahsan Morshed[b], Ritaban Dutta[b]
[a] School of Land and Food, University of Tasmania, Hobart, Australia
[b] Autonomous System, CSIRO computational Informatics, Hobart, Australia
*Corresponding author: Jagannath.Aryal@utas.edu.au, +61362262848

Abstract: Very high spatial resolution (VHSR) remote sensing imaging brings challenges and opportunities to intelligent autonomous interpretation of spatial data due to detailed information available in such images. Accurate extraction of information relies on expert knowledge which can be represented by an Ontology. Within the Geographic Object-Based Image Analysis (GEOBIA) framework, Ontological implementation is recently been started which has created different avenues of novel applications. In this paper, we have developed an Environmental Spatio-temporal Ontology (ESTO), using five different publicly available environmental data sources namely SILO, AWAP, ASRIS, CosmOz, and MODIS, where knowledge was integrated and captured in multiple-scales using resource description framework (RDF). RDF representation made the ESTO very effective way to publish on Linked Open Data Cloud (LOD) environment. ESTO and the RDF adaptation helped for the human-computer interaction with spatial data whereas an automated approach for object interpretation has also been developed. Our Ontological approach integrates thematic with the spatial semantics for the GEOBIA framework. This study tested a WorldView-2 imagery of Hobart, Tasmania, Australia in depicting land cover classes and effectiveness of ESTO for the GEOBIA framework.
Keywords: ESTO, GEOBIA, Ontology, Spatial semantics, Thematic semantics, WorldView-2.

1. Introduction

Land cover and land use classification using remote sensing image analysis has a long tradition of using pixel based approach. Pixels are considered as a basic and fundamental level of image analysis. However, pixel-based analysis is not representing our cognition, perception and interpretation to real world features and hence it has many limitations (Blaschke and Strobl, 2001). Alternative to pixel-based approach, object based image analysis takes individual objects into account where contiguous homogeneous pixels merged to form an object that represents our cognition. In forming image objects this approach considers the contextual and spatial knowledge on top of spectral similarities. This approach – GEOBIA - is now considered as a new paradigm in remote sensing image analysis and GIScience (Blaschke et al, 2014). From GEOBIA's early inception in 2000, scientific studies on methodological issues and applications of GEOBIA showed its usefulness to the remote sensing community and beyond (Blaschke et al, 2014) in the analysis of VHSR imagery. Although it has been used increasingly in many applications, there are challenges associated with the methodology which need to be addressed for its advancement. As it is knowledge-based approach the semantics plays a vital role in characterising the real world objects by developing rule sets (Arvor et al, 2013). Further, the challenge lies in the transferability of

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rule set in different territorial analysis. Considering the challenges in advancement of this methodology and the role of spatial and thematic semantics, in this paper, we customised the developed environmental spatio-temporal ontology – ESTO (Morshed et al, 2013a) within the GEOBIA framework. Specifically, we consider the object information and their association to ESTO. ESTO is used as a filter to refine the object information in different scale levels.

2. Ontology in spatial information and its relevance to GEOBIA

A few works has been done in this area and most well-known ontologies are SWEET ontology (URL2) for earth and environmental science, Semantic Sensor Network-Ontology (Compton 2009), ontology for sensors, GeoName- ontology for geographic names. All these ontologies help to interpret and query spatial objects from the spatial data. However, none of them acquire the demand of managing large metadata scale from different data sources. So, we developed ESTO for capturing the spatial data. Recent study by Blaschke et al, (2014) highlighted the ontological importance in GEOBIA.

3. ESTO in object interpretation

The big challenge in spatio-temporal data integration and sharing is to tackle the spatial semantic (i.e., location, Name, Area) and the thematic semantics (i.e., rainfall, temperature, evaporation) used in different data sources. In ESTO, Environmental attributes were semantically matched to form several subgroups, i.e. {SILO Max Temperature (degC), SILO Min Temperature (degC), AWAP Max Temperature (degC), AWAP MinTemperature (degC), and MODIS/Terra Land Surface Temperature (degC)}. Furthermore, it has been published as LOD cloud environment for further applications using RDF (URL1) and has been applied in recommending environmental knowledge (Morshed et al., 2013b) and agricultural decision making (Dutta et al., 2014).

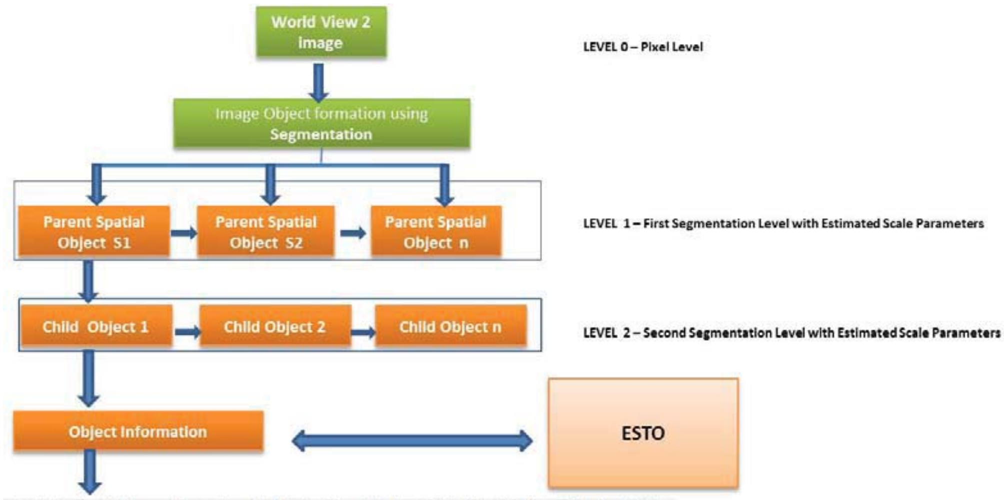
4. Data and proposed approach

The data used in this study is a WorldView-2 imagery acquired from a commercial Earth Observation Satellite owned by Digital Globe (Fig 1a). The imagery is segmented in multiple levels with a focus on land cover class extraction using multi-resolution segmentation (Fig 1b, and 1c). The segmentation and associated object information are used in proposed ontological architecture. The processes model (Fig.2) is based on the spatial, temporal, and object information of land cover classes. Each land cover class has been abstracted to object information based on the geometric and topological characteristics. Initially a VHSR image is processed by eCognition Software for image object formation in different hierarchies and to build object ontology (Fig.2). Each of the object consisted of different characteristics.

a. b. c.

Figure 1. from left to right (a) WorldView-2 imagery in false colour composite (b) segmented imagery in small scale parameter (40 - 0.5 - 0.5), and (c) segmented imagery in incremental scale parameter (120 - 0.5 - 0.5) showing the image objects in a hierarchical manner.

ESTO has contributed to further refinement of the spatial objects and ascertain the thematic classes with extra information provided by the integrated environmental data. In an object level the proposed ontology can be conceived as described in Fig 3.



Border.length	Width	Asymmetry	Rel..Border.to.Image.Border	Elliptic.Fit	Density	Number.of.pixels
140	24.00000	0.5319621	0.32142857	0.7289837	2.029480	797
262	54.00000	0.6096181	0.28625954	0.5975422	2.062383	2604
128	27.00000	0.1935389	0.00000000	0.7888000	2.194418	625

Figure 2. Process model for extracted objects from VHSR imagery (in this case WorldView-2) where ESTO can be used as filter in matching and refining the object information.

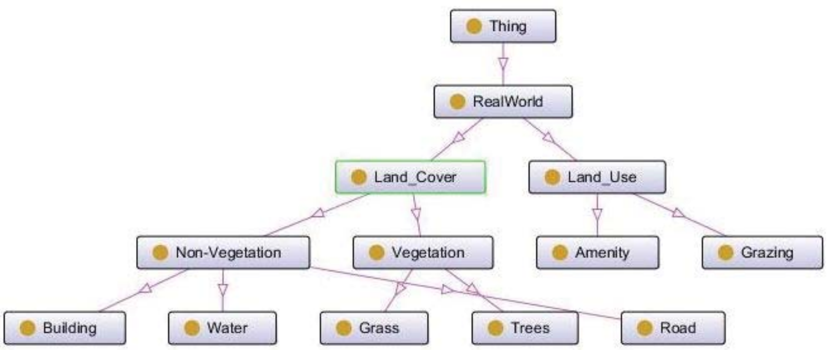


Figure3. An object ontology characterised by their information as presented in Table 1.

The object properties were clearly distinctive for the different land cover / land use classes. A vegetation object can only be characterised with area property on the other hand a tree object can be better characterised by the properties like texture, Area, Ellipticity, Border index, Shape Index, and NDVI.

Table 1. Object information and their spatial characteristics.

Objects	Properties
Vegetation	Area
Trees	Texture, Area, Ellipticity, Border Index, Shape Index, NDVI
Grass	Texture, NDVI, Area
Building	Shape Index, Area, Border Index
Road	Elliptic Fit, Shape Index , NDVI
Water	Area, Border Index, Shape Index
Amenity	NDVI, Texture
Grazing	NDVI, Texture

5. Discussion and Conclusions

In this paper, we developed an ESTO and applied as a filter to accurately define the real world objects in a GEOBIA framework. We conclude that there is a lot to do in terms of transferability of rule set and autonomous object interpretation. We believe our approach here contribute in advancing the GEOBIA methodology in particular for autonomous object interpretation which is considered as one of the challenges by the GEOBIA community.

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Useful links (accessed April 2014)

URL1: http://www.w3.org/TR/REC-rdf-syntax/

URL2: http://sweet.jpl.nasa.gov/ontology/