A Layered Architecture for a Fuzzy Semantic Approach for Satellite Image Analysis

Cecilia Zanni-Merk, ICube Laboratory, University of Strasbourg, Illkirch, France
Stella Marc-Zwecker, ICube Laboratory, University of Strasbourg, Illkirch, France
Cédric Wemmert, ICube Laboratory, University of Strasbourg, Illkirch, France
François de Bertrand de Beuvron, ICube Laboratory, University of Strasbourg, Illkirch, France

ABSTRACT

The extended use of high and very high spatial resolution imagery inherently demands the adoption of classification methods capable of capturing the underlying semantic. Object-oriented classification methods are currently considered as the most appropriate alternative, due to the incorporation of contextual information and domain knowledge into the analysis. Integrating knowledge initially requires a detailed process of acquisition and later the achievement of a formal representation. Ontologies constitute a very suitable approach to address both knowledge formalization and exploitation. A novel semi-automatic fuzzy semantic approach focused on the extraction and classification of urban objects is hereby introduced. The use of a four-layered architecture allows the separation of concerns among knowledge, rules, experience and meta-knowledge. Knowledge represents the fundamental layer with which the other layers interact. Rules are meant to derive conclusions and make assertions based on knowledge. The experience layer supports the classification process in case of failure when attempting to identify an object, by applying specific expert rules to infer unusual membership. Finally, the meta-knowledge layer contains knowledge about the use of the other layers.

Keywords: Expert Knowledge, Object-Oriented Image Analysis, Ontology, Ontology Reasoning

DOI: 10.4018/IJKSS.2015040103
1. INTRODUCTION

In the last few decades, the use of high and very high spatial resolution imagery has been widely extended. The increasing level of resolution has led to some rising complexities in spectral analysis (Herold et al., 2003) and sometimes to the persistence of the mixed-pixel problem (de Kok, Schneider & Ammer, 1999; Blaschke et al., 2000), when a pixel falls into two adjacent objects. Hence, the availability of high resolution imagery triggers an inherent need for very accurate, efficient and robust classification methods. Pixel-based classification methods are insufficient to meet this demand. A major drawback is the “salt and pepper” effect, in which single pixels are classified differently than the surrounding area preventing the generation of homogenous regions (Blaschke et al., 2000).

Object-oriented analysis focuses on the interpretation of the semantic underlying an image. Aiming at imitating human vision perception, this approach works by dividing images into meaningful objects and abstracting more intuitive features as a result (Blaschke et al., 2000). One of its main advantages is the incorporation of contextual information and domain knowledge to the analysis, since the semantics is not always explicitly contained in the image (Puissant et al., 2007). This considerably helps to bridge the semantic gap issue, which arises from the difference in levels of abstraction. It stands as the lack of concordance between the information extracted from the visual data and the interpretation a user may infer from them in a given situation (Smeulders et al., 2000).

Object-oriented image analysis approaches generally follow two steps: segmentation and classification, which are often preceded by some ancillary pre-processing and/or followed by an accuracy assessment step. The selection of an appropriate segmentation algorithm is a key factor in order to achieve a successful identification of the objects in a given image. Sets of adjacent pixels should be gathered together as homogenous segments from which meaningful objects could be derived afterwards. Yet, the definition of the term “meaningful object” encloses some ambiguity (Blaschke et al., 2000), since boundaries in nature are rarely hard and transitions in land cover may be clear, although usually soft.

2. OBJECT-ORIENTED IMAGE ANALYSIS COMBINED WITH ONTOLOGIES

A current tendency in formal knowledge representation is the implementation of ontologies, along with sets of logic rules for its management and exploitation. Ontologies are largely described in (Uschold & King, 1995; Guarino, Oberle & Staab, 2009). Basically, they are defined as conceptualizations of certain reality or domain designed for a specific purpose.

Several efforts have been done to delineate strategies combining object feature extraction from remote sensing imagery with the implementation of
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