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Semantic Representation of Raster Spatial Data
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Available in: http://www.redalyc.org/articulo.oa?id=61520765010
Abstract. When people think spatially, they do not usually consider geographic coordinates nor projections. Facing questions having a spatial sense, people do not answer with maps or coordinates, but use some references whose spatial location is "well known". For instance, the answer of a conventional geographic information system to the question "Where is the CIC?" would be "in coordinates 19.50314°N, 99.14759°W". In contrast, a person would answer "in Zacatenco" or "near to Eje Central". The semantic processing attempts to enrich an abstraction level similar to the one that people use commonly. This processing, applied to spatial data, does not depend on scales, resolutions, projections or others that are fundamental in conventional systems. We assume that the first step for making semantic processing is the semantic description of "raw" spatial data. Such description is the identification of the objects contained in data and the location of such objects within a conceptual framework, where they get a meaning. In this work, we present a methodology for making this semantic description using as a case study the digital elevation models. The methodology is build up of three stages: conceptualization, to define the conceptual framework for the description; synthesis, to process "raw" spatial data and to obtain the spatial objects contained in data; and description, to generate the representation of results from the synthesis according to the conceptual framework.

Keywords: semantic, knowledge, representation, ontology, raster spatial data.

1 Introduction

In this work we present a methodology for describing semantically spatial objects contained within a Raster Spatial Data Set (RSDS), particularly within Digital Elevation Models (DEM). We attempt to make a description based on the knowledge that people have about spatial things, like things we can see on a landscape. We propose a methodology based on three stages: conceptualization, synthesis and description.

On conceptualization stage, we attempt to capture the knowledge about the domain of problem. In other words, we must find and define the concepts used while people talk or think about landforms. The synthesis stage is the numeric one; we have many algorithms for extracting features from the RSDS. The stage is made in the way
images are commonly processed, having pre-
processing, processing and post-processing phases. 
As result of this stage we have parts of the RSDS, 
called “extracts”, that we consider to be an instance 
of a concept. In description stage we determine what 
an “extract” is, and build its semantic representation.

1.1 Previous works

Many of existing works are guided from a numeric 
point of view and a big number of them are focused 
on the flow analysis and extraction of drainage lines 
(Ackermann 1993; Hodgson 1995; Etzelmüller and 
Sulebak 2000). Also, we have explored some other 
areas related to landform analysis and processing; 
we find that geo-morphometry has been deeply 
studied by researchers, but almost always with a 
numeric approach (Weibel and DeLotto 1988; 
Etzelmüller and Sulebak 2000; Sulebak, Tallaksen 
et al. 2000); only some works used “categories” or 
“classes” for making analysis. We have studied 
approaches about conceptualizations and 
ontologies, where we have found philosophical 
works that lies with existence and reality. Those 
works serve as basis for the knowledge 
representation (Smith and Mark 2001; Smith and 
Mark 2003). Similarly, we have studied works about 
ontologies, in practical and philosophical terms; as a 
way for modeling and understanding reality.

2 Methodology

We propose to make a semantic representation of 
spatial data, which is composed of three stages: 
conceptualization, synthesis and description.

2.1 Conceptualization

The conceptualization stage has two parts, 
represented by means of ontologies: high-level and 
domain. Below the methodology for conceptualizing 
the geographic domain will be outlined (Quintero 
2007, Torres 2007). The main part of the 
methodology is the idea of minimizing the number of 
axiomatic relations used to define concepts and 
relationships. We propose a set with only three 
fundamental axiomatic relations (is, has and does) 
and a set of auxiliary relations (prepositions). It could 
seem that the reduction of axiomatic relations 
restricts the expressiveness of the conceptualization. Nevertheless, we state that the 
number of relations to make conceptualization could 
be bigger than in schemas where all relations are 
pre-defined. This brings with it two advantages: first, 
it can be defined as many “classic relations” as 
needed and, second, relations have a semantic 
associated to them, because they are defined by 
means of other concepts or relations. For instance, 
let us consider a widely used relation: “part_of”. 
Consider the following statement: “heart part_of 
body” (Figure 1a), in which there are two concepts 
(heart and body) and one axiomatic relation 
(part_of). Now, if we consider that “heart 
vital_part_of body” (Figure 1b), it is necessary to 
include “vital_part_of” in the set of axioms. Using the 
proposed approach, the first statement would be 
“heart is part of body” (Figure 1c), where we 
involved three concepts (heart, body and part) and 
two axiomatic relations (is and of). In order to add 
the second statement, with our approach, we have 
only to define the concept “vital_part” (that could be 
inherited from the concept “part” and the concept 
“vital”) and use it in the form described previously 
(Figure 1d).

Therefore, we propose that for conceptualizing 
the geographic domain, it is necessary to use and/or 
define the following elements: axioms, relations, 
constructs, properties, abilities and constraints. In 
(Quintero 2007, Torres 2007) are fully defined these 
elements.
2.2 Synthesis

In synthesis stage, we attempt to decompose RSDS in “extracts” according to the conceptualization. For obtaining “extracts”, we use a strategy similar to the one used by people for clustering objects: applying different criteria to different clustering level. We will apply different clustering criteria to each set of objects. In each level we can use different algorithms or criteria. As result of the conceptualization of criteria and algorithms, we obtain the ontology of application.

The conceptualization of the application produces the ontology with all possible results of applying the extraction algorithms (the results of algorithms, not the algorithms themselves). As well as concepts in the domain ontology, as part of conceptualization of application we must set up the relationships of existence between extracts (unnamed concepts) in the application ontology and concepts in the domain ontology.

2.3 Description

Description stage consists of representing, according to the conceptualization, the “extracts” obtained on synthesis stage. “Extracts” are described in the application ontology and linked to the domain and geographic ontologies. However, it is not always possible to link an “extract” to best concept on conceptualization. Then, it is necessary to analyze properties of concepts to improve the linking of them to concepts in the domain and geographic ontologies. To determine the best specialization of an “extract”, the clustering approach is used. In (Quintero 2007) the specialization algorithm is fully described.

3 Results

The conceptualization was made in three parts: conceptualization of geographic domain, of landforms domain and of application. As result we obtained three ontologies that we called Kaab, Hunxet and Wiinkil, respectively. The Kaab ontology has the classes defined to conceptualize the geographic domain, we have used the topographic 1:50000 vector data dictionary for Mexico (INEGI 1996), where are defined more than 70 topographic features which were applied in conceptualization. Detailed description of each class as well as all remaining concepts are presented in (Quintero 2007). The concepts of landforms are conceptualized in the Hunxet ontology, this conceptualization is based on the dictionary of the Spanish Royal Academy of Language. The application ontology, that we call Wiinkil is a conceptualization in form of hierarchy of “extracts” obtained from the extraction algorithms.

The developed ontologies must be integrated each other to use and enrich the knowledge described by them. First, in Figure 2 is shown the integration of Kaab ontology with Hunxet ontology by means of the assignation of the main class in Hunxet (forma del terreno – landform) to corresponding classes in Kaab. In this way we characterize landforms existentially, according to ontology of geographic domain.

The proposed synthesis algorithm generates three types of extracts: “elev” for elevations, “depr” for depressions and “llan” for plains; by applying it recursively, different combinations of these types are generated. We call signature to a specific combination. The algorithm has four steps: 1) compute the longer plain zone (ZLE), 2) region labeling, 3) segmentation and 4) extraction. In (Quintero 2007) this algorithm is fully detailed.

For testing the methodology, we use a DEM, obtained from USGS web site of Grand Canyon on Colorado State, USA. Figure 3 shows the result of segmentation step. Here, we can see four little images: labeled with “zle” is shown the Largest Plain Zone. Labeled with “elev”, “llan” and “depr”, we...
obtained data sets classified under corresponding signature. According to the conceptualization, we must obtain 21 data sets (21 signatures) before starting with extraction step.

5 Conclusions

In this work, we have described methodology for making semantic descriptions of raster spatial data sets. The conceptualization methodology is the most important part of this research; because we propose to make the conceptualization using only three axiomatic relations, that allows to move the “classic” relations to the conceptualization giving to them semantic richness. As part of case study, we have developed three ontologies: Kaab ontology for the conceptualization of geographic domain, Hunxeet ontology for the conceptualization of landforms domain, and Wiinkil ontology for the conceptualization of our application. Synthesis stage is made in the image processing fashion, with phases of pre-processing, processing and post-processing. Description stage is made by using the conceptualization and by applying some templates for describing spatial knowledge.

As future work, we consider that it is necessary to analyze and conceptualize geographic relations (topologic and geometric for instance) between concepts identified and described in this work. Also, we want to measure the quality of the description made. We propose the use of building blocks (basic landforms) for building a synthetic model and compare it to the original data set. On the other hand, we propose to make the description by using formal first order logic and comparing the resulting logics, in order to obtain a quality metric.
Acknowledgments

The authors wish to thank to SIP Project: 20110851 and CONACYT project 106692 for their support.

References


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