An ontology-based model for representing evolution of both data and semantic in GIS

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Abstract. Our research objective is to build a spatio-temporal data model that stores historical changes of geographical features. For this reason we study some existing models, and try to benefit from the existing features they provide. We built our approach on using MADS to assure the multi-representation of geographical objects, and ontology to add the possibility of adding, removing or changing concepts later on, and an explicit temporal relationship implemented in the ontology in order to keep the historical changes of the objects.

1 INTRODUCTION

The goal of GIS is to provide information about a given space. They include many types of geographical objects organized in themes frequently represented as layers (tiers architecture) containing objects of the same type (roads, buildings…). Each object consists of a shape and a description, also called its semantic. A GIS essentially allows answering questions on spatial (where is this object?) and temporal type (when did these changes happen?).

To be able to answer such questions, a simultaneous management of spatial and temporal dimensions should be provided within geographical databases, to insure that temporal elements (identifiers, attributes, metadata…) stored in these databases, translate the most faithfully possible the real evolution of the considered entities. But it is also important to be able to reproduce concept evolution through time.

Therefore, after a short review of existing models (section 2), we will study the important features of the MADS model (section 2.1) and also take a deeper look onto ontologies (section 2.2) that will be the bases for our approach (section 3). Section 4 will be devoted to conclusion and future work.

2 RELATED WORK

Various spatio-temporal data models that incorporate time in GIS have been proposed. The first model was the snapshot model (Langran, 1998). Later on, many improvements have been made and many other more effective models have been proposed. Pelekis (Pelekis, 2004) enumerates ten distinct spatio-temporal models. Among them, The Three domain Model, introduced in (Yuan, 1999) on the basis of "a feature relies on three dimensions for its representation", connects the three dimensions (space, theme (semantic), and time) to resolve spatial and nonspatial changes. It is not capable of representing the evolution in time, space and semantic because it is not able to handle the history of spatio-temporal objects nor the duration of events.

The object Relationship approach added the description of the process which caused the changes in space and time as a relationship type between spatio-temporal objects. This description did not exist before and it provided a better description for spatio-temporal events. Under this approach we find the MADS (Modelling of Application Data with Spatio-temporal features), a conceptual spatio-temporal data model with multi-perception and multi-representation features.

On the other hand, the development of Internet technologies opens new horizons in the field of information sharing using the concept of ontologies. In the following sections, we will have a deeper look at both the MADS model and ontologies.

2.1 MADS features

MADS (Parents et al., 1998) is a conceptual spatio-temporal data model with multi-perception and multi-representation features, enriched by the object-oriented structure that has multiple advantages like inheritance, effective manipulation of temporal data, and uniform handling of spatio-temporal data. It also offers a set of tools for an associated design method (Parent et al, 1999); it has a visual schema editor, an automatic translation feature to translates specifications into equivalent specifications of vendor tools and a visual query editor and viewer.

MADS also solves the fundamental issue of how to add the space and time dimensions by representing the modeling dimensions orthogonally. The orthogonality of its three dimensions (spatial, structural, and temporal) allows the association of a spatial or/and temporal dimension to any element in the model (Parent et al, 1999). It is composed of:

- A Spatial Dimension: provided for shape and location information; it includes representation of points, lines, and simple areas… A spatial feature is described in MADS either as an object or as an attribute. Spatial relationships come in two types: topological relationships and spatial aggregation.
- A Temporal Dimension: it includes representation of instants, intervals, and temporal elements. MADS timestamps the attributes, objects, relationships and/or aggregations in order to support dynamic relationships between objects. It also includes the relative positioning of activities in time to model inter-object dynamics.
- A Structural Dimension: it allows schema designers to represent basic concepts from extended entity-relationship modeling, e.g., objects, Integrity constraints, Is-A links… The structural dimension also allows inherited properties to be refined or redefined along generalization / specialization links.
- Multi-representation features: to allow users to retrieve specific representations from the set of existing ones, multiple representations have to be distinguishable and denotable. The redefinition described in the structural dimension of MADS allows for example to describe multiple spatial representations, one for each of its classes in the generalization / specialization hierarchy.

2.2 Ontologies and GIS

Ontologies are a part of the link between observation of the world and creation of databases and development of information systems. The (Studer, 1998) definition for ontology can be summarized as:

- It is capable of defining the concepts, properties, relationships, functions, axioms and constraints from which it is composed, making it explicit
- Being machine readable and interpreted makes it formal
- Because it is an abstract model and a simplified view of the domain phenomena it represents, it becomes a conceptualization
- And since there has previously been a consensus about the information and it is accepted by a group of experts, an ontology is shared

Briefly, we can say that an ontology is the definition of a set of concepts, its taxonomy, interrelation and the rules that govern such concepts. Therefore, they are mainly used to share knowledge and are an important step toward GIS interoperability (Bateman and Farrar, 2006). An interesting property is that their enrichment is possible (modifying the underlying conceptual model) in order to clarify the definition of some concepts, add/remove concepts or relationships.

3 OUR APPROACH: MADS + ONTOLOGIES

3.1 Comparison between MADS (as a conceptual schema) and Ontologies

Many researchers have asked themselves whether ontologies were actually the well-known conceptual data modeling techniques in disguise. But (Bishr and Kuhn, 2000) think that ontologies are external to information systems while a conceptual schema is internal. The conceptual schema of a database is not evolutionary (defined only once before creation of instances). Ontologies are alive, and updating bodies will be done without full knowledge of the ontology. Databases assume the closed world while ontologies assume the open world (Fonseca and al, 2003).

3.2 Benefit from MADS and ontologies

Our goal (Figure 1) is to create a new model for GIS which insures:

Multi-presentation of geographic objects

Keeping track of the historical data of objects

Adding, removing, and changing some concepts

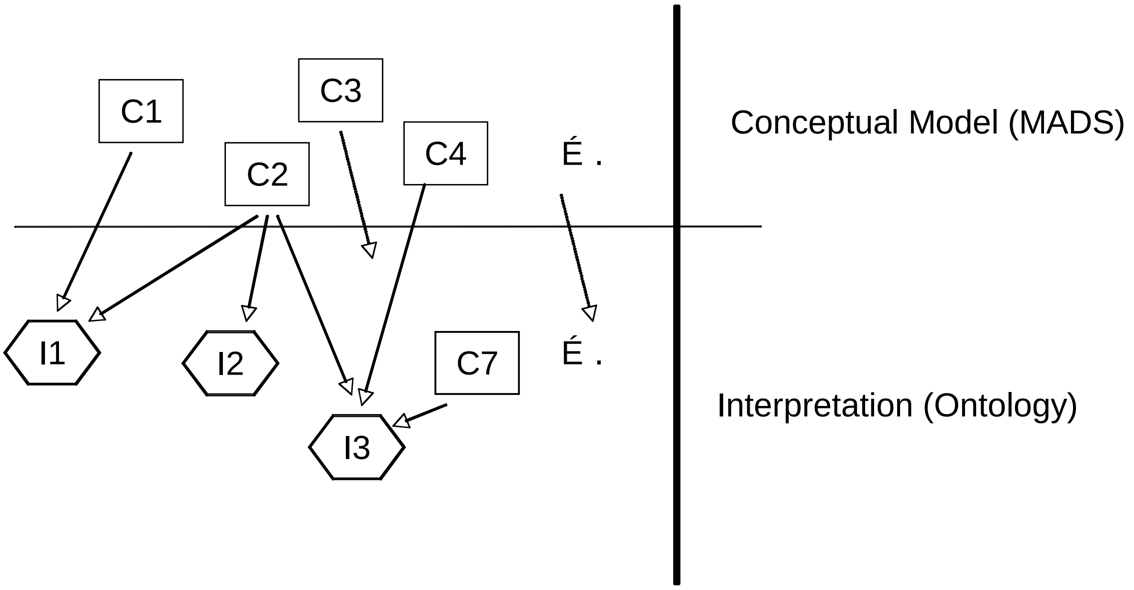

Figure 1: Combining MADS and ontologies (C stands for conceptual model, I for interpretation)

To achieve these goals, we benefit from pre-existing models by combining MADS with ontologies. MADS supports multi-representation of geographic objects (Murmur project (Parent et al, 2006) uses MADS for this purpose) while ontologies allow modifying the underlying conceptual model; an ontology is created respecting the MADS conceptual model (from scratch). By having this ontology, which shares the same concepts with the MADS conceptual model, concept changes are thus allowed; in other words, now we can add, remove and change one, or many concepts. These concept changes will be tracked within the new ontology aswell. To achieve history tracking of instances we define a new explicit temporal relationship that allows further temporal querying on individual feature history in both space and theme. This temporal relationship is, on one hand, implemented in the ontology and directly connected to the ontology's concepts and, on the other hand, linked to the "Space", "Theme" and "Time" classes of ISO's Temporal Schema which will be implemented using MADS.

An algorithm will be developed to construct the explicit temporal relationships knowing that each instance has a creation node and a destruction node and can be subject to several changes. The creation/destruction node is a timestamp indicating the time of creation/destruction. There is one concept change and eight possible spatio-temporal changes (Change in geometry, in topology, in attribute, in geometry, in topology and attribute, in geometry and topology, in geometry and attribute, in topology and attribute and finally no change) what makes 16 possible combinations to represent changes in geometry, topology, attribute and/or concept. In order to detect instance changes, the geometry, attributes, topology and concept of features are retrieved and compared through time and each instance change implies a temporal relationship creation.

An explicit temporal relationship (Choi, 2007) has three attributes:

- Start Node: Instant where the relationship began
- Finish Node: Instant where the relationship ended
- Value: the value of the temporal relationship that will be determined as follows:
  - At object creation, value is set to "Begin"
  - If an object is a new entity derived from a previous existing object the relationship value will be set to "Begin-Replaced" instead of "Begin"

- Each possible change from the sixteen possible changes above will have a specific value (“Changed geometry”, “Changed geometry and attributes”…)
- And when an object is destroyed the value will be set to “End”

3.3 Example

We will show how our model can represent the changes of concepts in a Urban Development Plan (UDP).

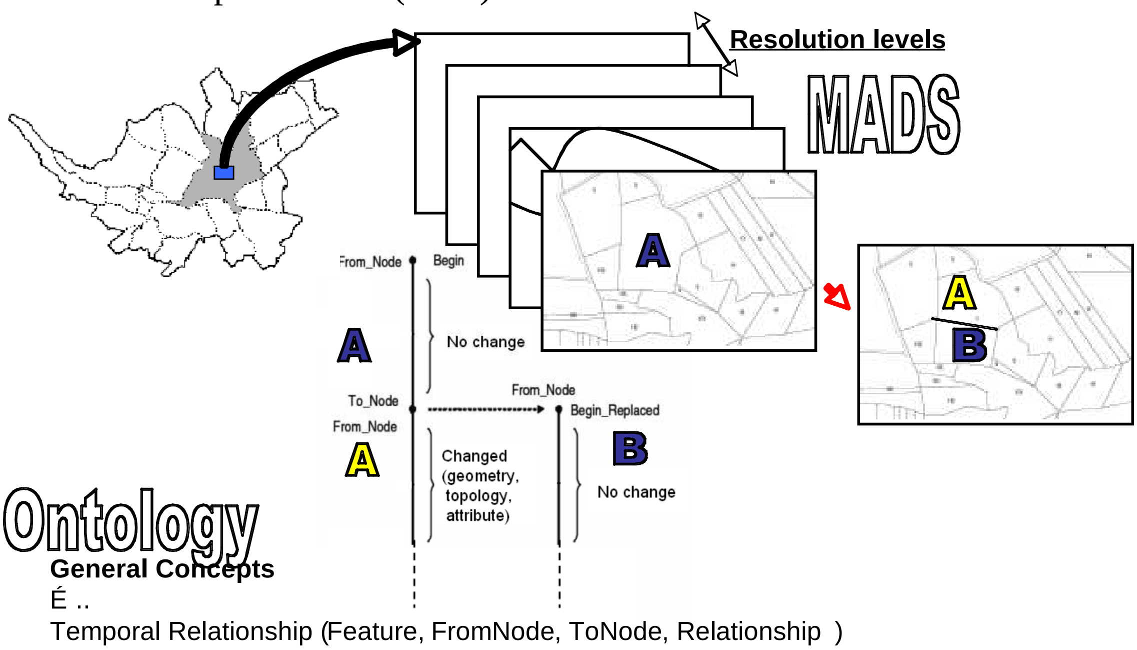

Figure 2: MADS+temporal relationships of ontology (history tracking)

In this example we:

1. Assume that geographical data is distributed between layers.
2. Represent all these layers using the MADS conceptual model which provides a multi representation of features. In our case multi representation is needed due to the multiple resolution representations of a single object.
3. Create the ontology for the UDP respecting the MADS model. This ontology is responsible of keeping track of historical changes of the instances defined in the MADS model. For example the merging of two land parcels, or dividing one parcel into two (Figure 2). These changes are explicitly written in the ontology. In addition, the ontology represents the general concepts related to the UDP and that might change (e.g. adding pedestrian zone).

4. Let for some zone Z have some concept defined in the UDP, for which a concept change occurrs. This change might be represented by adding or removing a layer or changing its composition.

For example an urban section becomes a pedestrian zone, the roads in this zone will be deleted since cars are not allowed anymore. In other words the interpretation of this same section will change whenever its classification changes (urban, historical, touristic, forester…). Nevertheless, new concepts might also be added to the ontology (new resolution level, 3D representation…)

4 CONCLUSION

In this paper, we have proposed a new spatio-temporal model with three main objectives: multi-representation of geographic objects, keeping track of the historical data of objects and to be able to modify concepts. This model uses the conceptual model MADS to benefit from its multi-representation feature, uses ontology as well to acquire the ability of adding, removing or changing concepts. In addition, we define a new explicit temporal relationship that will keep track of objects history.

Now, we want this model to be able to answer queries within reasonable time. We will study query processing and we might need to define new types of queries or to perform specific changes or translations on traditional queries. Then we intend to apply this model and test its efficiency in comparison with the other models using the geographic data of Nantes.

5 REFERENCES

Bateman J., Farrar S. Spatial ontology baseline. SFB/TR8 internal report I1-[OntoSpace]:D2, CRCSC, University of Bremen, Germany, 2006

Bishr Y., Kuhn W. "Ontology-Based Modelling of Geospatial Information," AGILE Conference on Geographic Information Science, Helsinki, Finland, 2000.

Choi J., Chang Seong J., Kim B., Lynn Usery E. "Innovations in Individual Feature History management—The Significance of Feature-based Temporal Model" Springer Science + Business Media, LLC 2007

Fonseca F., Davis C., Camara G. Bridging ontologies and conceptual schema in geographical information integration. Geoinformatica. 7(4):355-378, 2003.

Langran G. “A Framework for Temporal Geographic Information Systems”, Cartographica, 25 (3), 1988.

Parent, Spaccapietra, Zimanyi, Donini, Plazanet, and Vangenot. 1998. Modeling /Spatial Data in the MADS Conceptual Model. /Spatial Data Handling ‘98 Conference Proceedings, Vancouver, BC, Canada, July 1998, 138-150.

Parent C., Spaccapietra S., Zimanyi E., “Spatio-Temporal Conceptual Models: Data Structures + Space + Time”, ACM Symposium on Advances in Geographic Information Systems, Kansas City, MO, 1999.

Parent, C., Spaccapietra, S. and Zimanyi, E., The MurMur project: Modeling and querying multi-representation spatio-temporal databases. Information Systems. 31(8): 733-769, 2006.

Pelekis N., Theodoulidis B., Kopanakis I., Theodoridis Y. “Literature review of spatio-temporal database models,” Knowledge Engineering Review, 19(3):235–274, 2004.

Studer, R., Benjamines, V., Fensel, D. “Knowledge Engineering: Principles and Methods”, Data and Knowledge Engineering, vol. 25, pp 161-197, 1998.

Yuan M. “Use of a three-domain representation to enhance GIS support for complex spatiotemporal queries,” Transactions in GIS, Vol. 3(2):137–159, 1999.