Using Conceptual and Ontological Models for Tracking Changes of Spatio-Temporal Objects and Concepts over Time

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ABSTRACT

In this paper, we present a new approach that benefits from the advantages of both conceptual and ontological models in order to provide a powerful spatio-temporal data model for geographic information systems (GIS). We base our model on the MADS conceptual model that is transformed to a corresponding ontology model, using database to ontology mapping techniques and a set of transformation rules. The resulting ontology allows the system to be dynamic by adding or changing concepts. Our approach allows the tracking of historical changes of spatio-temporal objects and concepts over time by adding new explicit temporal relationships to the ontology.

INTRODUCTION

With the development of information technology, the will to save and manage geographic information started growing and appeared very essential and effective. In order to answer questions on spatial and temporal aspects, the geometry, location and temporal information of geographic object must be stored. In addition, a simultaneous management of spatial and temporal dimensions must be provided to insure that temporal elements translate the most faithfully the real evolution of the considered entities.

One the one hand, the literature shows that conceptual database models are extended in order to model and capture spatio-temporal information and have the potential to accomplish this task. On the other hand, ontologies also seem to be a good answer to this objective by allowing the representation of semantics of information. Therefore, we will present in the next section a state of the art for the spatio-temporal models for GIS, then our approach and finally a conclusion and some perspectives.

RELATED WORK

The snapshot model is the first proposed model that incorporates time in GIS and then this model has been greatly improved (Pelekis, 2004).

The object relationship approach is adopted for representing spatio-temporal data. Following this approach we find MADS (Modeling of Application Data with Spatio-temporal features) (Parent, 1997) a conceptual spatio-temporal data model with multi-perception and multi-representation features. MADS is enriched by the object-oriented structure that has multiple advantages like inheritance, effective manipulation of temporal data, and uniform handling of spatio-temporal data. MADS also offers a set of tools for an associated design method, it has a visual schema editor, and a visual query editor and viewer.

On the other side, an important research axis is the evolution of ontologies that manage geographic information (also-called geographical ontologies). The work of Grenon and Smith

(Grenon, 2004) falls in this direction. They consider two types of entities: "continuants" and "occurents", and two basic types of ontologies that are called SNAP (for continuants) and SPAN (for occurents). Grenon's work provides a framework in which it is possible to formulate relations between different spatial and spatio-temporal ontologies in order to solve problems pertaining to dynamic and geographical ontologies.

OUR APPROACH

We think that a good spatio-temporal data representation for GIS, should be based on conceptual models that support the definition of complex objects and varied semantic relationships, which allows a best representation of the real world. We also believe, as other researchers (Frank, 2003), that such model will be reached by using semantics offered by ontologies.

In our approach we did not work on enriching conceptual models with ontologies specifications, nor on extending ontologies to have the capabilities of conceptual models, but we proposed combining both models. The resulting model assures a good representation and (partially) surmounts the leak of evolutionary schemas in conceptual modeling. In opposition to conceptual models, ontologies are based on the open world assumption, and authorize the continuous adding and changing of concepts.

We chose MADS as the starting point of our model, in order to afford a good conceptualization of spatio-temporal data. And for the ontology we decided to use the Ontology Web Language - Description Logics (OWL-DL) that is optimized for reasoning. Nevertheless, OWL-DL is not able to translate all the MADS features, so based on (Sotnikova, 2006), we simulated the spatial and temporal structures of MADS in a structure of ontological classes, and we added some properties to express spatio-temporal characteristics of MADS.

We also enriched this ontological structure by new classes to explicitly represent changes of spatio-temporal instances. This idea is detailed in our previous work (Zaki, 2009). These classes assure history tracking of instances, and give a global view of each event produced in the area of study.

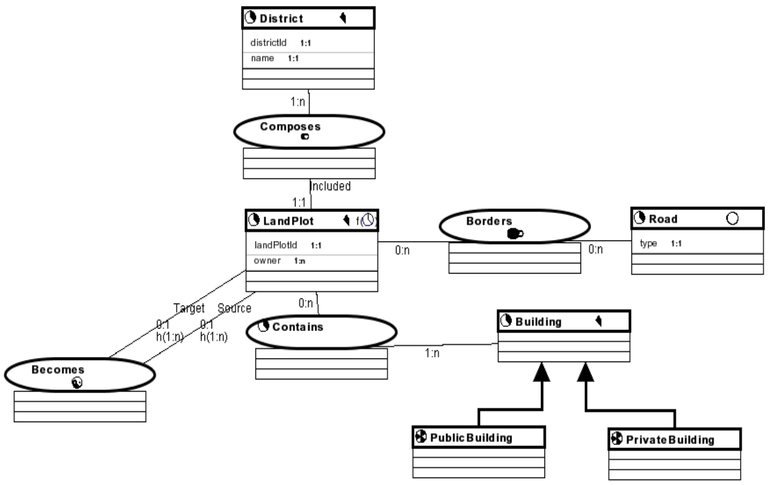

Figure 1: UDP Representation in MADS.

By applying a set of transformation rules (Figure 2), we transform any practical case study (a Urban Development Planning (UDP) in Figure 1 for example) from MADS schema into a corresponding ontological form. These Mappings are defined as correspondences between original MADS components (objects, associations) and ontological components (concept, property).

MADS concepts	OWL concepts
Object type	`owl:Class`
IsA link	`owl:SubClassOf`
Covering axioms: cover, disjoint	`owl:UnionOf`,`owl:DisjointWith`
no corresponding concept	`owl:sameClassAs`
no corresponding concept	Enumerated class `owl:OneOf`
Binary relationship type	`owl:ObjectProperty` with defined `owl:range`, `owl:domain`, and `owl:inversePropertyOf`

Figure 2: MADS- OWL transformation rules.

CONCLUSION

In this paper, we proposed a new spatio-temporal model that uses both MADS and ontology to acquire the ability of adding, removing or changing concepts. In addition, we briefly presented the method for mapping from MADS to OWL.

For the next we still have a perspective concerning query redirection. We also intend to benefit from other features of ontologies such as classification and semantic interpretations provided by some reasoning mechanisms.

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