GEOPROFILE
UML Profile for Conceptual Modeling of Geographic Databases

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Abstract: After many years of research in the field of conceptual modeling of geographic databases, experts have produced different alternatives of conceptual models. However, still today, there is no consensus on which is the most suitable one for modeling applications of geographic data, which brings up a number of problems for field advancement. A UML Profile allows a structured and precise UML extension, being an excellent solution to standardize domain-specific modeling, as it uses the entire UML infrastructure. This article presents the metamodel of a UML profile developed specifically for conceptual modeling of geographic databases called GeoProfile. This is not a definite proposal; we view this work as the first step towards the unification of the various existing models, aiming primarily at semantic interoperability.

1 INTRODUCTION

For the past 20 years, a number of research groups have been studying the requirements for conceptual modeling used in GIS applications (Bédard et al., 2004). A large number of conceptual models specific to this area were proposed. OMT-G (Borges et al., 2001), MADS (Parent et al., 2008), GeoOOA (Kösters et al., 1997), UML-GeoFrame (Lisboa Filho and Iochpe, 2008) and the Perceptory's model (Bédard, 1999) are important among these models.

Despite the maturity of this research field, to date, there is no consensus among designers and users as to which model best meets the requirements for modeling a geographic database (GeoDB). The lack of a standard model brings up serious problems in the development of the field, as for instance, communication difficulties among different projects. For example, considering CASE tools that support conceptual models specific to GeoDB, data conceptual schemas cannot be migrated between different tools, as it happens with conventional database designs.

These problems would not exist if there were a standard for modeling such applications that incorporated the main features of the existing models. The creation of a UML profile is one option to standardize this type of models. UML profile is a feature that allows for a structured and precise extension of the UML elements so that it can fit into a specific domain (Fuentes and Vallecillo, 2004).

This paper aimed to initiate the specification of a UML Profile for the conceptual modeling of GeoDB taking into account the requirements imposed on this application domain. Some models in the literature provided the basis for this task.

The remaining of the paper is structured as follows. Section 2 describes the GeoDB conceptual modelling and the main current models, while Section 3 details the proposal to the GeoProfile. Section 4 presents the conclusions and future work.

2 CONCEPTUAL MODELING OF GEOGRAPHIC DATABASE

The profile proposed in this paper is based on contributions from a number of models existing in the literature, as well as the concepts defined in Goodchild et al. (2007). The models that have contributed most significantly to the GeoProfile development are cited below, but certainly other predecessor models also had their contribution.

The OMT-G (Object Modeling Technique for Geographic Applications) model (Borges et al., 2001) has a rich collection of conceptual constructors, the strong point of which is modeling spatial relationships, including spatial aggregation. The GeoOOA model (Kösters et al., 1997) supports the abstraction of spatial classes, whole-part topological structures, network structures and

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temporal classes. MADS (Modeling of Application Data with Spatio-temporal Features) (Parent et al., 2008) approaches objects and relationships in its diagram, with structures very similar to the Entity-Relationship model. The Perceptory's model (Bédard, 1999) was the pioneer in the use of pictograms. These pictograms are grouped into the languages Spatial PVL and Temporal PVL (Plug-in for Visual Languages), which allow the addition of spatial-temporal characteristics not only to UML, but also to other visual modeling languages. The UML-GeoFrame model is based on a structured hierarchy of classes that make up the GeoFrame, providing the basic elements present in any geographic database (Lisboa Filho and Iochpe, 1999).

Finally, Clementini et al. (1993) formally describe a small set of relationships capable of reproducing all the possible topological relationships that can occur between spatial elements with the representation of point, line or area. This work has considerable importance in the scope of the GeoProfile design. Defining a minimum set of relationships, one eliminates the possible use of two relationships with different names, but having the same meaning. This set includes the following relationships: *touch, in, cross, overlap* and *disjoint*.

3 GEOPROFILE

GeoProfile is a UML profile built for the conceptual modeling of geographic databases. According to the proposed methods to guide the construction of a UML Profile (Fuentes e Valecillo, 2004) e (Selic, 2007), two artefacts are generated during profile development: the domain metamodel and the profile itself. While the first is useful to understand the addressed problem, the second presents the extensions received by the UML metaclasses.

Section 3.1 defines a metamodel for the geographical domain and section 3.2 proposes a set of stereotypes for the proposed profile.

3.1 Defining a Metamodel for Geographical Domain

At the beginning of the metamodel specification, elements are identified in a conceptual schema, observing the requirements of this type of conceptual modeling.

The way each considered conceptual model in this proposal (GeoOOA, MADS, UML-GeoFrame, OMT-G and Perceptory's model) meets the found requirements was examined. The inclusion of the main mechanisms present in each of these models into the GeoProfile allows it to meet most requirements of a geographic database (GeoDB).

Among the discussed conceptual models, the UML-GeoFrame shows the closest organization to a metamodel. GeoFrame is defined in a class hierarchy representing the elements present in a GeoDB. Thus, the metamodel development started from a GeoFrame adaptation (Figure 1).

A GeoDB comprises a number of themes, which is characterized by the metaclass *Theme*. A theme can be formed by the aggregation of other themes or objects with or without spatial representation, characterized by the classes *GeoPhenomenon* and *ConventionalObj* respectively.

When one chooses to associate a spatial representation with objects of a class, it is possible that the phenomenon is perceived in the geographic field view (*GeoField*) or object view (*GeoObject*). Depending on the technique used in geographic information acquisition in the field, its representation be selected from six options as described in Goodchild et al. (2007): *AdjPolygons*, *Isolines*, *TIN*, *GridOfPoints*, *GridOfCells* or *IrregularPoints*. Representation of geographic objects can be of the types point, line, polygon or complex (the object geometry consists of other geometries).

With basis on GeoOOA and OMT-G models, which provide more detailed solutions for network representation, Stempliuc et al. (2009) proposed an extension of GeoFrame to address the requirement. This extension was incorporated into the metamodel.

The classes in charge of storing alphanumeric data and information on which elements participate in the network are represented by the metaclass *Network*. Since this metaclass does not have spatial information, it was defined as a *ConventionalObj* specialization. The networks are formed by network objects (*NetObject*), which can be nodes (*Node*), unidirectional arcs (*Unidirectional*) or bidirectional arcs (*Bidirectional*).

For temporal aspects, the solution proposed by GeoProfile is to indicate only whether a class is considered temporary or not, as in the GeoOOA model. In this way, the metaclass *TemporalObject* was added to the metamodel. This metaclass has two attributes that characterize temporal information. One of these attributes indicates the temporal type (validity time, transaction time or bitemporal time), whereas the other defines the used temporal primitive type (instant or interval). There are two enumerations (*TemporalType* and *TemporalPrimitive*) for the possible values these attributes can assume.

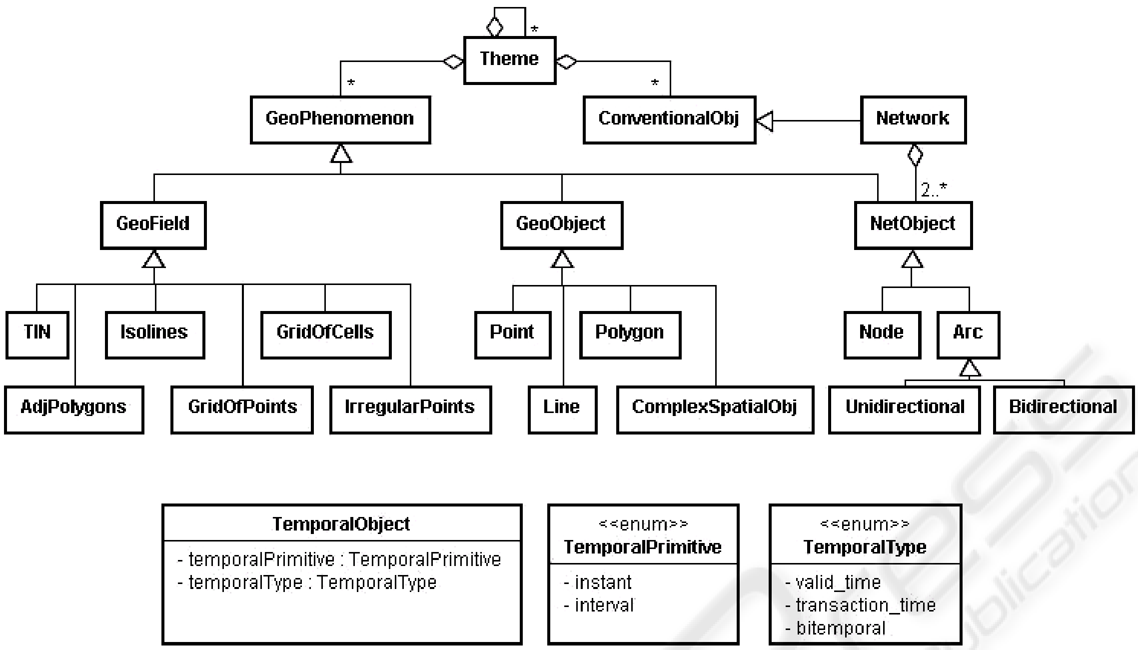

Figure 1: Metamodel for the geographical domain.

3.2 GeoProfile Stereotypes

After creating the domain metamodel, the next step is to extend the UML metaclasses to create the profile itself. Figure 2 illustrates the stereotypes of GeoProfile.

It is worth noting that not all metaclasses of the domain metamodel have a corresponding stereotype, as it happens with *Theme* and *ConventionalObj*. Themes can be represented by packages. Classes of conventional objects are, however, modeled by UML classes without addition of stereotypes. Therefore, the UML constructors themselves can reproduce these two concepts.

Geographic phenomena, extending the metaclass *Class*, are defined in a similar hierarchy to that found in the domain metamodel. The stereotype *Network* directly extends the metaclass *Class*, since there is no stereotype defined for representation of conventional objects.

To deal with temporal aspects, the stereotype *TemporalObject* was added to GeoProfile, as well as two enumerations (*TemporalPrimitive* and *TemporalType*). In addition, designers are allowed to indicate that an association between two objects is only valid for one period and this history should be kept in the database.

This is done by simply assigning the stereotype *Temporal*, which extends the metaclass *Association* to an association of the schema.

Finally, stereotypes were created to represent the topological relationships that were not considered during drawing up of metamodel. We chose to use the set of five relationships proposed by Clementini et al. (1993), as they are capable of representing any topological relationship between objects of type point, line or polygon. Thus, the stereotypes *Touch, In, Cross, Overlap* and *Disjoint*, all extending the metaclass *Association*, were added.

4 CONCLUSIONS

This article showed a standard conceptual model for geographic database modeling to be feasible. The existence of several alternative conceptual models of geographical databases prevents users and designers to migrate their projects from a CASE tool to another. Other major problem brought up by the lack of standardization is the difficulty in training designers, since although the models have been produced for the same purpose; each one has its differences and particularities. Users who are familiar with a model (and its respective CASE tool) show strong resistance to accept a new one.

The use of a UML profile will solve these problems. Besides the wide UML acceptance by software developers, the availability of CASE tools with support for profiles rule out the need for implementing specific tools for a particular model.

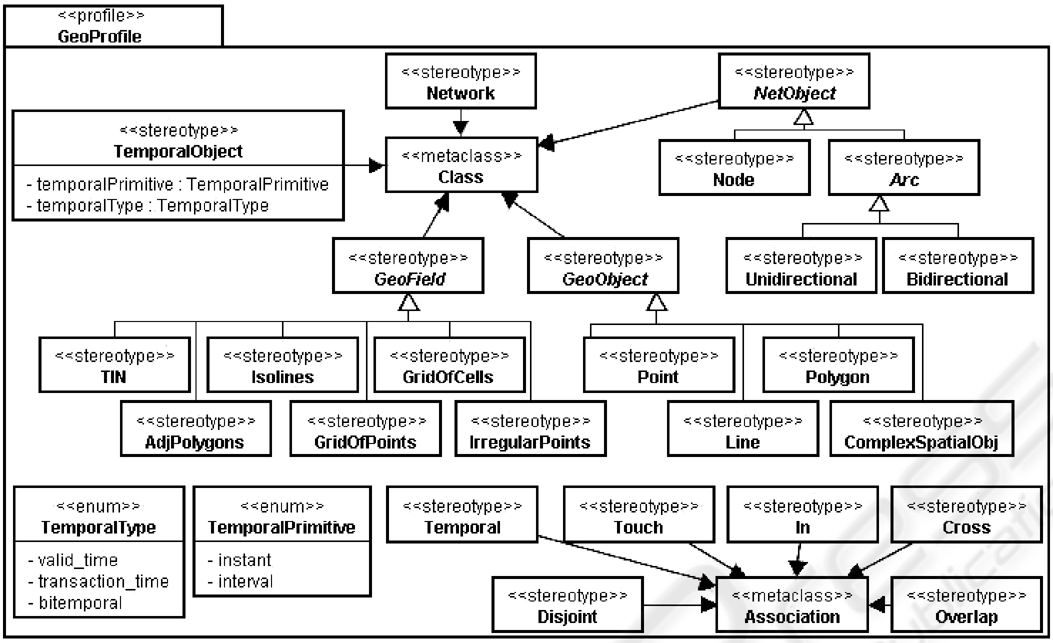

Figure 2: GeoProfile Stereotypes.

A subject for future work is the logical-conceptual transformation of schemas produced with GeoProfile. The existence of logical standards, as defined by OGC and the series ISO 19100, will have a strong link with the level of conceptual modeling. Finally, the great challenge is to make authors of the existing conceptual models contribute to improve the GeoProfile. Moreover, to know the opinion of the users is important, because in many cases the database of a GIS application is designed by then. Thus, it is also important to measure the GeoProfile use's facility and its learning curve.

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REFERENCES

Bédard, Y.; Larrivée, S.; Proulx, M. and Nadeau, M. 2004. Modeling geospatial databases with plug-ins for visual languages: a pragmatic approach and the impacts of 16 years of research and experimentations on Perceptory. In CoMoGIS. *LNCS.3289*, Springer, pp. 1148-1158.

Bédard, Y. 1999. Visual modeling of spatial databases: towards spatial PVL and UML. *Geomatica, v.53, n.2, pp. 169-186.*

Borges, K. A. V.; Davis Jr., C. A. and Laender, A. H. F. 2001. OMT-G: An object-oriented data model for geographic applications. *GeoInformatica*, v. 5, n. 3.

Brodeur, J., Badard, B. 2008. Modeling with ISO 191xx standard. In Encyclopedia of GIS, Eds. Shekhar, S. and Xiong, H., *Springer-Verlag*, pp. 705-716.

Clementini, E.; Di Felice, P. and Oosterom, P. 1993. A small set of formal topological relationships suitable for end-user interaction. In: Int. Symp. on Advances in Spatial Databases, *Springer-Verlag*. London.

Fuentes, L.; Vallecillo, A. 2004. An introduction to UML profiles. *UPGRADE, The European Journal for the Informatics Professional*, v.5, n.2, pp. 6-13.

Goodchild, M. F. ;Yuan, M. and Cova, T. J. 2007. Towards a general theory of geographic representation in GIS. *Int. Journal of GIS*, pp. 239-260.

Kösters, G. et al. 1997. GIS-Application Development with *GeoOOA. International Journal of Geographical Information Science*, v. 11, n. 4, pp. 307-335.

Lisboa Filho, J. and Iochpe, C. 2008. Modeling with a UML Profile. In Encyclopedia of GIS, Eds. Shekhar, S. and Xiong, H., *Springer-Verlag*, pp. 691-700.

OMG - Object Management Group. 2007. *Unified Modeling Language: Infrastructure*. V. 2.1.2.

Parent, C.; Spaccapietra, S. and Zimányi, E. 2008. Modeling and multiple perceptions. In Encyclopedia of GIS, Eds. Shekhar, S. and Xiong, H., *Springer-Verlag*, pp. 682-690.

Selic, B. 2007. A systematic approach to domain-specific language design using UML. In 10th IEEE Int. Symp. on Object and Component-Oriented Real-Time Distributed Computing (*ISORC'07*), pp. 2-9.

Stempliuc, S. M.; Lisboa Filho, J.; Andrade, M. V. A. and Borges, K. V. A. 2009. Extending the UML-GeoFrame data model for conceptual modeling of network applications. In *Int. Conf. on Enterprise Information Systems (ICEIS)*, Milão.