GEO-OMT

An Object-Oriented Method Supporting the Development of Facilities Management Systems

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This paper presents the support that Geo-OMT, an extension of the Object Modeling Technique for geographical applications, provided to the development of a Facility Management application for the telecommunication area. The specific characteristics of this class of applications are pointed out and the main requirements of a method tailored to support them are mentioned. The development process of the mentioned Facility Management System is described focusing on the use of some of the Geo-OMT concepts and capabilities throughout the different process stages.

KEYWORDS: Facilities management, Geographical applications, Software engineering, System development, Methodologies.

INTRODUCTION

This work addresses the specific problems of developing Facilities Management Systems from a software engineering point of view. The development process of these systems is very difficult and time consuming not only as a consequence of their complexity but also because of the lack of standards underlying the commercial Geographic Information Systems software commonly used.

To increase the efficiency of the development process, several generic Object-Oriented Methodologies have been researched and used [1] [2]. Their importance mainly comes from the fact that an appropriate development method may provide an effective tool for the creation of quality software, a goal that is not easy to achieve when the problem to be solved is complex.

However, the support of generic methodologies to the development of Facilities Management Systems is insufficient. The specific characteristics of spatial data and commercial software require particular care and those methodologies are not tailored to accommodate them. Consequently, they cannot be considered tools that adequately help the overall development process [3] [4].

The characteristics of geographical applications and the shortcomings of generic methods to support their development led to the specification and use of Geo-OMT, an extension of the Object Modeling Technique [1]. OMT is one of the most popular object-oriented methods for software development and strongly contributed to the creation of the Unified Modeling Language (UML) [5], a recently proposed standard notation for object-oriented development.

This paper aims to present the support that Geo-OMT provided to the development process of a complex Facility Management application for the telecommunication area. Moreover, this work also refers to methodological rules that make easier the development of applications on top of Framme [6], the Intergraph AM/FM software used.

The Geo-OMT includes concepts and constructs for the design of spatial data models. It also proposes a list of activities to assist developers on the creation of geographical applications and rules that may be used in the system design stage.

In the next section the Geo-OMT requirements, based on specific characteristics of geographical application development process, are briefly introduced. In the following sections the Geo-OMT main concepts are presented and their use in the context of a Facility Management System development process is described. Finally, some new research and application directions are referred to and conclusions are presented.

METHOD REQUIREMENTS

Different authors have addressed several success factors, for software projects [7] [8]. Among them it is possible to distinguish the system suitability to its requirements (concerning functionality, user interface and support of available data), reliability, robustness, efficiency, modularity, extensibility, reusability and interoperability. Some of the mentioned factors have a specific meaning in the context of geographical applications and must be supported by an appropriate development method.

For instance, the system suitability to its requirements firstly needs that all properties of the real world that are relevant to the system purposes are well understood in order to be well represented and managed by the system. In classic Information Systems such properties are usually either static or dynamic. However, in a Geographical Information System several of the spatial properties of geographic entities are crucial for the system goals. Therefore, they must not be ignored during the system development.

The engineering activities executed in order to achieve the final system constitute the development process, which may be subdivided in several stages. The specificity of geographical applications development is detectable in the three main stages of this process:

- In system analysis it is necessary to represent the structure of the geographic entities in the Geographic Data Model (GDM) and these structures can be very complex in some circumstances. Simultaneously, it is important to represent the entities' spatial properties that are relevant for the system purposes. Moreover, these representations must exhibit a satisfactory level of abstraction in order that implementation concerns do not difficult the understanding of reality.
- In system design it is necessary to choose a computational environment (hardware, operating system and GIS software) suitable to the system characteristics (known from the analysis stage) and to execute the transformation between the GDM and those concepts supported by the commercial GIS software, for example Framme.
- Finally, in the implementation stage some problems concerning the creation of user interfaces, the management and processing of non-spatial data and the data security are often relevant. However, presently the solution for this kind of problems depends mostly on the technological capabilities of the implementation software and is nearly independent of the development method.

Considering the specific characteristics of a system with spatial data and the particular difficulties of its development, the main requirements of a method specially tailored to assist this process may be stated as follows:

- To agree with the object-orientation general principles to make easier the creation of complex software with good capabilities.
- To provide a structure of concepts with expressiveness to enable the representation of the structural and dynamic characteristics of geographic reality at different abstraction levels along the various stages of the development process.
- To provide a structure of concepts that can embrace all the essential aspects, including the spatial properties, of geographic entities.
- To provide the description of the development process activities focusing on methodological aspects to assist the usage of the structure of concepts.
- To control the "impedance mismatch" problem that occurs when design specifications are translated to the language of the implementation tool.

GEO-OMT CONCEPTS

The Object Modeling Technique (OMT) is a widely used object-oriented method that has been used with success for the development of many Information Systems. It includes a structure of concepts supporting abstractions such as object, class, attribute, operation, association, aggregation and generalization to create the object model of the system. It uses Transaction Diagrams to build the dynamic model and Data Flow Diagrams to build the functional model. OMT also proposes a diagrammatic language to represent the system model and a list of activities to assist the development process, from analysis, trough design, to implementation.

OMT is a generic method; therefore it can also be used to create Geographic Information Systems as far as their non-spatial characteristics are concerned. However, the representation of the geometric properties of geographic objects requires that the object model includes more classes (point, line and polygon, that are not objects from the real world) and associations linking them and the classes grouping geographic objects. Therefore, the analysis model becomes too complex, less abstract that it should and it still do not represent many of the fundamental spatial properties of the system (adjacency or intersection among some geographic objects, for instance).

To adequately support the specific characteristics of geographical applications Geo-OMT was created as an extension to OMT. The main Geo-OMT abstractions and constructs are able to support:

- The existence of spatial and non-spatial objects that must be clearly and easily distinguished to help the identification of the relevant spatial properties of the system.
- The geographical attributes (usually called coordinates) of spatial entities and phenomena at a high abstraction level, as structural object properties that may also help to identify their relevant spatial properties and that may be coded using GIS programming languages in a natural way.
- The intensive usage of symbols for the representation of geo-referenced entities on maps. Actually, a symbol may be considered a special type of class attribute.
- The representation of spatial relations in the data model, expressing the relevant spatial properties that exist among entities. These relations are the most remarkable characteristics of geographical applications. The appropriate representation of these properties also involves methodological issues such as how to choose the right abstraction in each concrete situation and the right moment to do that representation.
- The construct cartographic class grouping objects that are maps, as a conceptual representation of spatial data and, simultaneously, as a fundamental unit of spatial data organization at the logical level.
- The specification of long transactions allowing concurrent access to the database that are the typical way of geographical applications update.
- The intensive use of spatial operators and functions in the specification of the system functionality.

In the following section, part of a Facilities Management System development will be described highlighting the use of some of the Geo-OMT concepts.

DEVELOPMENT PROCESS

Geo-OMT was used to support the development of a Facility Management Application for the Portuguese Army. The system is used mainly to assist the design of telephone network projects and the update of the network cadastre. This network has many components; namely several different type of cables, cable connectors, boxes and cable ducts. These devices must be designed on maps representing regions and buildings.

The functionality concerning the network cadastre includes queries involving spatial and non-spatial data, data update when a network project ends and general network maintenance support, for instance to identify damaged devices. The support to project design requires functions for planning and execution control. Several activities need different type of network tracing.

Some system requirements, particularly the support of telephone distribution inside the buildings and the simultaneous visualization of different building floors, increased the application complexity.

System Analysis

In order to build the three models (object, dynamic and functional) that are the main products of the analysis stage it is necessary to execute several activities. To build a system including geo-referenced data Geo-OMT points out the following activities:

1. Identification of the system end-users and characterization of their system views.
2. Identification of basic classes of objects; classification of classes grouping spatial objects according to their structure and geographic attributes.
3. Selection of a spatial reference system.
4. Selection of standards that may be used.
5. Definition of data collection, or selection of data sources, or both; definition of data input and data conversion.
6. Identification of relevant spatial associations and non-spatial associations among classes.
7. Identification of attributes (geographic, spatial, cartographic and ordinary).
8. To build scenarios of complex system interactions.
9. Identification of events triggered by the users.
10. Definition of object states and identification of the events that cause state transitions; identification and definition of state and event relationships; identification and definition of long transactions.
11. Identification of the system activities related to each state transition.
12. Definition of interfaces.
13. Identification of class operations.

The sequence of execution of the above mentioned activities is largely variable. Actually, the analysis work must be done in collaboration with the system users and it largely depends on how the users understand and describe the problem.

The object diagram mainly results from the execution of activities 1, 2, 6, 7 and 13. The activities 8 and 12 contribute to build the dynamic model. The activity 4 mainly provides the addition of detail to the object model but may also contribute to define the system structure and dynamic. The activity 5 may contribute to the three diagrams.

During the development of the telecommunication system, the analysis activities led to the following conclusions:

1. Two different types of end-users were identified: the network cadastre team and the project designer team.
2. The fundamental classes are: Area holding a telecommunication network (the network THEME),network CADASTRE or network PROJECT (representing an existent or a planned network) , NETWORK COMPONENT, and BACKGROUND MAPS. Among these, only the CADASTRE and the PROJECT are non-spatial classes. The NETWORK and the BACKGROUND MAPS are cartographic classes. The subclasses of the class named THEME are regions and the class NETWORK COMPONENT is a mixed spatial class because it includes both objects with geometry point and objects with geometry line.
3. The adopted reference spatial system was the one used by the background maps.
4. The system must agree with two different kinds of standards: the first concerns the cartographic symbols, used in the telecommunication field, and the second concerns the representation of cables crossing the building floors. The last one is commonly accepted as an adequate representation of entities from a 3D space on a 2D surface. Figure 1 depicts this kind of situation.

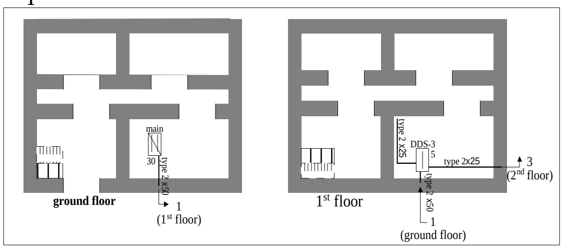

Fig. 1

This representation requires that the structure of system linear components allows that one object is composed by more than one line segment. Therefore, these components are represented in the model by spatial classes with a special geometry and denoted as follows:

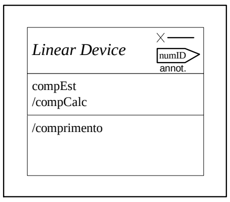

Fig. 2

5. The selection of data sources and data input added new requirements to the system. The study of this problem led to the conclusion that it was necessary to use two methods: data conversion of the background maps and system functionality to enable drawing with a manual locating device. The high number of maps, involved in the conversion process, and the need of specific functionality, to manage them and to query the corresponding metadata, justified that a sub-system for map manipulation was developed. This sub-system also has the capability to assist users on some conversion tasks. The requirements of this sub-system are general enough to support the management of maps that are organized according to a theme hierarchy.

6. In the system were identified two spatial relations (OVERLAP and ADJACENCY); these spatial relations were represented in the model using the Geo-OMT abstractions, rules and notation for spatial relation specification. Several associations were also identified in the system and represented in the object model using the OMT notation.

After the execution of the six activities a first object diagram was build (figure 3) representing the structural and spatial properties of the system. In this diagram are represented the two sub-systems that compose the system.

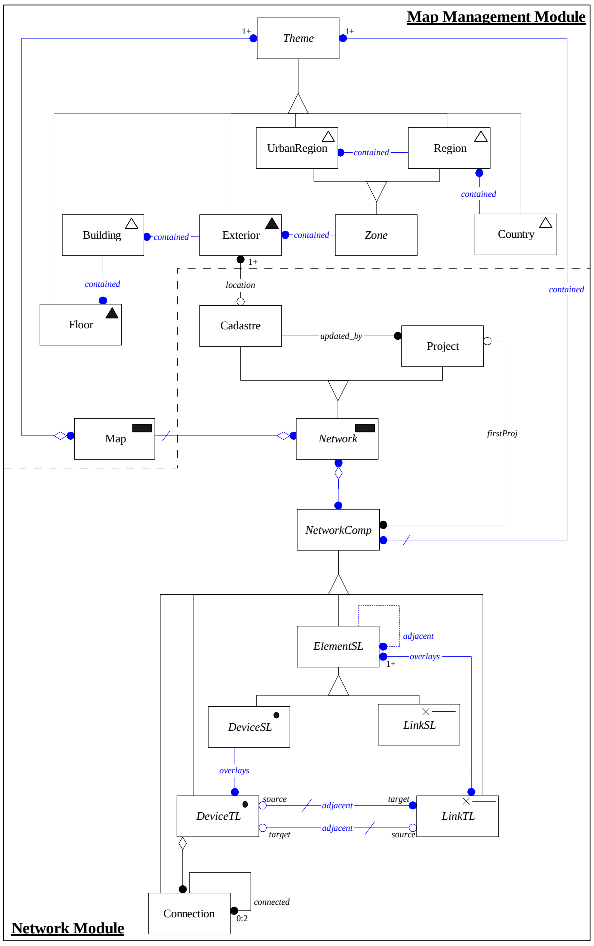

Fig. 3

This model uses some of the abstractions that belong to the OMT extension to enable the representation of object classes with geographical properties and spatial relations (represented in the diagram by lines in blue colour). For example:

- the class named EXTERIOR represents polygonal objects with known coordinates;
- the class named REGION represents polygonal objects with unknown coordinates (the inclusion of values representing their geographic location was postponed to a future extension of the system).
- the class named THEME represents objects that are maps;
- the objects of spatial classes DEVICETL and LINKTL are linked by the spatial relation adjacent.

In this diagram it is possible to clearly distinguish the geographical entities of the system. This type of representation of objects geometrical properties helped to identify the relevant spatial relations, which are also represented in the diagram. These capabilities of the Geo-OMT abstractions and notation enabled a much better and faster understanding of the application requirements.

The identification of attributes (activity 7) added some detail to the model. Namely, many subclasses were included as specialization of the class NETWORK COMPONENT. The Geo-OMT cartographic attributes were used in these classes (figure 4) to help the agreement with the symbol set standard and the identification of the cases where this standard could not be applied (it was necessary to create new symbols).

Activities 8 to 12 contributed to build the dynamic model, namely state diagrams representing long transactions [9] that were the most complex operational components of this system. From this model, it was possible to identify the operations of each object class (activity 13).

System Design

GEO-OMT also supported the definition of the relational database schema corresponding to the object diagram created during analysis.

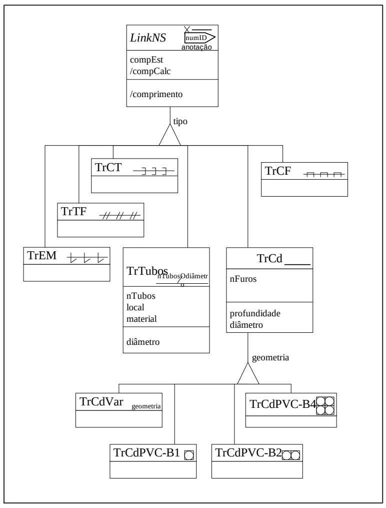

Fig. 4

For example, the class *LinkSL* of the diagram depicted in figure 4 (where different types of cable ducts are modelled) corresponds to the following SQL table definition:

```
CREATE TABLE LINKSL (
        [FRAMME columns]
        COMPESTIMADO SMALLINT,
        COMPCALCULADO SMALLINT,
        COMPRIMENTO SMALLINT
 );
```

Implementation (Framme)

Framme is an AM/FM software. It includes many specific concepts and constructs. Facility, one of its key concepts, enables that common semantics and structures are grouped in types. Each type has a geometrical shape. Facilities also have states, include different kind of components and may be spatially related to other facilities.

For the telecommunication system the complete definition of each facility type required about 200 code lines. Using the Geo-OMT diagram it was possible to identify most of the relevant parameters required by those definitions. Moreover, it was possible to state rules to translate the Geo-OMT notation to the FRAMME data definition language.

For instance, the diagram in figure 2 enabled the identification of the facility type named SUP and the following type definition was created:

```
feature 9. SUP/linear/split/class=SUPPORT
when NORMI consists_of
            SIMB/string
                 .LEVEL/default=2,
                 .STYLE/default=0,
               [other mandatory attributes]
            SIMBHPS/symbol/optional [graphical
               component corresponding to the
                graphical attribute of class LinkSL]
            ETHPS/text_node/optional [graphical
                component corresponding to the text
                of the graphical attribute of class
                LinkSL]
            REGREF/non_graphic/table_name=SUPPOR
T_REF/multi_reference/fsc
               [columns of the table defined by class
                ElementSL]
            REG/non_graphic/table_name=SUPPORT/r
eference/fsc
               [columns of the table defined by class
                LinkSL]
            REGC/non_graphic/table_name=COMMOM
/reference/fsc
               [columns of the table defined by class
                NetworkElement]
            CONNECTIVITY/non_graphic/repeating/o
ptional/table_name=CONNECTIVITY/reference/fsc
               [columns of the table
                 CONNECTIVITY]
when CPROI as_in NORMI
[other states definitions]
```

FUTURE WORK

The wide variety of GIS software does not allow formulating generic rules for the implementation stage. Nevertheless, the experiences already carried out (two different software, Framme and Arc/Info, in two distinct problems, telecommunication networks and water assessment in agriculture) led to the statement of some rules for the translation of the specifications obtained in the Geo-OMT analysis and design stages to these particular software concepts. These experiences evidenced that Geo-OMT may be an useful conceptual tool to produce specifications that can be implemented using this kind of software without need of data model modifications.

Some more experiences with other GIS software and application areas are needed to further test Geo-OMT concepts generality and, possibly, to improve the method elements that concern the implementation stage.

The development of a CASE tool, or the extension of one of the presently available, may also be considered in order to enhance the efficiency of development processes assisted by Geo-OMT.

CONCLUSION

The Geo-OMT methodology was successfully applied on the development process of a complex Facility Management system, minimizing the effort of producing the system on top of a complex AM/FM commercial software. However, due to the complexity of GIS software, more research is needed to enable the design of tools that may significantly improve applications development productivity.

REFERENCES

1. **Rumbaugh, J. et al.** *Object-Oriented Modeling and Design.* Prentice Hall, Englewood Cliffs, NJ , 1991.

2. **Booch, G.** *Object-Oriented Design with Applications*, second edition. Benjamin/Cummings Publishing Company, Redwood City, Ca, 1994.

3. **Bédard,Y. et al.** *Adapting Data Models for the design of Spatio-Temporal Databases.* Computers, Environment and Urban Systems, 20(1), 1996, pp. 19-41.

4. **Hadzilacos, T. and Tryfona, N.** *Logical data modelling for geographical applications.* International Journal of Geographical Information Systems, 10 (2), 1996, pp. 179-203.

5. **Quatrani, T.** *Visual Modeling with Rational Rose and UML.* Addison-Wesley, Object Technology Series, 1998.

6. **Intergraph Corporation** *FRAMME Reference Guide*, Vol. 1 and 2, 1995.

7. **Meyer, B.** *Object-Oriented Software Construction.* Prentice-Hall International, 1988.

8. **Yourdon, E.** *Object-Oriented Systems Design, an integrated approach.* Yourdon Press/Prentice Hall, Englewood Cliffs, NY, 1994.

9. **Abrantes, M.G. and Pinheiro, A.** *Behaviour Modelling in Geographic Applications*, in Proc. of the 3rd JEC — Geographical Information'97 — From Research to Application through Cooperation, Vol. 1, Wien, 1997, IOS Press, Netherlands, pp. 254-257.

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