AN URBAN ONTOLOGY TO GENERATE COLLABORATIVE VIRTUAL ENVIRONMENTS FOR MUNICIPAL PLANNING AND MANAGEMENT

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Abstract: The municipal planning and management tasks are generally performed based on text documents or through digital maps provided by geographic information systems (GIS). However, most municipal GIS follow different data models, leading to interoperability problems when there is a need to combine data from different sources. Furthermore, most of the time these tasks are performed in a collaborative way between the municipal technicians, emerging some difficulties in decision making due to the three-dimensional nature of urban space. Thus, this paper describes a methodology which can integrate multiple sources of real data from diverse municipal GIS, in a unified data model based on the CityGML specification. This model is mapped onto an urban ontology oriented for procedural modeling, which, in turn, produces the three-dimensional models of the urban environments. The system developed operates in a client-server approach, where the server is responsible for mapping the urban information to the unified data model and the client represents the procedural modeling technology that generates the urban environment in three-dimensional format, allowing users to interact and amplify the existing urban information.

1 INTRODUCTION

GIS systems are very common in urban planning and management, since they enable and facilitate the analysis, administration and representation of the urban spaces. However, most municipal GIS follow different data models, leading to integration problems, and in addition, these tasks are often performed in a collaborative way between the municipality technicians emerging thereby some difficulties in decision making due to the three-dimensional nature of urban space. In this sense, virtual urban environments can be used with great effectiveness, since 3D models are natural metaphors for the interaction with the urban environments.

Due to these factors, new perspectives arise concerning new ways of exploration and development of urban spaces, such as the use of automatic techniques to generate the virtual urban environments. Thus, this work has as its main goal the development of a methodology which allows the integration of real world data sources, from different municipal GIS, in an unified data model, mapped onto an urban ontology oriented for procedural modeling. This information is then displayed in three-dimensional format by employing procedural modeling methodologies, providing a more natural and intuitive system to operate on the virtual urban environments.

2 RELATED WORK

The main reason to use urban ontologies is because they can help extracting information related to the vocabulary used in the municipal planning and management, in order to minimize interoperability and cooperation issues between databases with urban information from different sources (Laurini, 2007). Over the years, several standard data models have focused on the issue of interoperability, such as the GML (Portele, 2007), KML (Wilson, 2008) and CityGML (Groger et al., 2008).

The Geography Markup Language (GML) is an XML data model for transport and storage of geographical information, including spatial and non-spatial characteristics and whose specification

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defines mechanisms, conventions and syntax in XML Schema., which provide an open framework for the definition of schemas and objects for geospatial applications.

The Keyhole Markup Language (KML) is an XML language focused on geographic visualization, including annotation of maps and images. Geographic visualization includes not only the presentation of graphical data on the globe, but also the control of the user's navigation in the sense of where to go and where to look.

The City Geography Markup Language (CityGML) is an open data model structure and standardized code based on XML for storing and exchanging virtual 3D city models. The common information model behind CityGML defines classes and relationships for the most relevant topographic objects in cities and regional models with respect to their geometrical, topological, semantic and appearance properties.

In comparison to GML, CityGML represents not only the geometry of the urban objects, but also represents the semantic and thematic properties of the city. The KML and CityGML overlap in the functionality, but they differ in other important issues. Both standards use similar geometry elements to represent the characteristics of the real world, but the KML lacks many of the semantic properties included in CityGML.

Finally, Kolbe et al. (Kolbe, Konig, Nagel, & Stadler, 2009) present a 3D geodatabase for CityGML. The CityGML data model is mapped into a relational database schema, allowing users to store, represent and manage virtual models of the cities. Additionally, this work provides a tool which imports and exports data in CityGML and GML structures.

3 WORK DESCRIPTION

The model of a city has certain characteristics that favor the use of procedural modeling for its generation, such as the existence of several repeated patterns in their shape or the possibility to structure its content hierarchically. Additionally, due to their size and complexity, these models require many resources, making it appealing to apply procedural modeling techniques in order to reduce the development time and costs.

Thus, the developed methodology intends to integrate multiple real world data sources, from different municipal GIS, into an unified data model mapped based on an urban ontology oriented for procedural modeling. The proposed urban ontology allows the integration of different data on the same data model, allowing the interpretation of this data to be always the same. This facilitates the later representation of urban information in three-dimensional format by using procedural modeling techniques, where the geometric information does not need to be stored, but can rather be generated when needed, producing the same results.

3.1 Definition of Urban Ontology

Having as base specification the CityGML (Groger, Kolbe, Czerwinski, Nagel, 2008) and the work of Kolbe et al. (Kolbe et al., 2009), an ontology was defined which meets the expectations presented in this paper. The selection of CityGML was used since it is an OGC standard and a very flexible and complete data schema, capable of describing urban environments in detail. However, whereas the CityGML specification is very focused on the representation of urban objects, through the association of geometric properties, this new urban ontology is oriented to the description of the main urban elements, in order to be used by procedural modeling methods. Thus, it is important that the procedural modeler is fed with all the semantic information of the city rather than a large quantity of geometric information, since it can (aside from some base geometries) generate automatically such tridimensional data.

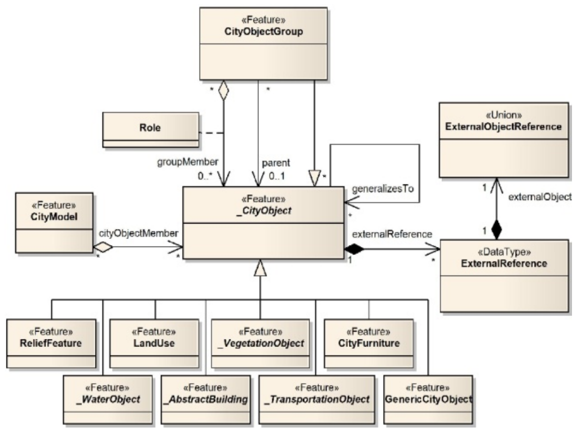

Figure 1: Core data model, defining the basic concepts and components.

The proposed urban ontology was materialized in an unified data model for procedural modeling of urban environments. Similarly to the CityGML standard, the new data model includes the geometric model, the appearance model and the different thematic models of the urban environment (Groger et al., 2008). The geometric model is responsible for storing the geometrical information of urban elements while the appearance model is responsible to store the information about the appearance of urban elements, such as the visible properties that reinforce their 3D representation. The thematic models allow the definition of classes which represent the different types of objects contained in a city, allowing the storage of the thematic and semantic concepts of the entities that characterize the urban space (Figure 1).

3.2 Data Mapping

Since the information about urban elements is not centralized on a single data source and, furthermore, knowing that this information is not common to the majority of GIS data sources of the municipalities and government institutions, different levels of mapping were defined, according to the available information detail of the urban elements. Thus, the concept of LOM (Level of Mapping) was introduced which refers the minimum information that an entity must possess for a certain kind of procedural method to be used. This allows the definition of more specific model generation rules, therefore eliminating the need to check for the existence and validity of each data field.

Besides the definition of LOMs, it becomes necessary to create processes that map the information from the municipal GIS into the defined data model, which is not a simple task, mainly due to the size and complexity of urban information. Additionally, data from the information sources of the municipalities have different formats and data models. These problems are derived by the lack of a unique and uniform data model.

Thus, a methodology was specified, allowing the mapping of the information onto the data model. The first stage is not automated, and human intervention is required in order to interpret the original data to be mapped, since most of documentation is only intended for humans. So, it is required that the meaning of the original data is interpreted, for which the data model tables and columns of these tables will be mapped, and the type of operations that will

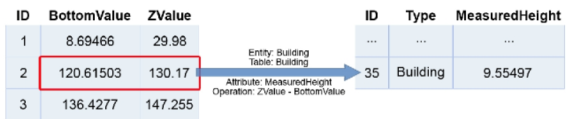

Figure 2: Mapping the original data (left) in the data model (right).

focus on these data. This information represents the settings for the mapping of the original data and it can be specified through external files such as XML, for example. Figure 2 illustrates an example of this process.

3.3 Implementation

The developed system operates in a client-server architecture, where the server is responsible for mapping the urban information and the client represents the procedural modeling technology. The mapping server was implemented with a PostgreSQL database management system, equipped with the spatial extension PostGIS and the procedural language PL/pgSQL. In addition to the mapped data, the server provides, through Web Services, a set of operations that allow the procedural modeling technology to access, edit and amplify the existing urban data. The procedural modeling technology, represented by the PG3D modeler (Silva, Coelho, 2011) has the responsibility for generating the information of urban space in three-dimensional format. After the procedural generation, users can view and interact with the urban environment. In order to achieve this, the mapping server contains a version control system capable of storing different instances of the same object, which means a previous version can be retrieved at any time.

Figure 3 shows an overview of the architecture of the implemented system.

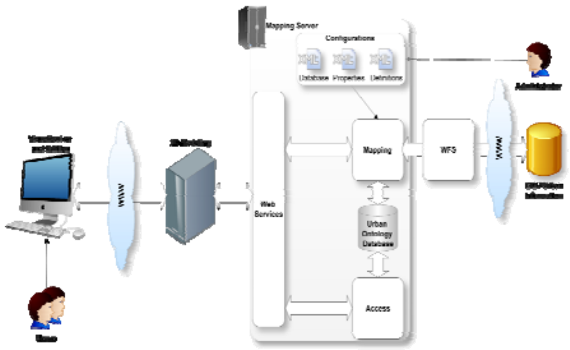

Figure 3: Overview of the architecture.

4 RESULTS

A proof of concept has been developed, consisting in the demonstration of each involved step. The original data was obtained from two different sources of information representing buildings that were defined in two levels of mapping (LOM0 and LOM1). This information was then mapped into the defined data model. Out of it, the visualization of an urban environment was achieved, which was created based on real data, and which allowed users to interact and to amplify the existing urban information. Figure 4 shows the final result.

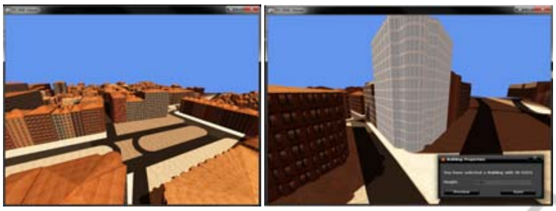

Figure 4: Viewing and editing of urban information.

After confirming the edition, the PG3D modeler requests an operation to the web service provided by the mapping server, so that it records the changes in the database of urban ontology. These changes involve the creation of a new version for the manipulated building. The previous version goes to an inactive state, but can be retrieved.

5 CONCLUSIONS AND FUTURE WORK

This paper presents a unified data model based on the CityGML specification oriented towards the procedural modeling of collaborative virtual urban environments.

Due to the size and complexity of the urban environments there is still much work to do. The real data used in the proof of concept represented only the buildings. In addition to these, a city consists of other entities such as streets, water bodies, vegetation, and city furniture, among others. Each entity requires a detailed and independent study about the mapping process of information sources of these objects. Therefore, future work will concern the study of the mapping data for these entities, allowing the development of a prototype with a higher quality of information about the urban environment. Additionally, it is necessary to refine and create new features for manipulating the existing urban information in order to perform tests that confirm the visual fidelity of the urban environment.

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