SDBMS Based Data Model for CAFM Systems

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Key words: SDBMS, CAFM, topology, 3D spatial data

SUMMARY

The need for maximum efficiency in (working) space usage resulted in 1980-s by emerging of first CAFM system. The technology in the field of spatial data management available in mentioned period (CAD+RDBMS) has significantly influenced further development of these systems and thus their current form. Current trends, like 3D modeled data in area of visualization being constantly requested by the user, or rapidly increasing need for 3D analysis of spatial data, mentioned technological basis simply can not satisfy. SDBMS technology, on the other hand, is more than capable to cope with such challenges. Although all currently available SDBMS do not natively support 3D spatial analysis, storage and querying of 3D spatial data is generally supported. Furthermore, by using available programming support (Java, PL/SQL, ...), at least some basic 3D analytical functionality is relatively simple to implement.

Spatial component of the developed data model, which is also the main objective of the research, is based on spatial planar surfaces representing walls and other surfaces typically found within a building. These basic spatial objects are used to model logically important object, called body, which can be empty (a room) or filled (a wall). System's entire spatial data is therefore contained within a single object type (planar surface) which is topologically structured (face-node structure) to ensure safe, consistent and efficient operation. The model is implemented on top of Oracle9i SDBMS. Data access interface is being developed based on 3-tier program architecture with JSP servlet for data querying and preparation, HTTP as transport medium and VRML as presentation and basic user interface technology.

Realization of a system based on the developed model directly enables performing of simple topological analysis (neighborhood), with thematic querying and resimbolization immediately available. Furthermore, by introducing temporal component of spatial data, reviewing of a system status in a specified moment is easily accomplished.

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1. INTRODUCTION

3D spatial data has proved useful for various visualization purposes during city development planning (Gruber 1999). A great deal of work has also been done in field of automatic or semi-automatic 3D building model extraction followed by its storing in DBMS (Gruen and Wang 1999). Ground based laser scanning give users large amounts of high precision 3D spatial data appropriate for use during as-built systems formation process (Roić et al. 2001). Furthermore 3D spatial data found its use in area of 3D cadastre. Efficient management of cadastral data in highly developed urban areas is now days significantly improved by 3D cadastral systems (Stoter and Ploeger 2003) with the need for implementation of 3D spatial data models in SDBMS (Spatial DataBase Management System) technology.

Computer based systems for facility management (CAFM) are being developed since early 1980s, based on, in that time contemporary technological combination of CAD+RDBMS. This technological basis is supported by significant number of software solutions and some standardization initiatives (IFMA, FMSFIE, IAI) concerning either with non-spatial data model or with mostly 2D spatial data exchange support.

Although CAD systems support 3D data manipulation almost since forever, their (spatial) analytical capabilities are more or less equaling none. GIS on the other side provides numerous tools for spatial data analysis, but limited to 2D data. Only few exceptions, mostly used for DTM (digital terrain model) visualization exist (Zlatanova et al. 2002). In order to be able to analyze and/or visualize 3D spatial data one should model it based on modern technological accomplishments and trends (object-oriented modeling, SDBMS, ...). Generally the importance of 3D spatial data in CAFM systems is pointed out by (Schürle et al. 1998), while (Schürle and Fritsch 2000) give an overview of CAFM data models non spatial component. One of the most comprihensive models for spatial component based on separate geometrical and topological segments of spatial data is given by (Gielsdorf and Gründig 2002). Key word here is capture and management of relative measurements followed by numerical data adjustment within the system.

Upon the recognition of needs for spatial data models within CAFM systems, while keeping in mind modern technological accomplishments, began within Faculty of Geodesy in Zagreb the development of core spatial data model for CAFM systems based on SDBMS.

2. 3D DATA MODELING AND SDBMS

Although numerous 3D data modeling techniques exist today, CSG (Constructive Solid Geometry) and B-rep (Boundary representation) emerged as most popular, each one with some advantages and some disadvantages over the other. CSG considers its final result as one unique object and stores data more efficiently while b-rep enables internal topology to be used and to differentiate each part of the object. Detailed description of these and other techniques is given by (Foley et al. 1994).

Separation of topology from geometry plays an important role in any segment of spatial data handling so 3D spatial data isn't any different. Unlike 2D spatial data where many research has been done in the field of topological models and relationships 3D topological data models are still being researched. Good description of their basic relations and a summary of several important 3D topological spatial data models based on edge as a central object type is given by (Zlatanova 2000). A proposition for a new one called SSM (Simplified Spatial Model) based on a face-node structure is also given there. SSM is further refined especially for City modeling as described in (Zlatanova et al. 2003).

Unfortunately 3D spatial data stored and maintained within SDBMS is now days still not a common thing. Commercial SDBMS dispose with only basic abilities concerning 3D spatial data. Most of them enable user to model 2D objects within 3D space or sometimes simpler 3D elements (3D line-string), but none offer native implementation of anything more sophisticated. Latest product from leading SDBMS vendor Oracle10g is no exception here. Further restrictions concern SDBMS analytical capabilities over 3D spatial data. Current products from leading SDBMS vendors mostly supply 3D (R-Tree or similar) indexing for primary filter acceleration but stop here (secondary 3D filtering e.g. 3D spatial querying not supported). Interesting idea of neglecting Z coordinate and indexing only 2 spatial dimensions thus gaining access to (only 2D) spatial querying capabilities with all its pros and cons is described in (Arens 2003).

Although not significantly, somewhat better situation is found in the area of general 3D spatial data modeling techniques. After leaving behind some solutions based on proprietary data models and CAD level data formatting, only few perspective efforts surface. Some of them are (Zlatanova and Verbree 2000) researching simple 3D data model based on topological structure on top of Oracle8i SDBMS, or (Arens et all. 2003) describing a proposition for 3D spatial primitive implementation in Oracle9i.

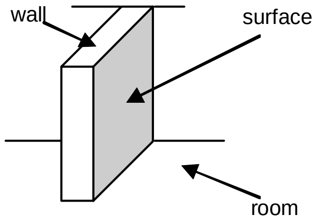
3. THE MODEL

When one starts to think about a building information system and its structure and one basic object type, a room comes in mind. A room is spatially bounded by walls (floor and ceiling) so one could recognize two basic object classes, rooms and walls (floors and ceilings). At the first look and based on mentioned presumptions it is easy to come to conclusion that a 3D primitive like described by (Arens 2003) and CSG oriented modeling technique would be appropriate here. Nevertheless when considering walls attributes a bit deeper one sees that it has two potentially different sides with different attributes (color, date of last repainting, ...). Even though this and similar problems are solvable using 3D primitive it is often necessary to spatially differentiate its sides (surfaces). Similar conclusions draw (Fritsch 2003).

In order to keep the model simple flexible it is possible to approach it in a different way. Let us say that the basic object class of the core model is body, spatially bounded by surfaces (for simplicity sake only planar). Within system a body can appear in two main variations:

- room (hollow or empty body),
- wall (body filled with, for example concrete).

Main spatial object class of the system is now a *surface.* In most cases it presents a boundary between two *bodies* of different variations (***Picture 1***), but can also in special cases bound two *bodies* of same variation (glass surface between two rooms could be modeled as a *surface).*

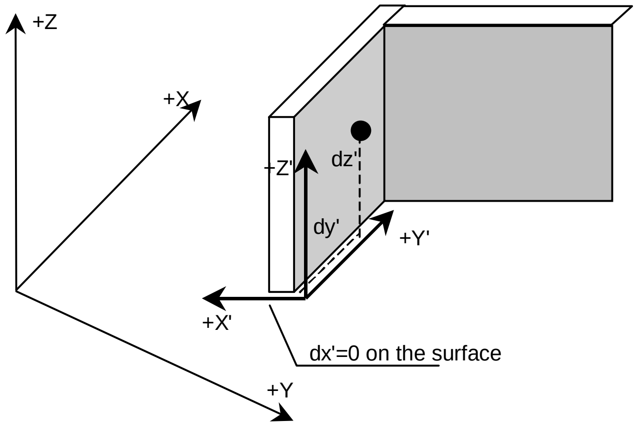


Picture 1: A surface bounding two bodies

Spatial component of class *body* is defined by four or more objects *surface,* while every *surface* presents a boundary between two *bodies* (all building exterior space is modeled as one body).

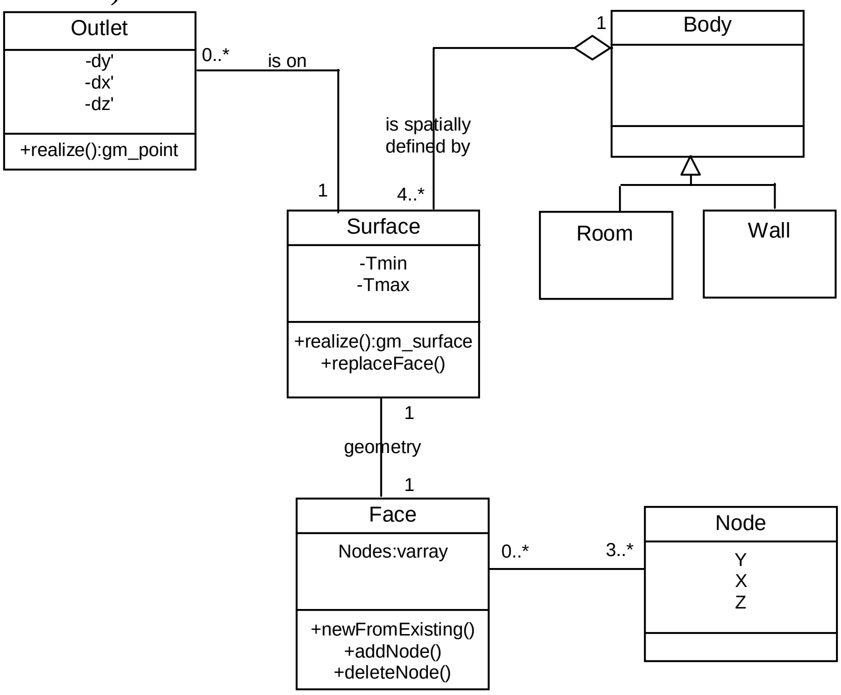
Without analyzing its mobile parts (furniture, ...) one could recognize further two important object classes, which are needed to make it possible to completely model a building. First, all sorts of outlets (electricity, communications, ...) are needed, and of course carpentry. Both these object classes are inseparable from their parent objects. An outlet and any part of carpentry is always positioned on a *wall* (ceiling, floor, ...) specifically on one of its *surfaces.* It is therefore natural to model their spatial component related to their parent *surface*. It is not necessary to determine absolute position of *outlet* (or origin of a door for example) but only its position within local coordinate system defined by its parent surface's origin and orientation. Simple coordinate transformation algorithms are used in "realization" methods for on-line computations. In this simplified model it is also assumed that walls are vertical meaning both Z axes (building coordinate system and wall coordinate system) are parallel so 2D coordinate transformation can be used (***Picture 2***). If necessary tilting can easily be compensated using 3D coordinate transformation.

Some conventions during data capture and modeling phases are of course necessary here. Counterclockwise order of points which make an outer ring of a surface (and clockwise for possible inner rings) enable system to determine surfaces orientation (normal) and thus its local coordinate system (with the origin in lower left most corner). Benefits from described approach are multiple. Measuring and data processing becomes simplified, consistency during visualization is kept in a natural manner and system's analytical capabilities become significantly improved.



Picture 2: Local and global coordinate system

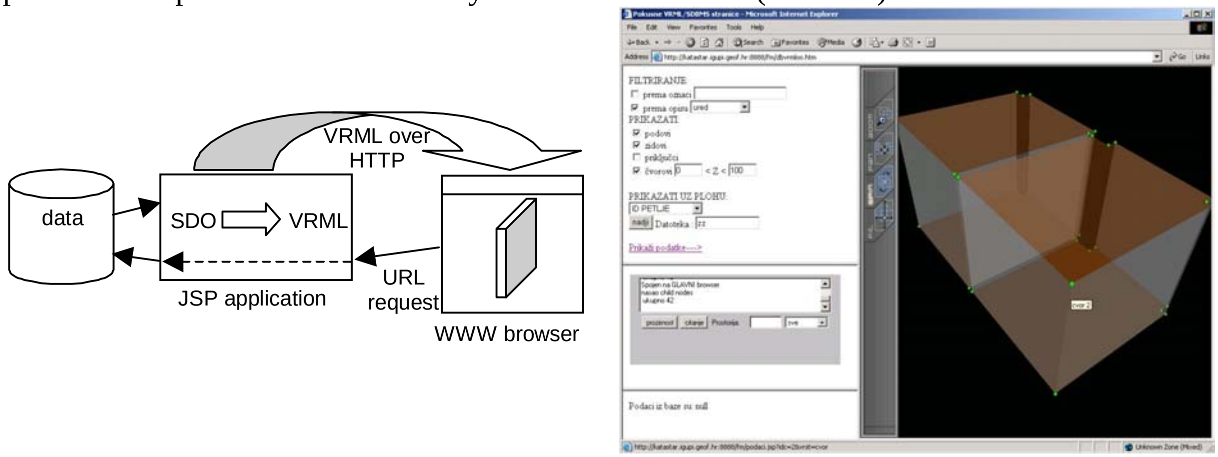
Following contemporary spatial data modeling directions, core of described model is based on topologically structured data composed of two topological primitives, face and node similar to earlier mentioned SSM. Face object class is purely topological and contains information referring to nodes which contain geometrical information. Spatial components of the described model is therefore based on Surface object class and its realization method used to combine topological and geometrical data (face and nodes). This concludes the definition of the model (***Picture 3***).



Picture 3: UML class diagram of the model

Implementation of the system based on the described (with no further development) model enables user to perform simple 3D spatial analysis through topological queries (for example neighborhood). On the other hand the described core makes a flexible base for any further development primarily through the adoption of future native SDBMS capabilities, but also through user developed procedures and algorithms. Network analysis capabilities should prove as one of the important new features in Oracle10g here, and could find its use in buildings shortest route computation or in utilities (wiring, plumbing, ...) maintenance. All well known attribute based analytical methods are easily implemented, together with 3D visualization and resimbolization. With introduction of object’s lifecycle information (Tmin and Tmax) in *Surface* object class, temporal analysis capability is added to the model making it suitable for dynamic building maintenance.

The model is implemented using Oracle9i SDBMS on Institutes server with a smaller test data set loaded. Also a simple interface for data access, display and modification is being developed based on 3-tier architecture. Through JSP on server side for data access and preparation, HTTP as a transfer medium and VRML as data visualization technology, fully platform independent access to the system will be enabled (***Picture 4***).



Picture 4: Data access interface

4. CONCLUSIONS AND FURTHER RESEARCH

In the area of spatial data management SDBMS has become one of the leading technologies. Although its 3D spatial data capability currently does not offer wider spectrum of analytical tools its overall flexibility enables user to implement at least some of it with little effort.

The described data model could make a sound basis for development of CAFM system of almost any scale, enabling user to perform basic spatial, attribute and temporal analysis (or any combination of these) without the need to extensively further develop it. Its topologically structured spatial component ensures high data consistency with low redundancy at a little cost of slightly raised computational requirements, today easily met.

Further research should be oriented to extending 3D spatial analytical capabilities either by adopting new native functionality offered by SDBMS vendors, or by user programmed extensions. It should also be tested which of current 3D data modeling standards (GML or X3D) suits better for similar systems needs. Both technologies enable combination of spatial and non-spatial data enabling system a better client-server load balancing which is at this point mostly sever oriented and requires a round trip for most of additional queries.

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BIOGRAPHICAL NOTES

Hrvoje Matijević is university assistant at the Faculty of Geodesy in Zagreb. He has acquired M.Sc. degree in 2004 with thesis "Cadastral Data Modeling" at the Faculty of Geodesy in Zagreb. His main research interests are CAD, GIS and DBMS technology in spatial data handling. Hrvoje Matijević has participated on several projects and has published several papers.

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