SEMANTIC ASPECTS FOR 3D MODELING

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ABSTRACT

The modeling of an object, a natural phenomena is a simplification of the real world which is based on hypothesis to be reproduced. A geographic information system is the consequence of a modeling process of the real world. A frequent used scheme in designing geographic information systems contains three hierarchic levels : the geometric, topologic and semantic levels. These three levels correspond to the different aspects which are managed by the system. There is a hard interaction between these three levels. It is particularly important to notice the high correlation between the scale of the geometric information and the detailing grade of the semantic modeling of the objects which can be acquired by measurements. The semantic analysis of a situation and the high relationship between semantic aspect, geometry and topology is used to define "concepts" of the real world to be modeled. These "concepts" exist in infinite forms and depend entirely on the choices which are made by the restriction of the detailing grade. The "concepts" defined in a topographic information system are particularly topographic concepts which have topologic dimension from 0-D to 3-D. All the objects of the system can be classified in a semantic hierarchy. This semantic hierarchy is then used to define rules which can be utilized in the reconstruction process of 3-D objects. This paper shows the concepts of this semantic approach, and the application of this semantic conceptual designing in different examples.

RÉSUMÉ

La modélisation d'un objet, d'un phénomène naturel est une simplification du monde réel qui se fonde sur des hypothèses qui doivent être résolues et vérifiées. Un système d'information geographique est la réalisation conséquente du processus de modélisation du monde réel. Un schéma classiquement utilisé lors de la conception de systèmes d'information géographique comporte trois niveaux hierarchiques distincts : la géométrie, la topologie et le niveau sémantique. Ces différents niveaux correspondent aux différents aspects qui sont gérés par le système. Il est notamment particulièrement important de remarquer la très forte corrélation entre l'échelle de l'information géométrique et le degré de détails de la modélisation sémantique des objets qui peuvent être saisis par des mesures. L'analyse sémantique de la situation et les étroites relations entre les niveaux géométrique, topologique et sémantique sont utilisées pour définir des "concepts" de la modélisation du monde réel. Ces "concepts" pourraient exister en nombre infini et dépendent entièrement des choix qui sont effectués lors de la restriction à un degré de détails. Les "concepts" qui sont définis dans un système d'information topographique sont des concepts topographiques particuliers dont les dimensions topologiques varient de 0-D à 3-D. Tous les objets de ces systèmes peuvent être classés dans une hiérarchie sémantique. Celle-ci est ensuite utilisée pour définir des règles qui peuvent être utilisées dans le processus de reconstruction des objets 3-D. Cet article explique les différents concepts de cette approche sémantique, ainsi que l'application de modèles conceptuels sémantiques dans différents cas concrets.

1   INTRODUCTION

The modeling of an object, a natural phenomena is an imitation, a simplification of the real world which is based on hypothesis, choices, particular qualities which are to be reproduced. A modeling is never unique, it depends on arbitrary choices that generally depend on the final destination of the designed model. A geographic information system is a representation of the real world built to respond to precise questions and needs, and so it is the consequence of a modeling process of the real world. The geographic information is modeled by using defined processes which respond to problems of spatial data and information location. A frequent used scheme in designing geographic information systems contains three hierarchic levels : the geometric, topologic and semantic levels.

An informal classification of these three levels could be from the concrete to the abstract :
- the geometric level is the inferior one. It contains the whole spatial data in form of geometry located in a co-ordinate system. It is the graphical part of the modeling which defines the position, the form of the objects and the graphical spatial relations between them.
- the intermediate level is the topologic level.
- the semantic level is the superior one. It contains all the semantic information which are linked to the geometric data. This level is used to define the objects to be modeled, and the attributes of the objects which are associated to them to respond to the needs of modeling.

These three levels correspond to the different aspects which are managed by the system. There is a hard interaction between these three levels. It is particularly important to notice the high correlation between the scale of the geometric information and the detailing grade of the semantic modeling of the objects which can be acquired by measurements.

2   SEMANTIC MODELING

2.1   General considerations

For the definition of the modeling, the conceptual approach can be privileged. The semantic analysis of a situation and the high relationship between semantic aspect, geometry and topology is used to define "concepts" of the real world to be modeled. These concepts exist in infinite forms and depend entirely on the choices which are made by the restriction of the detailing grade. They are usually considered from the most general to the most particular. The concepts which are defined in a topographic information system are particularly topographic concepts which have the topologic dimension of the represented objects, namely 0-D to 3-D.

All the objects of the system can be classified in a semantic hierarchy. The number of level in this hierarchy is not fixed but depends on the context.

The following concepts are given for examples :
- 3-D concepts : 3-D objects like houses, buildings or more generally constructions. Under the general concept building or construction, we find all the types of complex constructions which are the most important components of the urban landscape. Likewise we could take for examples bridges, tunnels that need in a same order a 3-D modeling. But, in a systematical modeling, we have to define general concepts which can be applied specially with standard objects.
- 2-D concepts : area objects like a road, a highway, a face in a DTM.
- 1-D concepts : linear objects like administrative boundaries. The particularity of this example is that it can be a major component of a topographic information system (for example the cadastral boundaries) which is often based on a ground plane defined with these same boundaries. The semantic modeling permits the take into account of well existing geometric objects, but in the same way permits the take into account of abstract concepts which have not really a physical reality in the real world.
- 0-D concepts : point objects, with a point as insertion element, like a tree or a panel of the urban furniture.

These examples are directly found in a topographic information system in urban areas ; they can be transposed in other cases which have a same dimensional hierarchy. When we abandon the topographic scale (ground level is a city, a quarter) and come to an architectural scale (house, façade) we can find out 3-D topographic objects like balcony, terraces, 2-D objects like windows, 1-D objects like property boundaries, special zones boundaries and 0-D objects like electric sockets, air-grids, etc.

2.2   Semantic pseudo-hierarchies

The collection of objects of such a system can be classified in a semantic pseudo-hierarchy. The number of levels is not fixed but strongly dependent on the context.

As definition (Koehl M., 1999), the N-level is the level which contains the general "concepts" previously described. The corresponding objects are those which are accessible by a measurement process and are the major objects of the system. Their geometry is not attached to them, but can be deducted from them of the concepts of higher levels. A general construction could be a good example of this definition.

Levels inferior than N are more general ones. They refer to the containing part. Their semantic dimension is more important in comparison to the geometry. In the example of the modeling of a city quarter, the city main concept is set on a lower level than N on which the quarters concepts can be found. The geometric and topologic aspects of the definition of the city are very complex but not really significant in the model. On the other hand, the semantic aspect contains all the objects from the superior levels.

The 0 level contains, in a semantic definition and in the case of the modeling of the whole space, the most general concept (global concept) which includes all the other concepts.

If we work with the example of the city, the O level could be the entire Universe... , the Earth, a country, a state, a city, a district, a quarter, a cadastral zone, an ownership, a parcel... This list is not complete, does not describe a strong hierarchy between the components of the organization in the world, but depends, like in all geographic information systems on the managed objects, the semantic natural or manmade clippings, depend in this way on the management choices made by the users.

The levels 1 to N, which are not more described here, represent different mean concepts between the level 0 (global concept) and the level N which contains measurable objects.

The superior then N levels consist in lower concepts which are aggregated forms of the N-level concepts. The semantic aspect is not as important, it loses in generality, it is a specialization. The geometry is more exact, but is not obligatory attached to the object.

In the directly superior than N levels, as in the N+1 to N+M levels for example, the geometric and topologic dimensions can be the same as in the N level. For the levels superior than N+M, the geometric and topologic dimensions are lower than in the superior semantic levels. A construction is a good example. In this case the "roof" is a part of the N level concept (construction) : the dimensions are the same. The concept "roof part shape" is a part of the "roof" and defined in the level directly superior than the "roof"-level but its topologic dimension is from 1 lessen (from 3-D to 2-D).

The conceptual approach of the modeling allows to find out semantic links between objects from adjacent levels. If we develop these logical properties, it is possible to automate a part of the integration (reconstruction, integration) of data into the system. Only the geometry from the higher levels is to acquire, the objects from the lower levels can be deduced from topologic considerations driven by rules which translate semantic understandings.
A conceptual design like this implies a logical organization of the specific information, particularly the graphical information. The principles of this modeling is described as follow. (Figure 1)

This pseudo-hierarchy is strongly linked to a representation in an object oriented context. The hierarchy permits here to define the notions of inheritance.
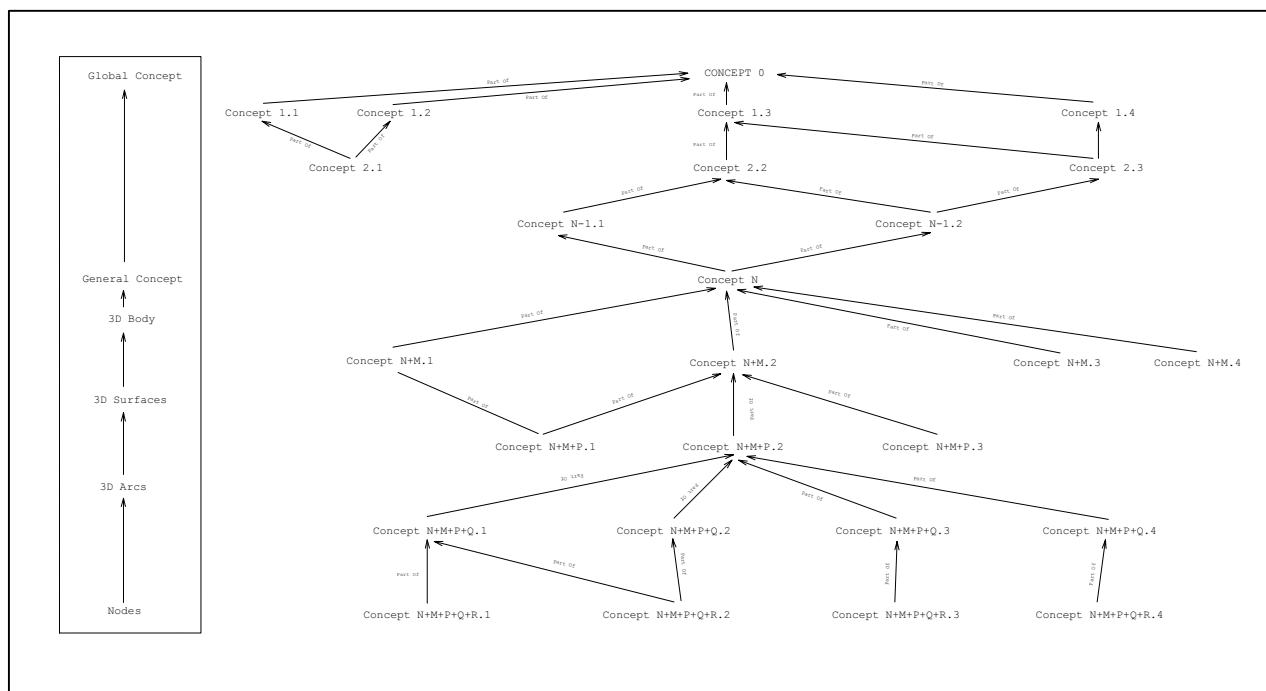

Figure 1 : General principle of semantic pseudo-hierarchy

2.3   Management of the semantic concepts

The previously described semantic concepts can be integrated into a (relational) database. The major conceptual element is placed on the N level.

On the inferior levels, with a predominant semantic aspect, we can find the elements which are linked to the records containing columns with the semantic attributes and columns which defines the hierarchical links between the different concepts (C2.2__PO_C1.3) (Figure 2).

Figure 2 : Structure of inferior
than level N element
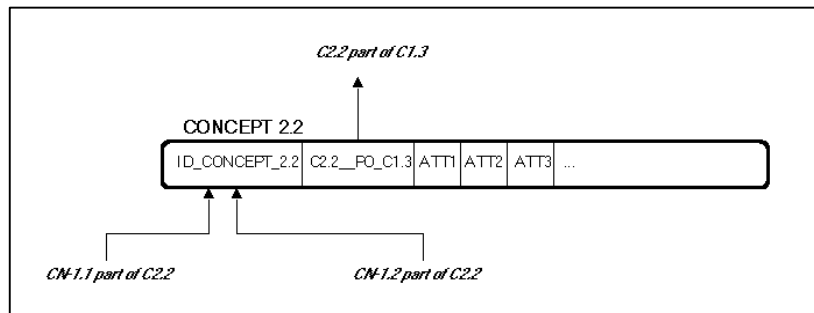
The N level is the major level of the model. Together with a primary key, the record linked to an element from this level contains columns which permits a quick location of the objects like the co-ordinates of a point for insertion (CPF) or the definition of a geometric envelope. Another column has the function to link the record with the geometric component of the object, this geometric component is itself linked to a logical topologic construction rule (ID_BODY_TOPOL). Finally, other supplementary columns describe the own semantic properties of the element, that is, contain the value of the particular properties of the modeled object (Figure 3).

Figure 3 : Structure of a level N element
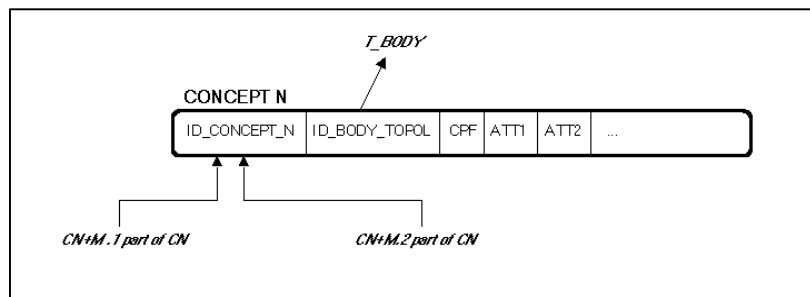
The objects from the upper levels are attached to records which have the same configuration than those linked to the objects of level N. The structure of these new records are completed with one more column to perform the link with an object from the directly inferior level.

This conceptual approach is a new way to define systematically, from a predefined and existing choice of management, the construction and the implementation of the different components of a topographic information system. In a relational database environment, the tables have a predefined structure and follow the construction rules described previously. This systematization is a pricey help for the users in the implementation of the topographic information system. It was tested and validated in different projects of the Photogrammetry and Geomatics Group from ENSAIS-LERGEC (Koehl M.,1999) (Nour El Din & al.,2000) (Gross Q., 1999).

2.4   3-D topologic model

2.4.1   Conceptual design

The modeling of the 3-D geometry can be done by following the principle of an entities-associations model when implemented in a relational database. To include as well the geometry as the topology we can use the basic definition of four primitives :
-   A node: it has for principal attributes the X, Y, Z co-ordinates and eventually qualitative information.
-   An arc : it is described by a primary key and other qualitative attributes.
-   The surface : it has the same structure as the arc.
-   The 3-D body : it has the same structure as the two precedent primitives.

These four entities and their respective associations define the 3-D model. Table 1 and Figure 4 show the detail of these primitives.

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ARC ------------- (1,1) -------------  ---- begin at -----  -------------- (0,n) ---------- NODE
ARC ------------- (1,1) -------------  ------ end at ------  -------------- (0,n) ---------- NODE
SURFACE ------ (1,n) -------------  -- bordered by --  -------------- (0,n) ------------ ARC
BODY ---------- (1,n) -------------  -- delimited by --  -------------- (0,n) ------- SURFACE
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Table 1. Relations between the topologic entities in a 3-D model

Figure 4 : Relation between Arcs and Surfaces
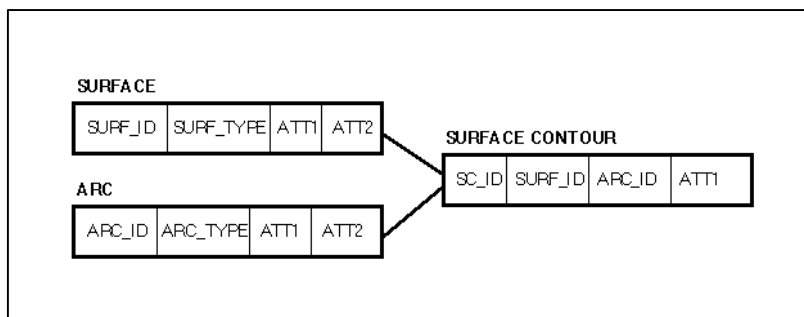
2.4.2 Logical design

The logical design is the step which principally correspond to the choice of the database management system and the choice of the structure of the information in the system. To simplify the process, and to take advantage of the manageability, and the facilities in the integration of the data, we use here a relational database management system.

2.4.3 Implementation of the 3-D topologic model

The transition from the conceptual design to the logical design permits to bring it operational. The entities are translated into relations between tables, or into new tables. The associations are translated in different ways depending on different cases and different cardinalities.

2.4.3.1 Translation into tables

- Nodes table : the node is the only one element of the structure that contains the geometric information. They are the ground elements. The uniqueness of the location of the geometric information has for major consequence to avoid redundancy in the recording of the geometry (Figure 5).

Figure 5 : Nodes table
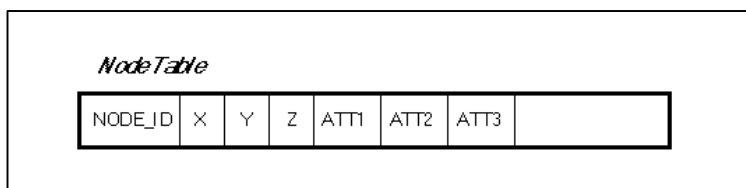
- Arcs table : the arc, linear element is defined by a begin and an end node number. In addition to these to attributes, the arcs table contains the different attributes which describe the arcs more in detail. The important is that arcs are not recorded with their complete geometry, but only in form of logical relations (Figure 6).

Figure 6 : Arcs table
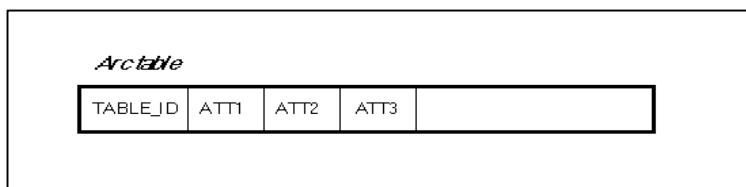
- Surfaces table : it contains only the primary keys of the surfaces and their semantic attributes. A face is described by a closed chain of arcs, so that another table is necessary. This definition is not a restriction to only planar elements. A 2-D topologic cell develops not only elements with the same geometric dimension.
- Bodies table : Like the table used for the surfaces, it contains only the primary keys and semantic attributes. A body is defined with faces as border elements. These description with border faces needs a supplementary table. If we

choose to orient the different arcs, we can give also an orientation to the faces so that it is possible to determine the position of the body relatively to the faces.

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2.4.3.2   Translation in relations

In the conceptual model we can find out tree principal associations : association between nodes and arcs, between arcs and surfaces, between surfaces and bodies.
-    The nodes-arc associations are right easy to understand.
-    The associations between arcs and surfaces are translated into relations between primary keys in the arcs table and primary keys in the surfaces table. For each surface there will be as much records of the relation as arcs in the contour of the surface.
-    The bodies-surfaces associations are similar in the principle than the surfaces-arcs associations. A relation (translated into a table) binds the primary keys of each body with the primary keys of all the surfaces that describe the body.

## 3   APPLICATION, IMPLEMENTATION OF THE MODEL

An object is now the designation of an accessible entity in the system. The definition of an object maintains the arbitrary character of the modeling. The choice of this modeling takes two specific constraints in account : the first are the specificity of the modeled site and the future use of the model, the second are related to the third dimension.

The precedent paragraphs showed a solution for a logical design which is able to consider efficiently the management of topologic, 3-D geometric information since semantic levels.

The objects in the 3-D space are in this case split up into an aggregation of entities with different topologic dimensions : nodes, arcs, surfaces and bodies. The semantic approach has for consequence to divide general concepts into different concepts of inferior orders which have own geometric and semantic signification and for which the exploitation permits to structure the different steps for data acquisition.

The Figure 7 shows an example for the structure of the Buildings with roofs models in the prototype of Metz (France) (Koehl M., 1999).

Figure 7 : Building structure with roofs models implemented in a relational database
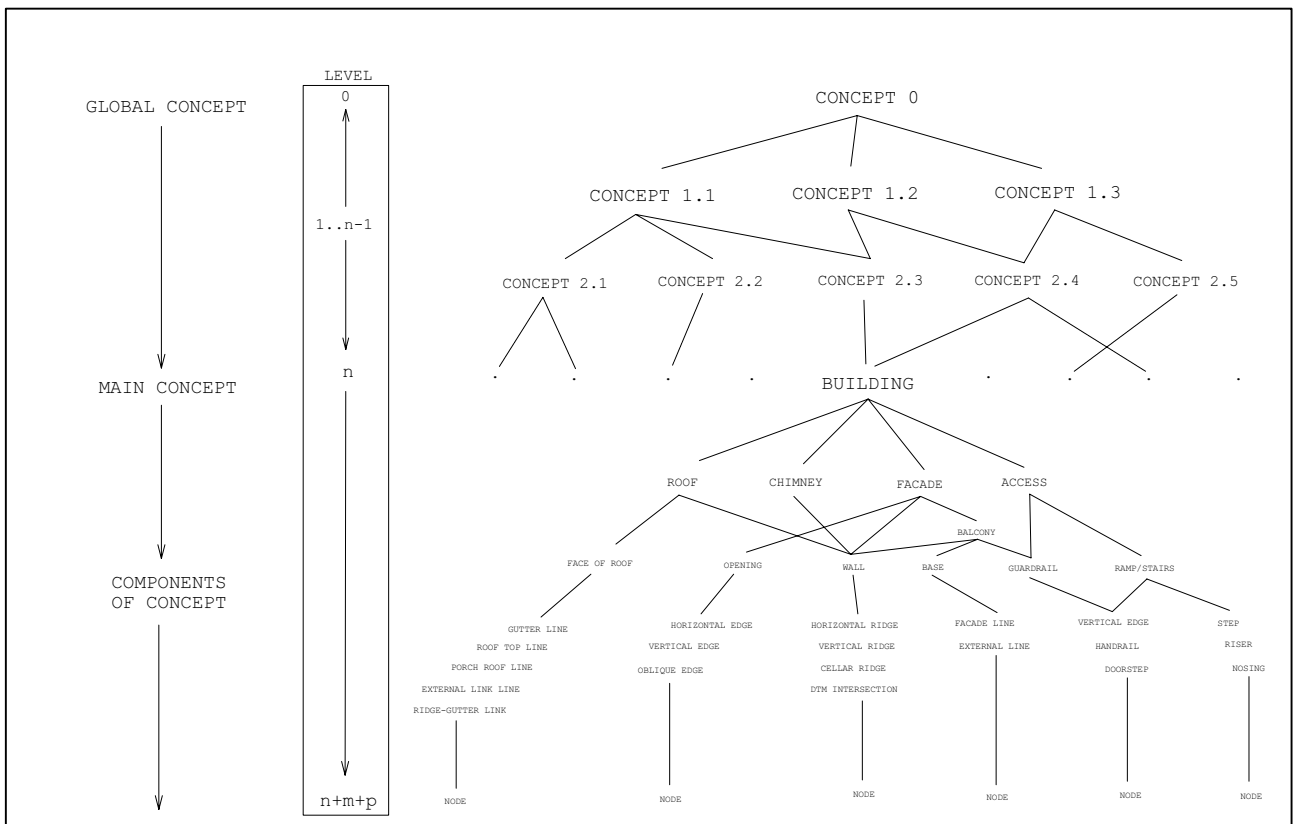
The Figure 8 is a part of the Figure 7 in which the only roof and façades are take into account.

Figure 8 : Detailed part of the semantic structure of a building
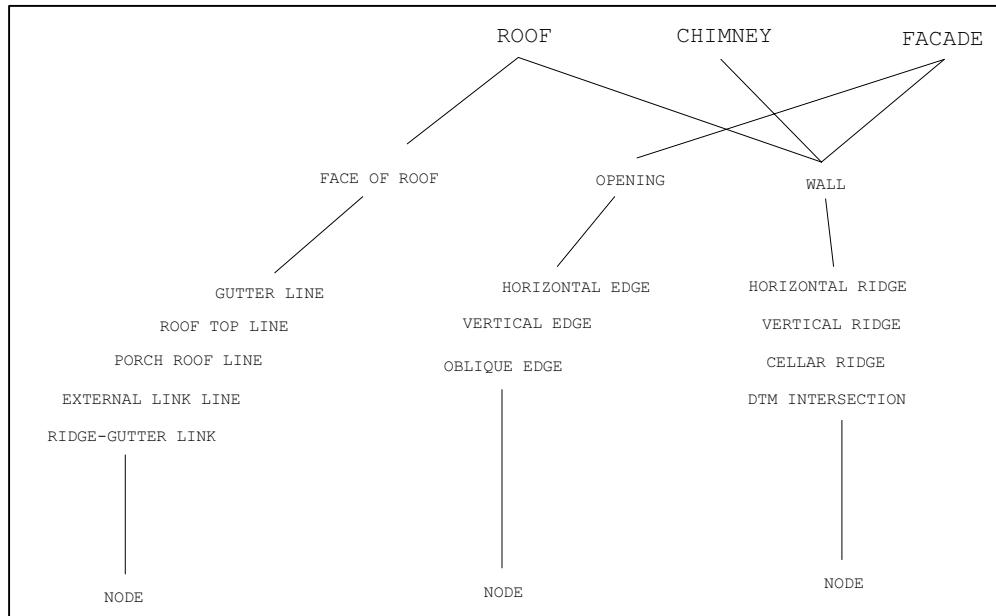
The Figure 9 shows the different tables needed to implement this only a part of the semantic structure detailed in Figure 8. We find here the main concept building (BAT_BATIMENT), the building components as bodies (--> T_BODYOBJ) : roof (BAT_TOIT) and façades (BAT_FACADE). A wall (BAT_MUR) is a surface (--> T_FACE) and can be part of a façade (BAT_MURPOFAC). Other surfaces are the roofs faces (BAT_TOIT). Then we have the different arcs (--> T_ARC) and a least the different nodes (T_NODE).
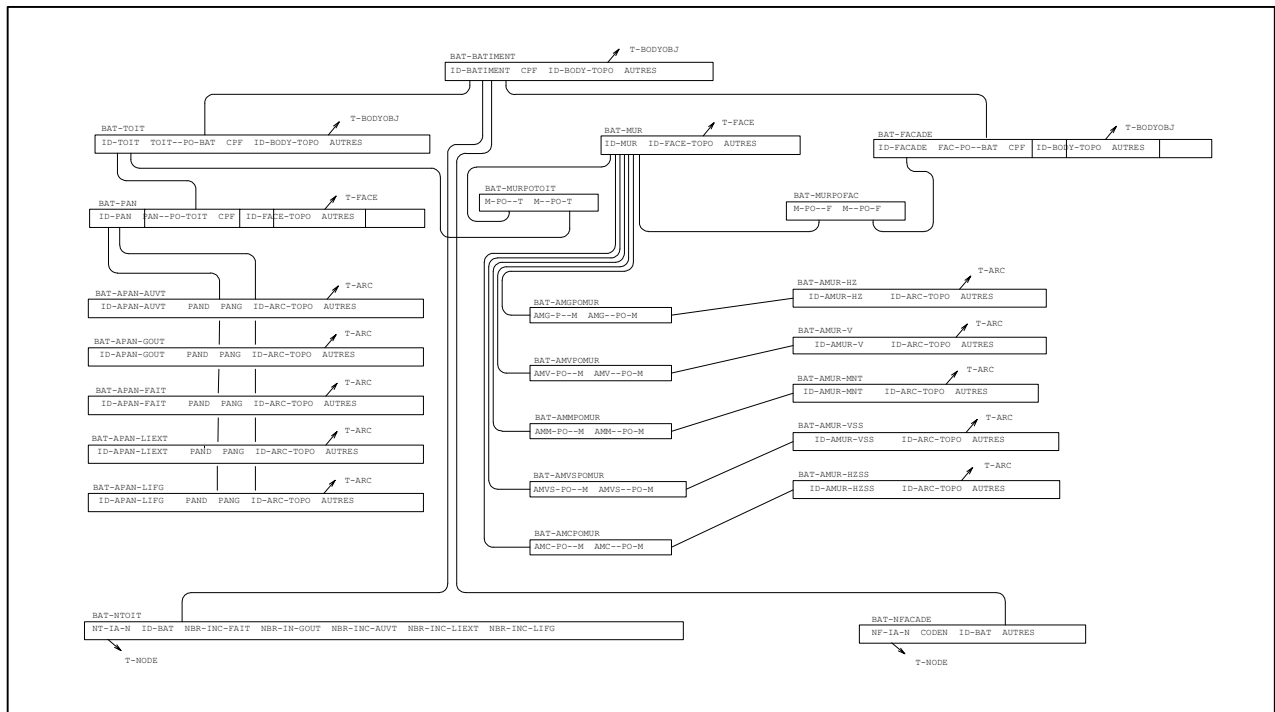

Figure 9 : implementation in a database

Another example for the structure of the simple buildings is given in the Sayeda Zienab project in Cairo (Egypt) (Gross Q. 1999)
In (Nour El Din et al., 1999) we can find a last structure of buildings implemented which takes also into account other architectural particularities.

These conceptual models and their implementation are the ground of the definition of construction rules that help the operator in the acquisition and in the reconstruction of the 3-D buildings. Thanks to the semantic definition and the topologic relations between the different parts of a building, semi-automatic building generators have been implemented.

They operate like the following general process :
- provisional recording of the faces of the underlying DTM
- location of the geometric elements which are component of a roof contour
- provisional recording of these elements in the system
- work out of each roof face
- computing of the complementary arcs of the structure
- topologic classification
- topologic generation of the building
- validation

4 CONCLUSIONS

Different projects of the ENSAIS-LERGEC show the potentiality of the principle of geometric reconstruction based on a priori semantic knowledge in the constitution of modeled objects. The implementation is at the moment based on very simple structures.
The modeling by exploitation of the semantic knowledge finds its justification in the case of the installation of a structured model in an environment for integration of the data. The characteristics of the site to model have to be favourable for the definition of semantic construction rules. However, it must be possible to find out characteristic features for a collection of elements. We have to limit to a minimum the particular cases, or to integrate them in the object generation process. Another rule is to precise the characteristics of the model according to the desired detailing grade, the available data set and of the constraints for the chosen reconstruction.

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