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ADDING TIME AND LEVELS OF DETAIL IN THE BUILDINGS MODEL

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ABSTRACT

The paper describes two improvements in the available three-dimensional (3D) data model-Urban Data Model (UDM) with surface and body objects. The advantages of these improvements reduce size of data storage; reduce the time cost of data show and visualizing data more realistic than the original model. The paper also added to the model time class to manage historical of changes on the spatial properties of 1D, 2D and 3D object. The levels of detail added to show buildings at four levels from simple to complex. Event class in the model should record the reasons to create changes on the buildings in their evolution.

*Keywords***.** 3D, data model, spatio-temporal model.

1. INTRODUCTION

The rapid growth in the field of economy and population has led to the speed of rapid urbanization. People wish to apply information technology in management of urban problems and 3D GIS solutions be discussed. Management issues need attention in 3D GIS: traffic management, land management, management of buildings. . . The management of the buildings considered one of the focal issues.

One of the keys in 3D GIS applications is data model design. The designed model will affect how to represent the data, store data, access data and analysis data. Characteristic of these models is more structured, more objects than 2D model. The models are classified by the model on surface, the model under the surface, model of the surface. Objects in the model have both non-spatial, spatial attributes. Over time the value of these properties were changing. The changes can discrete or continuous and evolutionary history should be stored in the full database to serve many purposes. There are two important purposes: knowing the trend for future mobilization of objects and providing information to support human decision-making. 3D urban information systems are divided into two groups: 3D GIS urban and 3D GIS geological. 3D GIS in urban models include [3]: transportation space model, trees space model, buildings model. Buildings model is emphasized among the models.

In recent years, many 3D models have been proposed [1, 9]. 3DFDS model of Molenaar 1990, TEN of Pilouk 1996, the OO model of DelaRosa 1999, the SSM model of Zlatanova 2000, SOMAS of Plund 2001, the UDM of Coors in 2003, and the CityGML model of Groger 2007. Characteristics of these 3D models follow: the 3D objects are represented at low levels as the 3D volume box. They are not represented the details as the roof or structure within the buildings [4, 5, 7]. The 3D models do not reflect the relationships the topology of space objects as well as lack of information about the semantics. While semantic information is needed, for example, we need to know the build time of a building C or the owner of the house B [3].

In addition, the studies of temporal-spatial data models also remarked. These issues also attracted many researchers for years [2, 6]; many models have been proposed with different authors: Event-Based model of Peuquet 2001, Chen 2000, Workboy 2005, State-Based model of Armstrong 1988, Langran 1992, and Liu 2006. 3D object-oriented data models Worboy 2005, Raza 1999. Most of these models performed for 2D objects [2].

These remarks show that these available 3D GIS models have the disadvantages:

- The dimensional time absences.
- Objects 2D and 3D are not specialized, so many cases data create very large.
- 3D objects are only represented by one level.

Therefore, the objectives of paper are to limit these disadvantages. Contents of the paper include: presentation summarize for UDM and disadvantages of it (2). Propose a method specialized for some 2D and 3D object of model data on the concept to reduce the volume of data and time data access (3.1 and 3.2). Propose adding the levels of detail on 3D objects by requirements the user. Levels of detail are four levels: 0, 1, 2, and 3 (3.3). Propose integration dimensions of time and events to keep track of changes on the properties of space-time. The changes will be stored fully and explicitly in the database (3.4). (4) Represent the experiments in Oracle 11g and C# language.

2. UDM AND DISADVANTAGES

UDM (Urban data model) which is a model of 3D GIS for urban management proposed by Coors in 2003 [8]. UDM built on four main subjects 0D, 1D, 2D, 3D by Point, Line, Surface and Body. Model (figure 1) used two geometric objects Node and Face. Node is described by three coordinates X, Y, Z. A Face is a triangle; it is represented by three Nodes. UDM is a 3D model that only describes the spatial properties of objects in a real world. UDM model has two main characteristics: size of data storage is small because the model omitted objects Arc and the model-represented surface of 3D block is good by triangulation. However, the model is still limited and this is the basis for recommending the paper proposed:

These disadvantages of UDM are:

- In UDM Surfaces, Bodies are represented by triangles. If the Surface is flat and the Body is the basic shape as the cylinder, prism, cone, and pyramid then the representation of UDM causes big storage size and shows surface need more the time cost and not the same reality.
- UDM has not mentioned the time dimension to manage the evolution of the objects.
- The representation of the geometric objects in UDM only describe in a fixed level.

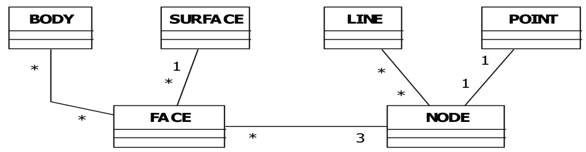

Figure 1. Urban Data Model

3. PROPOSALS

3.1. Specializing for surface

Comments: If the Surface is flat, the vertices of the Polygon used to represent the Surface. Example: For a surface S1 (figure 2) has 6 (n = 6) vertices 1, 2, 3, 4, 5, 6. If triangulation as UDM, S1 has four triangles: 01, 02, 03, and 04. In UDM method, relation FACE (IDF, IDN1, IDN2, IDN3, IDS) represents S1 in four rows (figure 3).

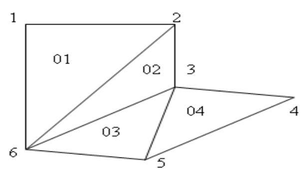

Figure 2. Surface S1

IDF	IDN1	IDN2	IDN3	IDS
01	1	1	6	S1
02	2	6	3	S1
03	6	3	5	S1
04	5	3	4	S1

Figure 3. Data S1 in FACE

In relation FACE, if each column size 2 bytes, number of bytes to represent S1: 10 × 4 = 40 bytes (40 = 10 n-20). Moreover, the UDM creates 3 (3 = n-3) redundancy edges: 62, 63, and 35, these edges are not in the reality. If using proposal 3.1, S1 is represented in relation POLYGON (IDS, IDN, SEQ). SEQ describes order of Nodes that create a polygon. In relation POLYGON, if each column size 2 bytes then number of bytes to represent S1: 6 × 6 = 36 bytes (36 = 6n).

In summary, if a polygon had n edges, the number of bytes needed to represent the polygon by triangulation method (10n - 20) bytes while the number of bytes needed to use an improvement in 3.1 : 6n. Therefore, bytes are reduced by 3.1: 4n-20 (4 n-20 = 10n - 20 - 6n).

3.2. Specializing for Bodies

Comments: If the building, roof of the buildings were pyramidal, frustum, the prism horizontally, the box, cylinder, Cone then these 3D blocks are represented by their geometric characteristics instead of triangular surfaces as suggested by UDM.

Then cylinder is represented by the bottom circle center, radius height, type of cylinder. The vertices coordinates of bottom polygon, height, and type of prism represent prism. Pyramid is represented by the vertices coordinates of bottom polygon and top of pyramid. Cone is represented by the center coordinates of bottom circle, radius, and conical vertex. A frustum is represented by the formed polygon.

Example: Given a prism B1 as figure 4, B1 has a bottom polygon 8 (n = 8) edges.

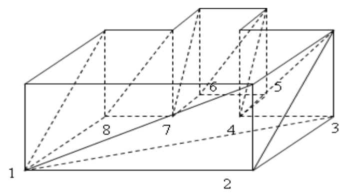

Figure 4. A prism B1 is modeled by UDM

IDB	IDF
B1	1
B1	2
...	...
B1	28

Figure 5. Data B1 in BODYFACE

The UDM method used triangles to represent B1 as figure 5. B1 is represented by relation BODYFACE (IDB, IDF) in 28 rows: 16 rows describe the side faces, 12 rows describe two bottom faces. Suppose each column is 2 bytes, the number of bytes required 4 × 28 = 112 bytes (112 = 16n - 16) and it generates 18 (18 = 3n - 6) edges, these edges are not in the reality. If B1 is represented by improvement 3.2, it is represented by relation PRISM (IDB, IDS, HE, TYPE-PRIS). There are two types of prism (TYPE-PRIS), vertical prism and horizon prism. Suppose each column in PRISM is 2 bytes, the number of bytes requires representation B1: 8 bytes. Overall, with the vertical prism B1 has n edge of the bottom polygon. Innovation 3.2 has the following advantages over UDM.

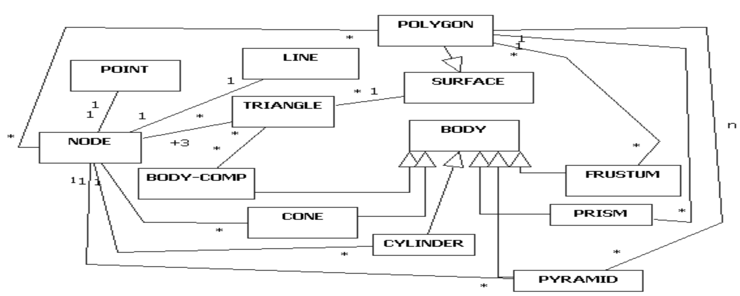

Figure 6. UDM after the proposal 3.1 and 3.2

- Volume data reduced (16n- 24) byte. (16n – 22 = 16n - 16 - 8).
- The numbers of unnecessary nodes reduce n.
- Reduced presentations of edges are not in reality: 3n - 6. (3n - 6 = 2n - 6 + n).

Summary, the advantages of the specializing for Body include reducing size of data, limiting storage of redundancy data in relation NODE, and displaying fast data.

Suppose the cylinder, prism, cone, pyramid, frustum has a polygon bottom n edges. Table 1 summarizes the number of bytes to be reduced by proposal in 3.2. This reduce will show fast data and true more UDM. UDM after the proposals 3.1, 3.2 is designed as figure 6.

Table 1. Comparison number of bytes between UDM and UDM after proposals

	Cylinder	Prism	Cone	Pyramid	Frustum
Bytes needed to represent by UDM	16n - 16	16n - 16	8n - 8	8n - 8	12n - 8
Bytes needed to represent after the improvements	8	8	8	6	4n + 4
Bytes to be shortened by improvements	16n - 24	16n - 24	8n - 16	8n-14	8n - 12

3.3. Additional time dimension to UDM

The historical management of the spatial changes over time is an objective of GIS applications. To solve this problem, time class will be added to the model. Classes and links added to dimensional time in the new model is described as figure 7. Time class: is divided into two types of time, instant or an interval of time. For example, a building X built on 21/01/2010; 21/02/2010 is instant time. If X built on January 21, 2009 to January 21, 2010, [21/01/2009, 21/02/2010] is an interval of time. DMY class is described by the day, month, year attributes. Event-Type class is described by the name attributes of event. Event class has a begin time and end time in real world and database. Begin time and end time can be instant or interval time.

Link between Time and Body describes time of begin and the end of each Body. A Body has both times, begin time and end time in real world and database. Begin time and end time can be instant or interval time. Similar, link between Surface and Time describes for the time begins and ends of Surface in real world and database. Link between the Line and Time describes time that Line begins and ends in real world and database. Link between Point and Time describes time that Point begins and ends in real world and database. Link between Body and Event describe a Body is created by what event. Thus, the objects 0D, 1D, 2D, 3D always has 4 times, the begin time, the end time in real world and database. These times may be instant time or interval time. If it is instant time then column INT - INST = 0 in relation TIME (IDT, IDDMY1, IDDMY2, INT-INST).

3.4. Additional display of building according to the different levels of detail

Displaying 3D objects depend on the following: viewpoint, distance between the observer and the position of objects, the size of real 3D objects, a range of importance of objects in a specific application. Table 2 presents the criteria levels of detail in the building management applications. Levels of detail divided into four.

Line is specified by Real-Line and Edge. Edge class is used to describe the segments in showing the building at Lod2. Surface is specified by Polygon and Window. Window class is used to describe windows of apartments in showing the building at Lod3. Link between Body and Lod describes the Lod of each Body. Link between Window and Lod describes detail level of a Window. Link between Line and Lod describes detail level of a Line. Furthermore, there are links between Edge, Window, Body and Building, these links describes own relationship of Building with Bodies, Windows and Lines. The Building entity is described by Building class.

The recursive link of Building describes their parent and children relationship. UDM after two improvements to the storage object 2D, 3D and integrating time, LOD classes has as figure 7.

Table 2. Levels of detail (Lod) to represent a building

	Lod0	Lod1	Lod2	Lod3
Model	2D	3D	3D	3D
Level of overview		Buildings as blocks	Buildings have floors	Buildings have roof, windows, balcony
Structure of the roof	None	Flat	Flat	Close to reality
Size (can change)		> 5m × 5m × 5m	>3m × 3m × 3m	>2m × 2m × 2m
Sub construction		Important construction	As blocks	Close to reality

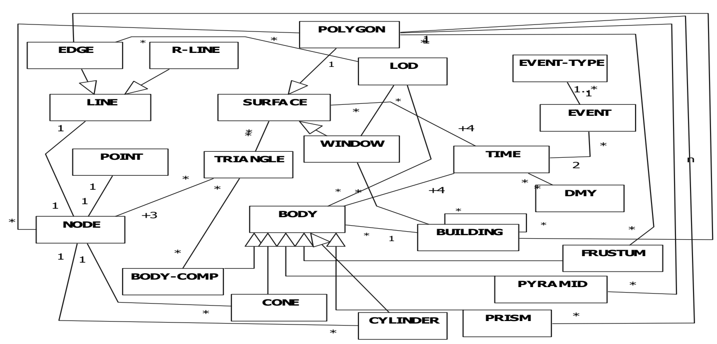

Figure 7. UDM after adding Time, Lod classes

4. EXPERIMENTS

The following experiments are installed in Oracle 11 g and C #. The sample data in database have inserted 100 houses H1 and 4 buildings B1 (Fig. 8) and they are built in different years. The tables (table 3, 4, 5) evaluate for data size in UDM and UDM after the proposals. It reduces from 54,400 bytes to 23,200 bytes for 100 houses and from 4,352 to 1,800 for 4 buildings. Average rate of reduction is 3.6 times.

Table 3. Bytes of House H1 for UDM

	NODE	TRIANGLE	BODYFACE	Sum	Amount	Total
Bytes	136	272	136	544	100	54,400

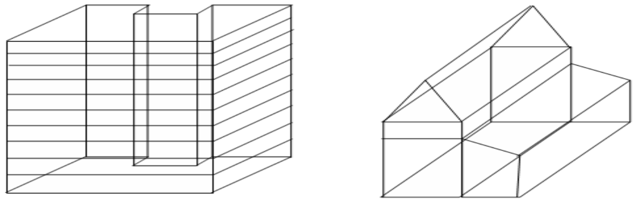

Figure 8. (Left) a building B1 and (right) a house H1

Table 4. Bytes of House H1 for UDM after proposals

	NODE	LINE	POLYGON	PRISM	Sum	Amount	Total
Bytes	112	12	84	24	232	100	23,200

Table 5. Bytes of Building B1 for UDM

	NODE	TRIANGLE	BODYFACE	Sum	Amount	Total
Bytes	320	512	256	1088	4	4,352

Table 6. Bytes of Building B1 for UDM after proposals

	NODE	LINE	POLYGON	PRISM	Sum	Amount	Total
Bytes	280	108	54	8	450	4	1,800

Results of spatial query for time and LOD are presented through the forms. Form1 illustrates two the buildings were built from 2004 to 2005 and their data are shown in the level 0 as planes (Fig. 9). Form2 illustrates the buildings was built from 2004 to 2005 and their data are shown in the level 1 as the blocks (Fig. 9). Form3 illustrates the buildings was built from 2004 to 2005 and their data are shown as the building has 10 floors (Fig. 10). Form4 illustrates the buildings was built from 2004 to 2005 and their data are shown as the building has 10 floors and windows of apartments (Fig. 10).

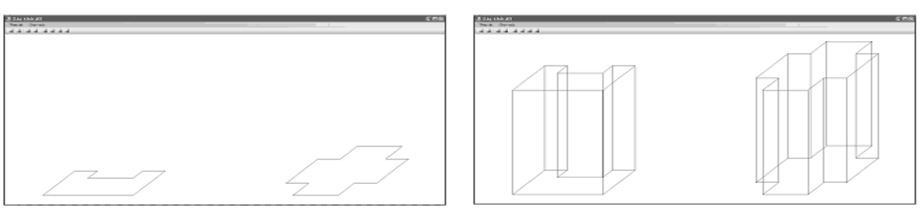

Figure 9. Form1 (left) and form2 (right)

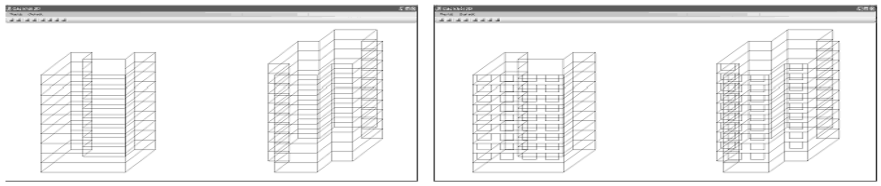

Figure 10. Form3 (left) and form4 (right)

Form5, form6 in figure 11 illustrates a building was presented by UDM and UDM after proposals. Thus, form6 shows a building more realistic than form5.

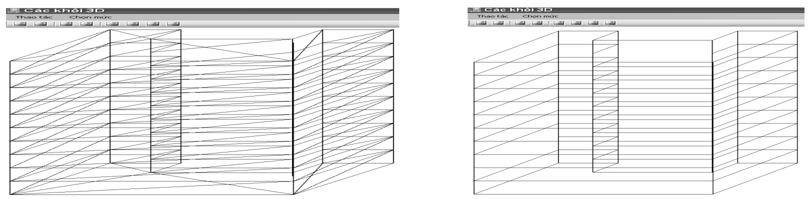

Figure 11. Form5 (left) and form6 (right)

5. CONCLUSION

The paper has made two proposals to represent a flat Surface and Body that has the basic geometry. This representation was reduced storage space simultaneously to speed display 3D data quickly and more similarity that is real. The paper also offers time dimension on the concept data model to record the evolutionary history of 0D, 1D, 2D, 3D objects over time. Finally, the paper also suggested adding LOD class into the model to server visualization of buildings at different levels. Last model reflects full GIS information for managing the building in the urban, including a full range of attributes: spatial, temporal and LOD. Particularly changes in the properties of spatial-temporal objects are stored completely in the database for the exploitation of information needs over time.

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