TOWARD A GENERAL SPATIO-TEMPORAL DATABASE STRUCTURE FOR GIS APPLICATIONS

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ABSTRACT:

Handling time in geospatial information systems (GIS), the applicability of these valuable systems will increase, so, there hardly exist an application dealing with spatial information which can not be benefited from a temporal GIS. Despite many efforts undertaken since 1980, there is no generally accepted model which can satisfy all temporal GIS requirements. One of the most important problems in designing a temporal GIS lies within its database structure. In order to handle time in GIS, one must decide about how to organize such dynamic information. In the other word, extending spatial databases to include time is an essential issue. In this paper, a comparative study on different spatio-temporal database structures including three-domain model, extended versioning database structure and object-based spatio-temporal data model is undertaken and based on their advantages, a general spatio-temporal database structure is proposed and successfully implemented.

1. INTRODUCTION

Database structure is one of the most important parts of any geospatial information systems. This is especially important for spatio-temporal GIS in which spatial and/or aspatial information changes over time [Nadi et al., 2003]. So far, a number of researches have been done in this field such as three-domain model proposed by Yuan (1996), extended versioning relational database structure developed by Claramunt and Theriault (1995) and object-based database structure proposed by Worboys (1992). In this paper, based on the advantages and disadvantages of the above-mentioned models, a general database structure for spatio-temporal applications is proposed.

In Sections 2 and 3 of this paper, a comparative study on the cited models is undertaken. In Section 4, our proposed database structure is described, implemented and tested with a data set at a scale of 1:500 from parts of Isfahan Province in Iran. Finally conclusion and future works are explained in Section 5.

2. A REVIEW OF THE SPATIO-TEMPORAL MODELS

There are number of data modeling approaches in spatio-temporal GIS such as snapshot data model [Armstrong, 1988], space time composite data model [Langran and Chrisman, 1988], event-based spatio-temporal data model [Peuquet and Duan, 1995], object-based spatio-temporal data model [Worboys, 1992], extended versioning database structure or event-oriented approach [Claramunt and Theriault, 1995] and three-domain data model [Yuan, 1996].

As the three-domain model, extended versioning database structure and object-based spatio-temporal data model are most general [Nadi and Delavar, 2003], in this paper a comparative study on this models is presented and the results used to design and implement a general data model.

2.1 Three-domain model

In three domain model, the time domain is considered separated from space and attributes domains as illustrated in Figure 1.

a. Semantics Table				b. Time Table		
Sem. ID	Landcover	Management	Address	Time ID	Time	Operator ID
1	Old Growth	USFS	12 Forest Rd.	1	1600	2439
2	Clear-cut	A. Log Co.	3 Clear Dr.	2	1700	2439
3	Burn	USFS	12 Forest Rd.	3	1800	7473
4	Clear-cut	B. Log Co.	45 Pine Ave.	4	1950	1029
				5	1960	1029

c. Space Table			d. Domain Link Table (Links among temporal, semantic, and spatial objects)		
Space ID	Area	Perimeters	Sem. ID	Time ID	Space ID List
4	A_1	P_1	1	1	1
6	A_2	P_2	1	2	2
8	A_3	P_3	2	2	3
9	A_4	P_4	3	2	4
10	A_5	P_5	1	3	5
11	A_6	P_6	2	3	3, 6
12	A_7	P_7	1	4	7, 10
13	A_8	P_8	4	4	8, 9
14	A_9	P_9	1	5	10, 11, 13
15	A_{10}	P_{10}	2	5	6, 12
			3	5	4, 14, 15

e. Elements stored in the spatial domain.
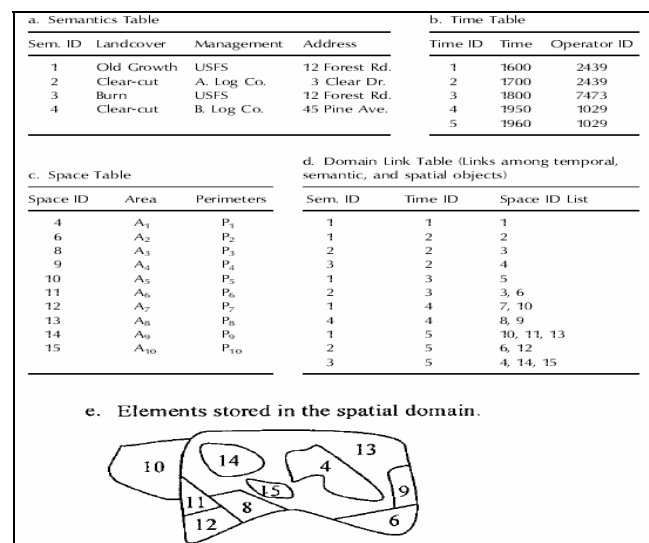
Figure1. Three-domain spatio-temporal data model [Adopted from Yuan, 1999]

The data from these three domains is stored in three separated tables and these tables as well as different versions of objects are linked through a table containing three unique primary keys. This table is named domain link table and can be visualized through a spatial graph [Yuan, 1999].

2.2 Extended versioning database structure

Extended versioning database structure is an extension of basic versioning database schema which is common in computer sciences. In this model the basic versioning database schema is extended so that events involving several entities can be added [Claramunt and Theriault, 1995]. This model is illustrated schematically in Figure 2.
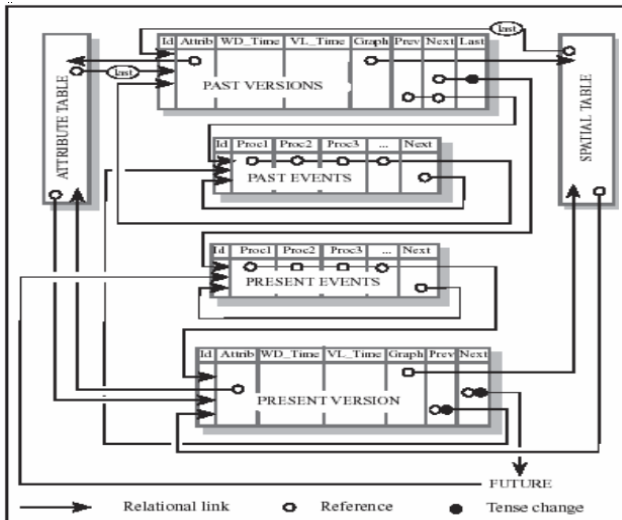

Figure 2. Extended versioning database structure [Claramunt and Theriault, 1995]

2.3 Object-based spatio-temporal data model

Object-based spatio-temporal data model is proposed by Worboys in 1992. In this model as illustrated in Figure 3, time length of each object version, its attributes and spatial object are stored in one table.
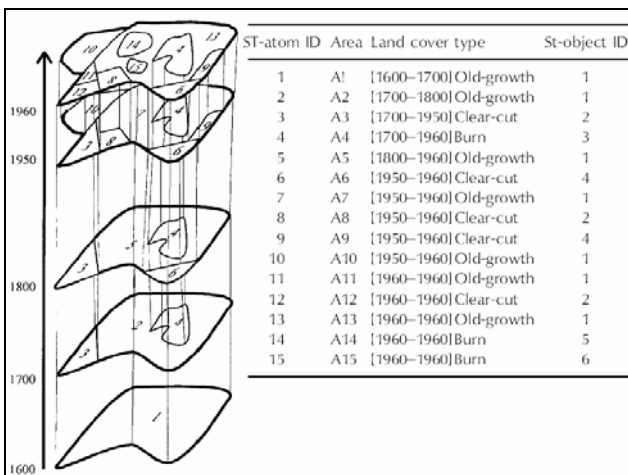

Figure 3. Object-based spatio-temporal data model [Worboys, 1992 cited in Yuan, 1999]

3. COMPARISON OF THE MODELS

There are some important requirements which can be used to compare the above-mentioned models. Each model has to maintain at least three requirements for a spatio-temporal GIS which are as follows [Nadi, 2004]:

1. The ability of changing spatial information independent of its attributes and vice versa.
2. The ability of handling event based queries about how an object has been changed.
3. As information in a spatio-temporal GIS is subject to change, a mechanism is needed in order to maintain the integrity and security of information.
4.

In object-based model, despite its simple structure, none of the afore-mentioned requirements are maintained. In three-domain model only requirement number one is attained. In extended versioning database structure only requirements number one and two are attained.

4. DESIGN AND IMPLEMENTATION OF A GENERAL SPATIO-TEMPORAL DATABASE STRUCTURE

As it is depicted in Figure 4, we proposed a database schema which consists of five tables organized at three access levels. The successful test of the proposed model proved that this structure maintains the three requirements for a spatio-temporal GIS.
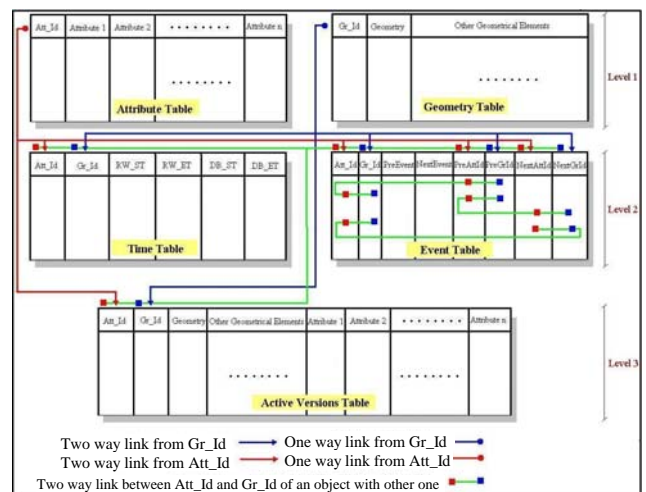
Figure 4. Designed database structure

As illustrated in Figure 4, storing attributes separated from geometries, the requirement number one is preserved and as the events are stored explicitly in a separate table at level two, the requirement number two is also attained. Security and integrity are also preserved organizing these five tables at three access levels and using some constrains in addition to linking tables, respectively.

5. IMPLEMENTATION

As illustrated in Figure 5, the designed database structure implemented as an extension for ArcView 3.2 package and used to manage urban land use changes at a scale of 1:500 from some parts of Isfahan province in Iran.

Figure 5. Implemented application under the designed database structure

In Figure 5 the three represented levels and links are equivalent to those in the Figure 4.

6. CONCLUSION AND FUTURE WORKS

We designed a database structure for spatio-temporal GIS applications based on a comparative study over existing models and explained that how this model overcomes the shortages of the other models. The developed model enjoys the main advantages of the mentioned models in terms of the ability of changing spatial information independent of its attributes, the ability of handling event-based queries about how selected object has been changed and security and integrity of its spatio-temporal information in the developed temporal GIS maintained. The most important issues remained are to evaluate the performance of the designed and implemented data model and to develop a spatio-temporal indexing method to improve it which are the next steps of this research.

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