IMPLEMENTATION OF WITH THE SPATIO-TEMPORAL GEODATABASE USING A SERVER “OODBMS”

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ABSTRACT:

As known, the most greater part of the systems GISs that come projected today have the ability to use for the data management the Geodatabases, or rather spatial database whose principal characteristic is that to model the geographical data using the object paradigm. Unfortunately such type of modeling, able to maintain the bank dates consistent and efficient, it is implemented in the various softwares GeoDB alone in the layer of representation (and with limited functionality), or of user interface; on the contrary, in data storage, you deals with DBMS servers using a relational approach.
This choice not only implies an important fall in the system performances, but the representation inside a GIS of the contexts endowed with notable dynamism becomes complex, in fact in such cases the data management (population and quering) you must have effected to every level through operational interfaces endowed with a tall degree of abstraction.
In consideration of these facts, we develop an alpha OODBMS server, named "Kosmos", oriented to GeoDatabases, differently from all other DBMS softwares. Kosmos making passes through a preliminary step in which we are going to define an algebraic structure and a rigorous formal model to describe GIS objects and functional operators acting on these objects. Kosmos, thanks to these characteristics, it allows a simple management and at the same efficient time of database geographical spatio-temporal, is for instance possible to effect some operations of geoprocessing (intersect, union, etc…) multi layers - multi temporal, tracking areale and to define some relationships spatio-temporal between features. Software design follows the Open Source philosophy; in particular, Kosmos is released under GPL license and anyone can take part in its coding.

1. INTRODUCTION

The manipulation of complex data, like the big sized space-temporal ones, has become one of the recent challenges of the current research. Many applications, such as GIS, the geometric modelling systems, and temporal database need a certain experience and competence to memorize and manipulate temporal and geometric databases.
This is due to the particular lack of a high level formalism dealing with this kind of informations, in the most abstract and, in the time, closer to the reality.
The traditional databases are not able to manipulate such high level abstraction complex data. In fact, conventional GIS data models, deals with a static representation of the reality. The geographic informations for a specific area are separated in a whole of layers, as models of regular framing (raster) or irregular (vectorial).
Only on these layers, GIS has the possibility to represent dynamic informations, such as the transitions and the movement. Raster cells, codify the attributes values in every specified data, disregarding the object’s special features they represent. On the contrary, the vector object geometrically indexed, force the framing of boards, represented in separated layers, when they act in the time and in the space.
The annexation of temporal components has been implemented with the relational model, first, and with the object oriented model. The main problem, is the semantic of data in the modelling of informations; the basic idea used in the environment scope, is increasing the abstraction level, concerning tables/layers and the objects/events.
The theoretical analysis and the assessment on the field, confirm that it would be useful to have a space-temporal system (Renolen, 1995), shaped in four dimensions, where we have the possibility to mode space in three dimensions and adding the temporal component as the fourth one.
A space–temporal object coul be represented by a four dimensions vector (a, g, p, t), where the first component describes attributes, the second one the geometric composition, the third one the topological description and the fourth one the temporal description. Such way of describing objects has several advantages; in the first place, it disregards the numbr of space 2D and 3D dimensions, and in the second one, it defines topologies as the disjoined dimension indicating the system can obtain directly a topology, instead of make it derive from geometric or temporal components.

2. THE TEMPORAL DIMENSION

Time is defined like something catching changes or the evolutions of phenomena. Changes made on geographical data, often reflect the real life ones.
In GIS, this can be integrated through the modelling of objects change whose properties are different during the time (Langran, 1992), like a series of transition of their current stage, distinguishing the map’s change and the objects composing it.

The map has a different stage for every change, while objects have a different version for every change. We must stress how an event can arise a map change and a mutation can provoke an object's change.

In general, there's no difference between a map's stages and the objects' version, in fact, according to the examined point of view, an object version is equivalent to its state and mutation and vents are synonyms. An objects change on a map, provokes a stage transition, but the new stage can be defined even like a new version of the map; so the paradigm of change is used to deal both with the stage transitions, and the new versions.

In this sense, we can see a kind of integration of a more flexible temporal component (Skjllaug, 1996); in fact, we can consider the concept of map to define a digital data structure, catching informations about phenomena of a shaped reality.

A map model is a structure populated by objects representing phenomena.

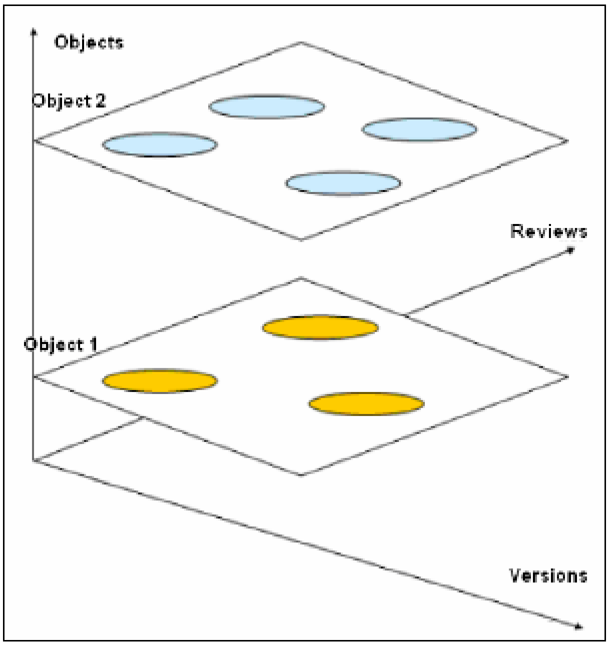

Figure 1. Topology of dynamic objects

In the figure 1, there's a representation of dynamic objects, changing their properties in the time. Every object has a change sub-space, indicated through rectangular planes, where the different versions and revisions are managed. Versions represent the alternatives of an object and revisions catch both the valid time paradigm and the trasition one.

The main problem in the temporal GIS, is to show to the user the changeable nature in the time of geographical data. The common method of representation of geographical data are maps and chats; for instance, analogical maps allow to catch phenomena and their changes in a complete way. The next changes of the basic map are made by human sources modifying or replacing representations of phenomena. In the digiatal maps, make arise a series of manipulation problems, not exing in the analogical one. A digital map is generated by an analogical one, together with different features or attributes to build a complete whole of geographical data.

The whole is considered as a board, and this is considered as a physical photo of the reality.

In general the problem is that changes made on their whole are not considered above the same whole, but from the comparison of the current version of the same with the precedent one.

The task concerning the temporal dimension is to change data, that's changes of the shaped reality, we must catch geographical data. in this sense, we can say that time is the feature of shaped data.

In GIS, one of the problems, is just the lack of mechanism allowing to manage the temporal component characterising the main part of the geographical applications.

Such limit is well known in the scientific community (Langran, 1992, Michael, 1992) and many resolution approaches have been proposed (Skjllaug, 1996). Today, a universally accepted and affirmed on the other ones proposal is not yet existing. Today, GIS systems don't provide any primitive feature in the time, so if it's necessary, time is introduced as an explicit attribute or managed through system extensions specifically developed.

In this paper, we'll see how a possible approach to this kind of problem can be endowing geographical system through languages, able to manipulate informations, both special and temporal, adopting two instruments: MuTACLP and STACLP languages (Raffaetà, 2001), and the integration of this in Kosmos, an "OODBMS" server, oriented to the development of Geogrphical informative systems with Geodatabases.

In this paper, we'll speack only about MuTACLP language, to stress the opportunities of the introduced approach.

3. THE LANGUAGE MuTACPL

The declarative MuTACLP (Multi–theory Temporal Annotated Constraint Logic Programming), extends the classical logic planning with mechanisms to manage space-temporal "geometries".

After, we'll consider how the usage this integrated language with Kosmos through its own declarative approach, instead of procedural, allow to improve the analysis functions of space-temporal functions.

The MuTACLP language has been used, in particular, for analysis concerning the animal endeavour and the detection of urban areas with particular features. In this paper, we'll show a possible implementation of mobile objects, having a specific aim.

This language allow to represent indicating in which moments of time a specified formula is valid, while space data are represented through constraints in the style of relation database constraints.

In the MuTACLP temporal dominion, the time can be discrete or dense; in particular, the temporal points are totally ordered by the relation "=".

On the whole of temporal time, called T, the same operations "+, -" are also defined. Moreover, we assume that the temporal line is limited to the left side by the 0 and opened to the infinite, (toward the future), with the symbol "8 ", used t indicate a temporal point, very far from any other.

It's necessary to add that, a temporal period, in this case, is an interval [r,s], where 0 = r = s = 8 , r ? T, s ? T; this represents the convex whole, not empty, of temporal points {t ? T | r = t = s}. The interval [0, 8] indicates the total temporal line.

The basic components of programs written in MuTACLP, are noted formulas, of the form Aa, where A is an atomic formula and a is a note.

Three kinds of notes and based on temporal points and priods, are existing. For instance, if we take a temporal point t and a temporal period J=[r,s], we'll have:

1. (**at**) the noted formula *A* **at** *t*, meaning that *A* is equal to the instant *t*;.
2. (**th**) the noted formula *A* **th** *J* meaning that *A* everywhere, that's in every istant of the period *J*. The definition of the note **th** in **at** terms is:

$$A\ th\ J \Leftrightarrow \forall t(t \in J \rightarrow A\ at\ t) \qquad (1)$$

3. (**in**) the noted formula *A* **in** *J* meaning that *A* everywhere, that's in every istant of the period *J*, but we don't' know exactly the moment. This note allow to represent indefinite temporal informations. The definitions of the note in **at** terms is:

$$A\ in\ J \Leftrightarrow \exists t(t \in J \wedge A\ at\ t) \qquad (2)$$

The whole of notes has the relation of partial order **µ**, contained in a "lactice" (an algebric rack).

For instance, if we consider two notes a and ß, it will be a **µ** ß, if a provides less informations than ß.

4. TRACKING MODELING

The space tracking, the geoprocessing and the area tracking, are operations based on defined methods, starting from the formalization of aims and movable objects. (Sheikholslami, 1998).

Here, we show how they can be shaped, in the languages of reference MuTACLP e STACLP, aims of movable boards, and their evolution in the time.

Amond the different implementable models, the broken model is the one joining two very important features for GIS querying: speed of execution and good representative flexibility.

If we have a whole of incoming data, of points with a temporal component, that's a triple (x, y, t), where x and y are the coordinates of the relevation point ant t the temporal instant, or timestamp, where the relevation has been done.

In this first case, aims are shaped and represented through the interpolation of the control points; in other words, the aim will have the shape of a broken line or a curve, according its interpolation, as we can see in the figure 2.

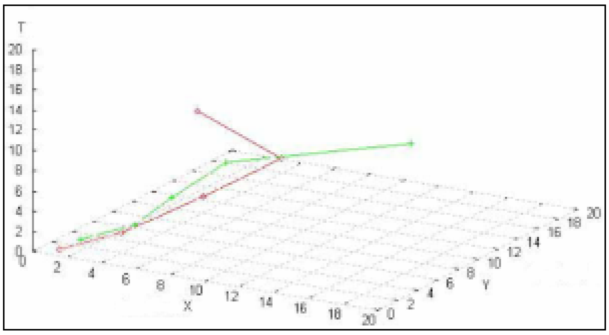

Figure 2. Aim's representation

In the figure 2 there are two possible aims, evolving in the temporal axe. In this case, we assume that between two instants of relevance, the speed of an object shifting is costant (that's it'moving in a uniform and straight way).

The linear local interpolation is a kind of interpolation suitable to represent this kind of aims.

This allow to approximate in a simple way the object's movement and, in temporal instant, ti, involved between the two instants of relevance [t1, t2], are able to supply a "theoretical" special coordinate (xi , yi).

Considered the two next relevances in the time, and detected by (x1, y1, t1) and (x2, y2, t2), where t1< t2, we can formalize (employing MuTACLP and STACLP languages) in this way:

$$p(x)atp(x_1, y_1)at\ t_2 \leftarrow t_1 < t_2 \qquad (3)$$

$$p(x)atp(x_2, y_2)at\ t_2 \leftarrow t_1 < t_2 \qquad (4)$$

$$p(x)atp(x_i, y_i)at\ t_i \leftarrow t_1 < t_i < t_2$$
$$x_i = \frac{x_1(t_2 - t_i) + x_2(t_i - t_1)}{(t_2 - t_1)} \qquad (5)$$
$$y_i = \frac{y_1(t_2 - t_i) + y_2(t_i - t_1)}{(t_2 - t_1)}$$

The theoretical points (x_i , y_i) are obtained using the formula to calculate a straight line passing for two points and applied separately to the x and y components, in comparison with the time. For instance, as for the abscissa, x_i has been calculated starting from the formula :

$$(x_i - x_1)(t_2 - t_1) - (x_2 - x_1)(t_i - t_1) \qquad (6)$$

5. INTEGRATION OF THE MODEL IN KOSMOS

The usage of GIS software for a "short typization" modelling, through mere layers, as we saw before, don't' allow to represent efficiently geogrphaical objects evolving during the time (Han, 1998).

The models of construction of GIS mentioned before, give birth to problems, even in the stage of insertion and modification of data, since it's difficult to build some operational bindings, (such as inserting, erasing and modifying them etc), because this is not strictly topologic.

As for the GIS designer, even if endowed with very good skills of buildings for abstract models, if he uses softwares employing traditional paradigms it will be difficult to hope in a debugging brief time.

During these years and in order to overcome this limitations, the great multinational have implemented different software solutions, working in this field and creating the objects to shape elements in the so called "virtual map". Shortly, the above-mentioned paradigm, deals with the usage of particular formal structures, called Classes; these are characterized by the concept of the"whole", generalizing the ownership defined by Cantor.

The Classes of objects can be defined, both as a declaration of the types contained in them, and the specialising of other ones, adding to these ones, the declaration of other kinds (in such case, we can talk about the so called "derivation"); moreover, the elements contained in them, can be functions operating on several dominions. Classes and dominions can be dynamically different from a parent Class to a derived one, so the object belonging to different Classes, but deriving by an only common Class "behave" in a different way in the same representative context.This last property, is probably the most important in the GIS scope and it's called "Polymorphism"; so it's easy to understand why a class function is called "methods" or "endeavours", and, therefore, the ability of abstraction can be easily obtained for the GIS with space temporal extensions.

The most common GIS software of the current market, allow the building of an informatic system, using a project paradigm, oriented towards the objects (that's the modelling with the Geoclasses, or rather Geographic Class), and implementing the so called "Geodatabase". Unfortunately, the physical storage of the alphanumeric and space data, is done through the RDBMS Server Database; so,while the user is relating with the Geoclass, these are "physically", implemented by the system employing the algebra ratio; this choice, restricts the model's power and involves a considerable decay of the performance.

This, involse a hard suitability of the software as for the insertion of the temporal component, because of the lack of the degree of absrtraction, and, moreover, it's complex to integrate the intepreters MuTACLP e STACLP to face all the situations. Because of this consideration, we decided to develop an experimental software called "Kosmos" (Barrile, 2005), which is both a general purpose software GIS, and an OODBMS server, to store data.

Another common GIS feature is the user has few chances to define Geoclasses Custon; often it's allowe o define them only starting from alphanumeric attributes and not from the methods; the same happens for the derivations where it's possible to add the definition of alphanumeric elements. Hence, the polymorphism among the Geoclasses defined by user is consistent with defined events, such as the inserting of a value in a specific attribute or the control of relations' cardinality.

Kosmos wants to overcome such limits, allowing the definition, from the GIs user, of Geoclasse complex hierarchies in easy and intuitive way, and ready to be used once more.

Such operation, is possible, since basic classe implemnted in java inside Kosmos, it's foreseen a "charging" mechanism of definitions of Geoclasses defined by the user, becoming "classes", derived from the first ones, as they were implemented directly in Java! The advantage is to extend the polymorphism mechanism insight the processing language to Geoclasses.

Observing the figure 3, it's possible to see how Kosmos is good to integrate declarative languages spoken before and, consequently, it can face the shaping of geographical context where the temporal component is present.

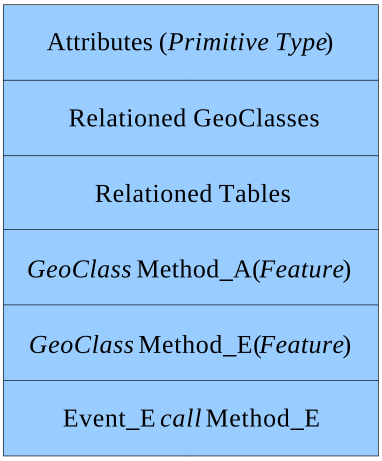
Attributes (*Primitive Type*)
Relationed GeoClasses
Relationed Tables
GeoClass Method_A(*Feature*)
GeoClass Method_E(*Feature*)
Event_E *call* Method_E

Figure 3. The Custom GeoClass

Geoclasses defineable by user allow to define methods containing guidelines describe d by an inner parser or previously implemeted by Kosmos (or dynamically linked). Such guidelines can be series of SQL-Like queries, but also rules to interpret MuTACLP or STACLP. The Custom GeoClass allow to define association among different pre-defined in Kosmos and "polymorphic" methods to act, cointaining the MuTACLP code, thanks to which we can obtain the next position stage of the same.

This kind of approach, make easier both the definition of a feature through temporal extention, and, starting from this, it's possible to make the same for Querying, Geoprocessing and Tracking.

6. CONCLUSION

The declarative language MuTACLP allows to define, through the definition of non equivocal rules, a consistent and complete representative methodology of the temporal space data, and at the same time the interpretation of such rules allows the interpreter to define the behavior of the same.

Evidently the use of the only interpreter take away the possibility to use all the functionalities typical of the GISs; therefore it must be integrated into a General Purpose GIS software, but if such integration really happens not in Object - Oriented systems there are the problems of representation that we have discussed before. Kosmos follows, instead, an approach of objects implementation in rigorous way and not restrictive, allowing the definition from the consumer of complex hierarchies of GeoClassi; this makes it proper to integrate the MuTACLP and STACLP parsers. Besides the polymorphism, elegantly structured, it allows us to create some generalized rules, and accordingly it simplifies the part of coding of the same from the planners. Finally you must be underlines that the definition of GeoClassi with space temporal characteristics can also be defined by not programmer user, it needs, in such case, to derive these from other GeoClassi, not much specialized defined by other users, freely internet dischargeable or buyable.

REFERENCES

Langran G., 1992. *Time in Geographic Information Systems*. Taylor & Francis Ltd.

Michael F., Worboys A., 1992. *A generic model for planar geographical objects*. In International Journal of Geographical Information Systems, Vol 6, pp. 353-372.

Renolen A., 1995. *Maps and Temporal Geographical Information Systems*. Departement of Surveying and Mapping, The Norwegian Institute of Technology.

Skjllaug B., 1996. *Time and Temporal Data Management – Operationalization in a Temporal GIS*. SINTEF Report STF40 A96063.

Sheikholslami G., Chatterjee S., A. Zhang, 1998. *WaveCluster: A Multi-Resolution Clustering Approach for Very Large Spatial Databases*. Proceedings of the 24th VLDB Conference, New York, USA.

Han J., Nishio S, Kawano H, Wang W., 1998. *Generalization-Based Data Mining in Object-Oriented Databases Using an Object Cube Model*. Departement of Information Systems Engineering, Osaka University and Kyoto University, Japan.

Raffaetà A., Frühwirth T, 2001. *Spatio-Temporal Annotated Constraint Logic Programming*. Dipartimento di Informatica, Università di Pisa.

Barrile V., Cotroneo F., 2005. Kosmos: un server “OODBMS” per I GeoDatabase. ASITA Catania, pp. 234-240.