CONCEPTUAL BASIS FOR TIME USAGE IN GIS
Leandro Andrei Beser de Deus, Luiz Felipe Coutinho Ferreira da Silva
IME – Instituto Militar de Engenharia - Rio de Janeiro – Brazil

ABSTRACT

Nowadays, most of the GIS - Geographic Information Systems - available considers the entities representation in only one instant of time, usually the present. Although analysis, planning and decision, on the geographic space, are very frequent and current activities in GIS, there are still several difficulties on working with temporary phenomena, specifically concerning the modeling, storage, space-temporal analysis and representation of geographical data. The main subject on the association of geographical data with time, is not due to its modification or update, but for the possibility to register past states. This can subsidize the study of spatial phenomenon transformations in an integrated way, leading to production of dynamic sceneries. Moreover, specifically about GIS, to use it as a technological instrument for accomplishment of space-time analysis, and not only "space" as it is being used thoroughly. This kind of analysis is only possible within the implementation of spatiotemporal models that consider not only apparent entities and its geometrical shapes, but it's processes and transformations. In this context, a bibliographic review in the scientific literature was made to establish the state of art on the temporal characteristics that ought to be considered in the construction of a TGIS (Temporal GIS). Thus, theoretical studies and discussions were accomplished on time epistemology associated to each discipline that, directly or indirectly is related to GIS, such as geography, cartography, computer science and statistics among others. This paper aims to form conceptual bases for time usage in GIS, through the integration of these disciplines.

1 – INTRODUCTION

Some studies need temporary aspects for analyses accomplishment and inferences about a specific phenomenon. These studies can be done through tools that are useful when a decision has to be taken such as the GIS (Geographic Information Systems). They have been conceived as analysis tools, planning and decision about the geographical space. According to THOM and FORNARI (2000, page 13) “time is an essential concept for the understanding and modeling of space phenomenons in several applications, such as: biophysical sciences, epidemic researches, political sciences, social sciences and economics and several applications of real time for management and planning”.

The use of a space-time model in GIS increases its capacity of being analyzed, facilitating the study of the evolution of geographical phenomenons. Besides those applications, there are other specific ones that can be identified when temporal dimension is incorporated to GIS, as forest resources management, urban and regional planning, transportation, and so on.

However, most GIS available nowadays consider the representation of entities in only one instant of time, which is usually the present. MEDEIROS and BOTELHO (1996, page 1) mention that “in spite of GIS ability to analyze a great amount of data in an integrated and flexible way they are still unable to represent the changes that happen along a time, assuming a limited and instantaneous vision of a modeled reality”.

Since the beginning of the nineties, there were studies about the need of insertion of temporal information in GIS. In LANGRAN (1993), it is possible to analyze some technical requirements for the insertion of time in GIS. However, currently, there are still several difficulties on working with temporary phenomenons, specifically concerning the modeling, storage, space-temporal analysis and representation of geographical data. Two groups of difficulties in relation to time usage in GIS can be mentioned. One of conceptual domain and another of practical domain where aspects that obstruct the insert of time in this instrument are concentrated.
Within the conceptual domain, the GIS have a challenge to overcome in relation to the insertion of temporal dimension in its structure. That is due to the fact that they are part of several branches that come from different epistemology basis and have different points of view about the time which in most part of it do not match directly. The main issue towards time concept is mainly concentrated on how it is supposed to be dealt in GIS. However, to answer this topic, it is necessary to figure out essentially what time is. This way, more studying becomes necessary either from a scientific-philosophical point of view about time as well as inside the concept basis to the time usage in GIS. This theoretical structure will help in its conceptual characterization.

Within the operational domain, some authors mention that temporal dimension is not still fully incorporated to any software of GIS commercially available, and that forces softwares development professionals to implement a temporal layer on a non-temporal GIS software. Besides that, this problem becomes more complicated when it is verified according to PINHEIRO and FORNARI (2002, page 1) that “some models for Temporal GIS were created, but the non existence of a temporal commercial DBMS (Database Manager System) is the main difficulty to apply conceptual models”. It is also necessary to define a “standard” structure for temporal treatment of non-geographical attributes. In spite of, some prototypes were developed and are still being developed with temporary aspects incorporated to the geographical data. Thus, there is a need of practical studies, objectifying construction and implementation of space-temporary models in currently used softwares, in researches environments as well as in other areas that deal with these space-time topics.

In summary, in relation to the two difficulties mentioned for time usage in GIS, it is possible to conclude that:

- The first, which is in relation to the conceptual domain is important to the accomplishment process of a conceptual space-time integration, inserted commonly in an abstract field. It can serve as a base, for instance, to the conceptual modeling (inside of the abstraction cycle);

- The second, in relation to the operational domain is related to the modeling processes (conceptual, logic and physics) and implementation (associated to the concrete field of process) which seeks, for example, the accomplishment of space-time analysis.

To such an extent, a thematic mix can be done. The main goal of this paper is to study the first difficulty (the conceptual one) mentioned focusing some subjects that form a GIS (geography, cartography, computer science and statistics) and its relationship with temporary aspects. This kind of theoretical discussion will be essential to the definition of the concepts which will lead to the practical and operational phases. After understanding these four areas, a conceptual schema of time in GIS will be structured. This schema will be subsidized by a philosophical-scientific study (accomplished in another stage) so that a concept of time could be modeled, implemented and analyzed in GIS.

The importance of the study about time in GIS is reflected in the capacity that this instrument will have to guide us before a decision could be made. It will also provide a dynamic space understanding. Through dynamic models, it will be possible to get into the processes and flows and also to subsidize the planning, management and decision on territory so that diagnoses or even prognostics that a space-time analyses allow could be done.

2 – GOALS

This paper’s goal is to form conceptual basis for time usage in GIS, through the integration of the main subjects that compose a GIS (geography, cartography, computer science and statistics). That theoretical framework will help to understand the concept of construction of time that will subsidize the space-time conceptual modeling of historical-geographical data of a TGIS (Temporal Geographic Information System). TGIS will support studies in relation to the transformations and evolutions of public spaces in urban areas. Thus, this can be applied to a project which has been developed at the Military Institute of Engineering about the Campo de Santana park, located in the center of Rio de Janeiro - Brazil.
3 – TIME IN GEOGRAPHIC INFORMATION SYSTEMS

PEUQUET (1999, page 101) mentions that “still remains a lot to be done before a temporal geographic information system can truly be accomplished”. So to speak, the best thing to be done would be to join temporary dimension, even if in a conceptual way, to this instrument. That way, it would be possible to discuss and to insert temporary aspects in the conceptual composition of GIS, which could be stressed mainly by four subjects (geography, cartography, computer science and statistics). Following, a brief presentation of temporary aspects in GIS usage of each subject. It is expected that the choice of these subjects will be justified in the study.

- TIME IN GEOGRAPHY

When developing a geographic information system, one of the first stages refers to a phenomenon perception from the researcher. In geography and other sets of knowledge that use the geographical space as a main study target, instance or basis for social or natural practices, it is essential to describe what it means. Frequently, several GIS can be seen made. However, its space analysis power can be reduced. This might happen when the user does not know what a geographical space is or means. The geographic space it is not a product of the present. Its construction, which was accomplished socially, actually comes true historically. So, time is an important element to the comprehension of the space. In relation to the modeling of geographical phenomenons and the concept of geographical space to be considered, it is important to stand out that some geographers, like SANTOS (2002), defined a space reality that finds its dynamics and changes into itself, and it does not stay static such as other GIS do.

- TIME IN CARTOGRAPHY

Although cartographers have done little to define time in maps they have tried to call attention to the matter in different situations. Such debates have appeared lately and this lack of attention changes when the target of debate focus the GIS and the animated maps. Specifically in relation to the representation of time in maps it is possible to notice some technological development and also that cognitive theories may propitiate new ways to the space-time representation. In this case, the answer might be in these studies about time in cartography and its power as a representation of the language. The subjects involved regarding time should consider what is important to represent and as to do that, for example, through cartographic animation as suggested by some authors (for example, PETERSON, 1995). LANGRAN (1993) defines and frame such subjects as “Cartographic Time” or “Time in Cartography”. That is, the cartographic time defines the time characteristics that are essential for a space-time representation inside of cartography.

- TIME IN COMPUTER SCIENCE

The focus given about time in computer science will be restricted to information systems and to databases. Information Systems with time characteristics associated to temporal database constitute basic elements to the construction of a TGIS. Specifically about a time database, it can be noticed that most of current applications have a need to manipulate somehow historical information - relative data to last states of the application. Conventional DBMS however do not provide support to this information. In the last 20 years, the need to supply this lacuna has provided many researches in the area of temporal database with the idea of defining concepts and strategies to historical information treatment. Currently, there are several concepts in relation to the representation of time aspects in information systems and in database. Some of these aspects were published and can be checked in EDELWEISS and OLIVEIRA (1994); EDELWEISS (1998), THOM and FORNARI (2000), PINHEIRO and FORNARI (2002) and EDELWEISS (2003).

- TIME , STATISTICS AND OTHER DISCIPLINES

Besides the already mentioned disciplines, the GIS have a link with several other branches of knowledge in which the time could also be studied and singularized such as mathematics, psychology, statistics, architecture and other ones. This item will deal with time focusing in one example of these disciplines associated to GIS reinforcing the joining role of this instrument (CASTRO, 2004). Then, one discipline was chosen to emphasize aspects of the concept arrangement of this environment. One of the branches of knowledge to be presented is statistics that will emphasize the issue of the space-time analysis as an essential characteristic of a temporal GIS. Time in statistics influence mainly in the data compilation stage to support the space-time analyses. However, it should be emphasized that this process when associated to the thematic representation of data does not have the same importance seen that the scenery in this temporal-space becomes more important as became evident according to VISVALINGAM (1994). Consequently, statistics will act as a supplier of concepts to organize and to present in a more intelligible way the space-time data to be modeled as well as collaborate to the comprehension of technical limitations of current GIS to produce a space-time analysis.
4 – INTEGRATION OF THE DISCIPLINES

After understanding those four disciplines it is possible to integrate them considering their most important temporary aspects to the construction of the intended conceptual base. Picture 1 shows the conceptual composition of time in GIS.

Later on, conceptual mixes will be presented in a general way in each branch of knowledge and that indeed, will be used for composing the theoretical and practical construction of a Temporal GIS. The schema (picture 1) refers to the second part, because the first part, which was not published in this paper, refers to the philosophical-scientific study about time that will also corroborate for the consolidation of the temporary conceptual bases in this instrument.

In relation to the time in geography, what can be taken to the understanding of a “geographical” in GIS, can be found in notions of the critical geography and in its space historically built. Besides that, considering the space analysis done for example in GIS those normally ended up using just one instant of time reducing though the knowledge and consequently the study that then do not really represent what a geographical space or its dynamics is. The study of a geographical space in GIS presupposes an integrated model that does not only indicates its forms as well as its processes and its contents which are almost always not considered. Finally, the time in geography that will compose the base of a GIS will act as an important link for a space-time integration of analyzed phenomenons.

In relation to cartography time, what can be taken to the understanding of this “representation” of the language in GIS are the cartographic notions which are worried with the space-time representations, as mentioned by VASILIEV (1997) and PEUQUET (2002) and the cartographic time by LANGRAN (1993). So, the conceptual and practical construction of a Temporal GIS needs evidence, that is, some sort of visualization of the aspects of space-time phenomenons, focusing studies about simbology in space-time maps and data presentation using cartographic animation as a resource.

In relation to computer time, what can be taken to the understanding of this “structure” in GIS in a brief way refers to the area systems in which the temporal focus is located in dealt concepts (time granularity, instant in time, temporary interval, and so on) in the time representation field and in temporal database. Thus, it should be possible to have a construction of a joined base that propitiates the production of consults and complex analyses.

And finally, in relation to time in statistics what can be taken to the understanding of statistical methods, is that in a direct or indirect way, which are somehow linked to GIS, can be noticed in “Space-Time Statistics” concepts, seeking the accomplishment of space-time analyses that could help in the subject being studied.
4.1 – CONSTRUCTION OF THE CONCEPTUAL SCHEME

Through a study about time and concerning the subjects that compose GIS, it is possible to build a conceptual schema that will serve as a base to join conceptual basis studied and that also subsidize time conception in GIS as well as the modeling conception of space-time phenomenons so that a temporal GIS could be built.

Peuquet’s chart (PEUQUET, 2002) will be used and act as a matrix to the integration. This chart, at the most essential level is about the historical visions about time and space that were classified inside something that can be considered both continuous or discrete and absolute or relative. It should be mentioned though, that this is a general scheme and consequently not all necessary information through the specific subjects related to each vision is given. However, the bibliography studied was respected. Based on the concept presented and in the way time is noticed the branches of knowledge analyzed in chart 1 can be included.

<table>
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<td>STATISTICS</td>
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Chart 1 – Base for the conceptual scheme

After including some data in chart 1 it was possible to build a graphic scheme of these dualities which can be found in picture 2.

Picture 2 – Time modeling for GIS including the studied subjects
(adapted from PEUQUET, 2002).
In relation to the scheme mentioned above it is important to notice that the areas of intersection show epistemological conflicts when this integration is tried. As a result the temporal GIS is inserted focusing the instrument in a computer structure which is already available. It is also possible to notice that the places where the disciplines are in the picture are the same as the process of the abstraction cycle (a cycle that starts at the modeling process of data taking in consideration the reality and then moves to a physical surface in a computer environment) used as a base for a GIS construction. Assuming some conceptions about the disciplines mentioned in this article and joining them to the scheme above it is possible to do some proposals:

- Geography can be inserted in a continuous and relative posture when the geographic concept of space is mentioned by SANTOS (2002), in which space is something built to the society in its social time.

- Cartography can be inserted in a continuous - discrete and relative vision because there is a way of representing the time phenomena in a continuous manner besides most data be dealt in a discrete way. The relative side corresponds to cartography patterns that express a relative reality even when they are brought to the concrete reality of maps. Nowadays, a leading to relating subjective representations, for example, which were proposed by VASILIEV (1997) and PEUQUET (2002), as those ones of mental maps. For that reason the space occupied by cartography in the picture goes beyond its relative limit to the absolute so it can not be seen by the symbolic representation of overlap.

- In relation to the computer science environment it is important to mention that in physics time is considered something continuous. However, considering the time of database the technical restrictions of a computer should be understood. In such a manner, a computer related structure will make possible studies with a discrete and spaced calculated time; absolute.

- Finally, in statistics which in spite of dealing with continuous variables, the discrete variables (that’s why they are located in the discrete axis ) are used in time phenomena in an extensive way and possible to the current structure taking just this kind of pattern to space-time database. Its absolute-relative side, which moves toward the picture's center, can be found when database is manipulated by researcher’s previous idea of emphasizing something (pre-processing stage) and, later on, in the process to a concrete matrix.

4.2 – CONCEPTION OF TIME IN GIS

Based in picture 2 that presented the time conceptions of each discipline studied, the time to be used in GIS in an extensive and joining manner could be classified in two: as in discrete and relative. Thus, the concept of time in GIS which is based on the ideas of discrete and relative time is detailed below:

- PEUQUET (2002) mentions that when time is discussed, what we have nowadays as a technological instrument is the possibility of studying with a discrete time and measured in space. Actually, the researcher’s time perception is continuous. However, in a computer environment it will be discrete. GOMES and VELHO (1998) mention that the representation and implementation universes can be found in this environment (discrete). When there is a change from continuous way to the discrete some information is lost. These losses are worthy as the ones that exists in space cartography patterns. Time is divided in as many parts as necessary respecting the criteria of granularity. So, according to this conception, time in GIS will act in a discrete way. The discrete way of treating time will make the process of implementation in the DBMS easier.

- On the other hand, time can be considered as relative because there are several options of patterns specially in distinct cultures or societies which had already been registered by PEUQUET (2002). Thus, there is also a possibility of an intuitive instrument become consolidated, that is, opened to phenomenon and cognitive conceptions; opened to ideas of social time emphasizing its relative side. Considering the relative time, the maps that illustrate the information in GIS could represent changes that would depend on different kinds of time (there are different ‘kinds of time’ because changes can be done in different ways, getting into its relative or subjecting characteristic). However, not only the change matters but how time is measured and used considering distinct cultures and their sense. In this case, time would be closer to a philosophical and sociological time than to a physical one or even historical. It should also be mentioned that the time implemented would undertake an absolute manner.
5 – DISCUSSION

Some epistemological issues involving the construction of that schema still need to be discussed as well as some conflicts mentioned when a link among the subjects of a technological instrument such as GIS were tried. However, some suggestions were also mentioned to reduce the impact of this interdisciplinary tentative of integrating time respecting the epistemological basis of each subject studied.

One suggestion to time integration and the studied disciplines to GIS may be found in another thought about time. Seeing GIS as an interdisciplinary instrument it is possible to argue about each branch of knowledge that will be responsible for the time treatment in GIS, for example to the application of geographical-historical studies. According to that answer, new ideas and methods can be opened to enrich a TGIS. That answer can be found in HISTORY, essentially interdisciplinary. Besides that, History associated to cognitive sciences could also help in the representation process.

After the consolidation of those discussions and of a time characterization for GIS, the modeling and the implementation of temporary aspects for the construction of a Temporal GIS will be focused later on. Therefore, conceptual modeling can use the epistemological, conceptual and structural bases of temporary aspects studied. The logical modeling can follow the structure supplied by the temporal database conceptions. And finally, the implementation process can evaluate the limitations and potentialities of the prototypes and commercial programs which are available nowadays as a base to the construction of a geographic information system. Thus, it will be possible to understand the conceptual and operational limitations when temporary studies are done using GIS as an analysis instrument. In relation to the data exit and its way of presentation more studies are necessary focusing computer animation associated to cartography and to geography.

6. FINAL CONSIDERATIONS

It can be mentioned that knowledge on temporal structure in GIS, even in a general way, is already possible mainly by the accomplished study considering time from a theoretical point of view in the subjects: geography, cartography, computer science and statistics. It was possible to emphasize in each discipline its most important temporary aspects that can be used in a temporal GIS organization. However, concerning the subjects’ integration and time in GIS some conflicts, suggestions and proposals are essential. Besides that, a branch of knowledge such as HISTORY should be showed as it can lead a time perception to concepts basis of time treatment in GIS, to the study proposed. That way, specific concepts basis of each discipline were identified helping in the construction of the concept scheme and distinguished the time to be used in GIS.


BIOGRAPHY

Name: Leandro Andrei Beser de Deus
Birth date: 01/08/1979 Nativeness: Rio de Janeiro, RJ Nationality: Brazilian
Position: Geographer and Academical Professor

PROFESSIONAL FORMATION

Master of Sciences: Cartography and Geographical Information - Military Institute of Engineering – 2005
Teaching Specialization: Geography - Federal University of Rio de Janeiro – 2003
Geographer - Federal University of Rio de Janeiro – 2002