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MULTI LEVEL REPRESENTATION OF SPATIAL DATA ; APPLICATION IN ARCHAEOLOGY AND ANTHROPOLOGY

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Abstract

This paper deals with concepts allowing to integrate and manage different levels of abstraction of spatial data within a GIS. We point out how we resolved the problems set up by the management of multi-view and multi-level spatial data. Finally we detail how the previous resolution approach has been applied efficiently in the framework of a common project at the University of Corsica involving archeologists and anthropologists around an Archeoastronomy project.

Introduction

Starting from a joint project undertaken at the University of Corsica between computer sciences researchers, anthropologists and astronomers we deal in this article with the problem of the definition of the concepts of abstraction levels and views of spatial data for analyzing archeological data. This interdisciplinary project begins with a first research work concerning in particular :

- The GPS localization of Neolithic sites and toponyms in the Corsica Island.
- GIS representation of the previous data through spatial entities
- Analysis of the previous spatial entities described at various abstraction levels.

This first work enabled us to highlight a set of problems when dealing with data coming from the following domains: archaeology, anthropology and astronomy. The solution that we propose for solving the previous problems rests on a definition of abstraction levels for spatial data, as well as the definition of automatic transfer functions between abstraction levels. The implementation of the solution has been carried out using an oriented object design. We present in detail in this article how the definition of the concepts of levels of abstraction and of transfer functions allows the resolution of problems previously highlighted.

Moreover we point out how starting from these concepts we can offer a generic software infrastructure allowing in particular:

- To manage several levels of abstraction,
- To define or use transfer functions between levels,
- To carry out geometrical or astronomical analysis between various spatial archeological data.

The generic software infrastructure is developed in Visual BASIC because this language facilitates on the one hand the implementation of the various concepts and on the other hand the integration of these concepts in a GIS.

The validation of the software is carried out within the framework of the interdisciplinary project : in a last part of the paper we present how using the previous generic software we have been able to analyze how legends, megaliths and astronomy are linked in the Nebbiu Region in the north part of Corsica..

2. Problems

2.1. Context of the study

The study presented in this article belongs to a set of work concerning the use of the GIS in archaeology. In our case the context of the study is the following : by taking a mix of data from natural and cultural inheritance, the general

objective is to offer a powerful software tool for archeologists or anthropologists. This tool should be "open" in the way that it has to offer possibilities, which can comply with complex requests. This gives the researcher all freedom to correlate information. As we will see it below the archeoastronomy rests on studies coming from three distinct fields: archaeology, anthropology and astronomy.

Indeed, space is for a society of orality the receptacle of all the inscriptions of its past, its stories and its beliefs. The toponym allows for the restoration of the awareness of gestures, sounds, the resonance of the place, its values and its properties, supplemented and perpetuated with past generations.

The goal is to work at the interface between the preceding fields in order to try out the capacities of the GIS to being used in the context of a research in archeoastronomy. Archeoastronomy [RUG 99] is the science which relates to the discovery and the study of beliefs and the astronomical practices of the ancient societies; it is initially a tool to include/understand the intellectual achievements of the primitive cultures, such as for example, the builders of megalithic alignments. In order to help archeoastronomers from a point of view of software tools, we have to facilitate the following analysis using GIS: (i) simulate the sky of the ancient people and to calculate the suitable ephemerides, to then be confronted with oral saves (reconstitution sources of celestial phenomena by the simulation of the aspect of the sky at one time and with a given place); (ii) to establish geometrical links between the different sites, (iii) to study the bonds between toponym and interesting sites from a point of view of archeoastronomy.

The goal is to be able to help the archeoastronomers to define following information in a GIS :

- GPS localizations of menhirs and dolmens
- Abstractions of this information (for example a point represents an alignment of menhirs)
- It must possible to carry out geometrical and astronomical analysis.

2.2. Space data management and multi-representation

The Geographical Information systems (GIS) started actively to be employed in archaeology during second half of the Eighties [SAU 90]. The capacity of the SIG to incorporate many data, highlighting the bonds between space and human society, made it possible to show the interest of the GIS to undertake research in fields such as archaeology [MAR 90] or anthropology [ALD 96]. According to [ALD 96] the use of the GIS in anthropology is particularly effective in the 5 following cases:

- The management of the regional data [MC G 96],
- The management of the satellite data [LOK96, NEY & GRE 99],
- Regional environmental analysis,
- Simulation [V WES & KOH 96] and
- The modeling of the sites [ALD 96].

Concerning more particularly archaeology, we can highlight the following uses:

- Definition of models for the localization of the sites,
- Analyses of archeological sites by the GIS and
- Studies related to the archaeology of landscape [SAU 90].

The recent efforts in the field of application of the GIS in archaeology made it possible to start relevant studies concerning the precise knowledge of the landscapes around archaeological sites [GAF 96]. It is certain that in the future the GIS will be more and more associated work of the archaeologists and anthropologists and will integrate also concepts resulting from the artificial intelligence, virtual reality and of course multidimensional modeling [CLA 95, HAR & SER 95].

The use of the SIG in archaeology or anthropology will rest in any event on the capacity of the researchers in the field of the GIS to progress in the problems related to the multi-representation.

Research in multi-representation can be classified in two types of approaches : approaches known as directed treatments using the algorithms of generalization [RUA 99] or many approaches known as directed representations which use a base of data where are stored the various levels of detail [VAN 98 & ALL 00, SPA 00], [BED 02]. With the sight of the analyses and syntheses of these two types of approaches, we can affirm that the definition of concepts authorizing a combination of the two approaches would make it possible to answer effectively the problems highlighted into 2.1. Indeed the user is in certain cases in the obligation to seek new representations not yet stored in the base of data. He cannot in this case be satisfied only directed approaches representations. He must thus call upon approaches known as of treatments what implies a use of generalization in order to generate new representations.

3. Basic concepts: concepts of domains and levels of abstraction

After an analysis of the capacities of the GIS for researches undertaken in archaeology we identified the following problems to be solved from a computer science point of view :

- Difficulty of representing information about space at various levels of abstraction
- Difficulty of representing information about space, corresponding to various points of view of localization
- Difficulty of connecting information about space in a geometrical way
- Difficulty to deduce and of represent data resulting from an astronomy point of view on a GIS.

In order to propose a solution for solving the four previous highlighted problems we developed the concept of levels of abstraction and the concept of domain of spatial data.

A spatial zone will therefore have to be able to be visualized according to various points of view (domains) and at different levels of abstraction : several spatial representations could be associated at a spatial zone. In our study we represent a spatial object as being an elementary spatial pertaining to a representation of a given domain and to a given level of abstraction.

The translation of a representation towards representations more (less) detailed requires the definition of transfer functions of information making possible the automatic generation of a new representation more (less) detailed.

For the same domain, the generation of a representation from a level of abstraction N towards a level of abstraction higher $N-1$ is named aggregation. The opposite generation is named decomposition. The transfer functions describe how aggregation and the decomposition must be carried out. They are defined by the user or by default in the software system that we propose to create, we can quote like example of transfer function the algorithms of generalization [RUA 99] and [BED 02]. We illustrate in figure 1 all of the concepts previously introduced. The illustration of the generic concepts presented is of course restricted within the framework of the figure of the three fields (archaeology, astronomy and anthropology) but can obviously be generalized for unspecified numbers of fields and levels of abstraction. We highlighted in figure 1 how a user interested in the three fields: (archaeology, astronomy, anthropology) will be able to define with no problem, the representations of the same space zone according to different fields and on different levels of abstraction. Moreover they will be able to visualize, navigate and of course generate a representation from another, for a given field.

Within the archaeology field we see on figure 1 that the representation $R1$ ($N-1$ level, Archeology field) is composed of a space entity of point type $A1$ (coordinates x and y) and models for the archaeologists an archaeological complex. However in order to be able to study this complex with one level lower of detail (N), the user will be able, by using the decomposition to generate the representation $R2$ (level N , archaeology field) made up of three space entities of point type ($A2, A3, A4$). In this concrete example the point $A2$ represents a site made up of a dolmen and a menhir, the point $A3$ an alignment of menhirs and the point $A4$ a funerary site (trunks + menhirs). The dolmen and menhir are represented in the $R3$ representation by $A21$ and $A22$, we also see in $R3$ the alignment corresponding to $A4$. Of course the user can if they wish refine the level of detail by generating the representation $R3$ (level $N+1$, archaeology field). The user can of course within the framework of his studies carry out an automatic passage of the $R2$ representation towards the $R1$ representation by using aggregation.

The principle of defining of the levels as well as the associated representations is of course similar within the anthropology field. In this case the basic space entities are polygons and represent toponyms associated with pieces of grounds (example $T1, T2, T3$). We see clearly on figure 1 that toponym $T1$ breaks up into $T2$ and $T3$ on a level with finer detail, etc.....

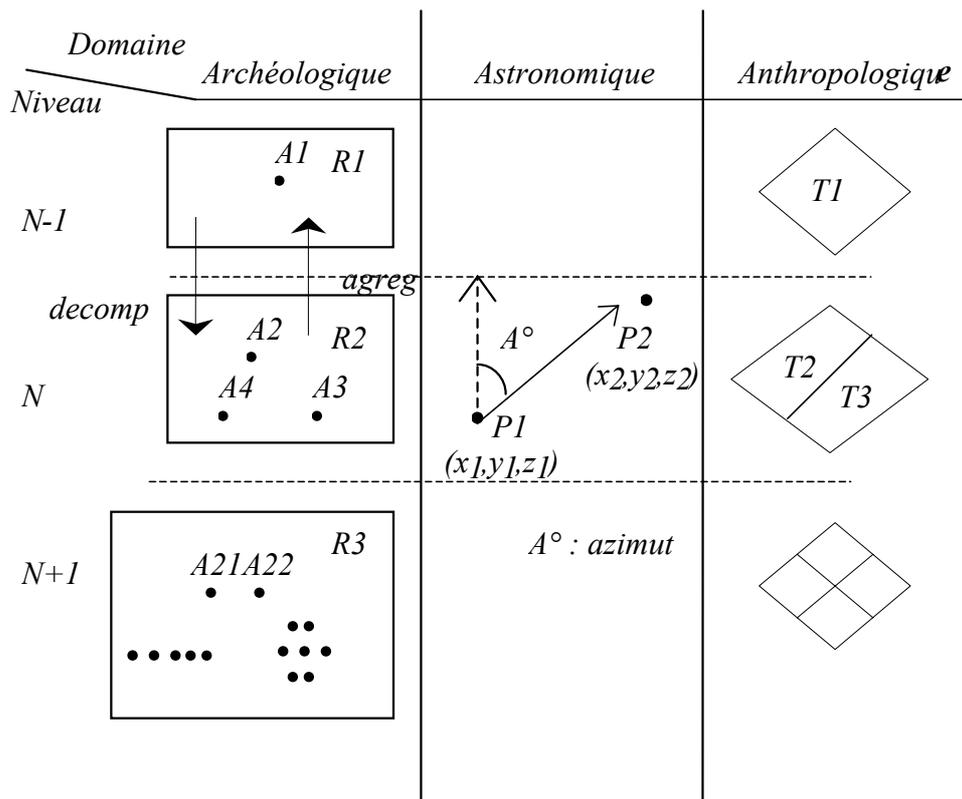


Figure 1. Representation of the various levels of abstraction for the 3 fields.

The case of the astronomy field is a little different and allows us to illustrate the need for geometrical and astronomical studies. Indeed for a given level of abstraction, the user will be able, for example, to automatically calculate the variation of a space entity of point type P2 (attributes x2, y2, z2) starting from an entity of the point type P1 (x1, y1, z1) and angle A (azimuth). We represent on figure 1 how the angle called variation and associated P2 can be calculated from angle A, and the co-ordinates of P1 and P2, it is necessary to note the importance of the altitude (coordinate Z) in this calculation. Of course the visualization of the data and the results will be backed up by the software system that we develop.

4. Oriented Object Conception.

In this section we present how the problems highlighted in section 2.2 are solved by an object oriented design of the concepts described in section 3. We call Gis-Archeo-Astro the software system resulting from the implementation. We highlight in particular in this section how:

- To allow a user to define as many domains and levels of abstraction necessary within the framework of a given application.
- To allow a user to associate spatial representation data to a domain and a level of abstraction.
- To allow the user to define transfer functions of information which describe the passages between levels of abstraction for a given domain (decomposition and aggregation).
- To allow the user to refer to preset transfer functions which are offered by the software system Gis-Archeo-Astro
- To allow the user to carry out geometrical studies between the spatial elements of a given representation
- To allow the user to carry out astronomical calculations associated with spatial elements with a given representation and to visualize them.

One can distinguish four stages within the framework of the use of the GIS-Archeo-Astro software:

- Stage 1: the user will be able to define the domains and the levels of abstraction which have to be handled in the following stages ; for each domain, the user will have to define the order of classification of the levels.
- Stage 2: the user will have to define the elementary spatial entities which have to belong to the different levels as well as either to define the transfer functions between levels or to refer to preset transfer functions.
- Stage 3: the user will be able to perform geometrical functions of tracing between the spatial entities defined at stage 2 for a domain and a level of abstraction, defined at stage 1.
- Stage 4: the user will be able to perform calculation of archeoastronomic functions and visualization of these results associated with spatial entities defined at stage 2.

Stages 1 and 2 are backed up by the instantiation of the classes characterizing the following concepts: APPLICATION, ABST-LEV, ENTITY, and TRANSFER. We briefly present the attributes and the main methods that were implemented, for each of the four previous classes.

- The class APPLICATION allows a user to initialize for a given application the levels of abstraction, the domains, and the entities necessary to resolve problems within the framework of the application given.

- Class APPLICATION

Attributes: Nb-abs-lev, list-ord-abs-lev, Nb-domains, name-domains:

Methods: def-abs-lev, def-domains

Class ABS-LEV describes the levels of abstraction implied in a given application

Class ABS-LEV

- *Attributes:* name-lev, sup-lev, inf-lev

- *Methods:* give-name, to give-sup-lev, give-inf-lev,

- Class ENTITY describes an elementary spatial element belonging to a representation at a given level of abstraction and at a given domain. We highlight the two attributes *decomp* and *aggreg*. The value of the attribute *decomp* corresponds to the list of the entities describing the entity considered at a lower level of abstraction, while the attribute *aggreg* corresponds to the entity at an higher level of abstraction. Finally the attribute *transfer* corresponds to the name of an instance of the class TRANSFER that will describe the transfer function which will be carried out (decomposition or aggregation).

- Class ENTITY

Attributes: abstr-lev, domain, coord-x, coord-y, coord-z (altitude), angle-azimuth, angle-height, angle-declination, decomp, agreg, transfer

Methods: affich-circle, affich-polygon, affich-line, afich-azimuth, display-height, affich-decl, calculation-decl

- The class TRANSFER describes the transfer functions between levels of abstraction. The entities implied by decomposition or aggregation are enumerated in the attributes entity-departure and entity-arrived. The name of the transfer function to be activated to carry out the decomposition or aggregation is indicated in the *name-fct-of-trans* attribute, this function will be defined by the user or will be referenced to a preset function.

- Class TRANSFER:

Attributes: entity-departure, entities-arrived, name-fct-of-trans,

Methods: declch-fct-trans

Stages 3 and 4 are backed up by the definitions of methods associated with the class ENTITY. These methods correspond to the various preset geometrical functions of tracing (methods AFFICH-CIRCLE, AFFICH-POLYGON, AFFICH-LINE, etc.) as well as astronomic calculations (method CALCUL-DECL). Moreover the foolowing methods of visualization of archeoastronomic data have been also defined : methods AFFICH-AZIMUT, AFFICH-ALTITUDE, AFFICH-HEIGHT, AFFICH-DECL.

5. Implementation of the concepts in Visual Basic

The concepts presented in part 3 are validating by the realization of a prototype of a software called Gis-Archeo-Astro developed in Visual BASIC. We chose to validate the previous concepts using the language Visual BASIC (VB) for two main reasons : (i) the integration of the concepts in the GIS Arcview is facilitated by the use of VB since the personalization of Arcview rests on the use of VBA (Visual BASIC Application) ; (ii) the use of VB completely meets the requirement in terms of the ergonomic features associated with the development for interfaces dedicated to not-data processing specialists such as archaeologists or anthropologists.

We highlight in this part how a user interested by the three fields (archaeology, astronomy, anthropology) will be able to define without problem the representations of the same spatial zone according to 3 different fields at different levels of abstraction. Moreover it will be able to visualize and of course to generate a representation from another for a given field.

In the examples which follows the concepts of multi-windowing, the functions of geometrical tracing and astronomical calculations are not illustrated for preoccupations with a clearness of presentation. However these concepts are completely integrated into the Gis-Archeo-Astro software which we implemented.

The validation was carried out starting from a concrete example concerning the archaeological sites of Monte Revincu.

We have to point out that the megalithic Corsican civilization flourished in the first half of the fourth millennium B.C. This early phase has left numerous traces in Corsica that are to be found everywhere in the southern half of the island and in some very few parts in the northern part (Nebbiu region). As regards burials, there seems in megalithic times to have been the same orientation custom all over the island. The site of Monte Revincu is located in the area of Agriate at the North of Corsica. The landscape is contrasted enough here, it is composed of small narrow valleys or broad depressions. Figure 1 highlights the landscape in 3D as well as the 3 funerary sites of Monte Revincu (called Lurcu, Orca and Monte Revincu). Each one as of the 3 sites is him even made up of one or more megalithic tombs.

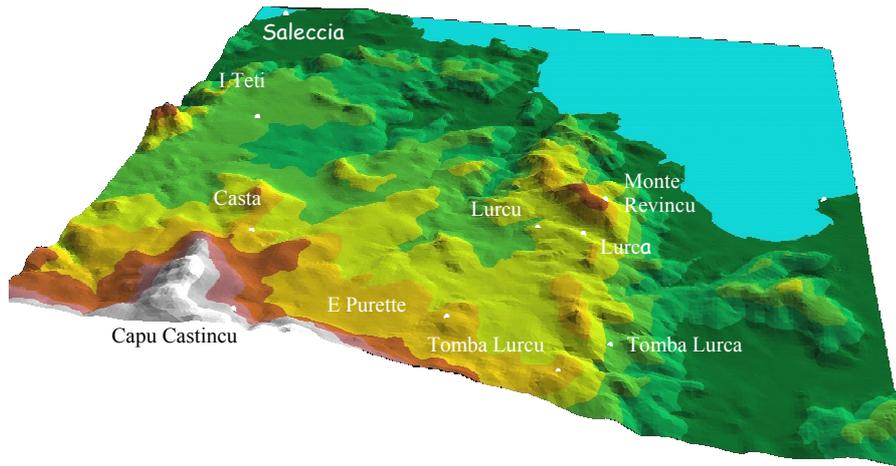


Figure 2 : Sight 3d of Agriate, Corsica of North

Figure 2 illustrates the different buttons of the user interface corresponding to the concepts presented in section 3. This figure also highlights a representation of the localization of the site Monte Revincu at the highest level of abstraction ; we will call thereafter this first representation R1 (level 1, Domain archaeology). Figures 3 and 4 highlight the transition between levels of abstraction. We see on figure 2 that the first representation R1 is made up of a space entity of type node (coordinated X and y) and models an archaeological complex. However in order to be able to study this archeological complex we need a more detailed view of the complex (level 2). For that , the user will be able by using the decomposition to generate the representation R2 given of figure 3 (level 2, archaeology field) made up of three space entities of type node. These three points can be broken up on a lower level (level 3) in order to study the types of structures composing each one of these sites (dolmens or non-dolmenic tombs). Of course the user can if it wishes it to refine the level of detail by generating the representation R3 (level 3, archaeology field) starting from the representation R2 by clicking on the button «Down ». Figure 4 illustrates this decomposition. The user can also carry out an automatic passage of the representation R2 towards the representation R1 by using aggregation (button «Up "). The passage between levels is carried out using transfer functions. These transfer functions are defined by the users .

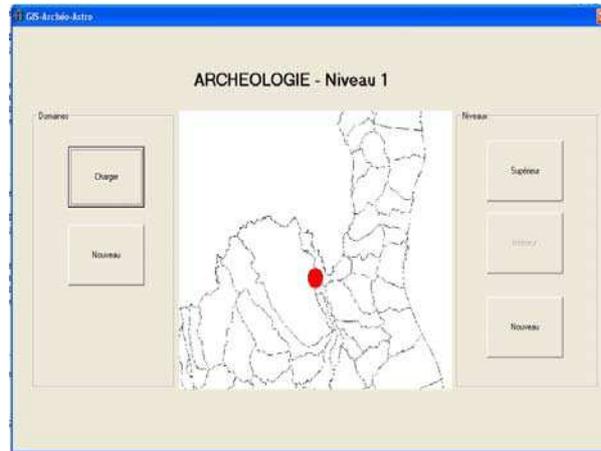


Figure 3 : Localization of Monte Revincu (Representation R1)

We must moreover note that the sites at the highest level are indicated by a red point, on level 2 by squares red (see figure 3). Finally on the level 3 several types of points are available corresponding to dolmens or non-dolmenic tombs. The dolmens are located by a red symbol pointing out the shape of a dolmen while the non-dolmenic tombs are represented by a blue symbol having the shape of such a tomb.

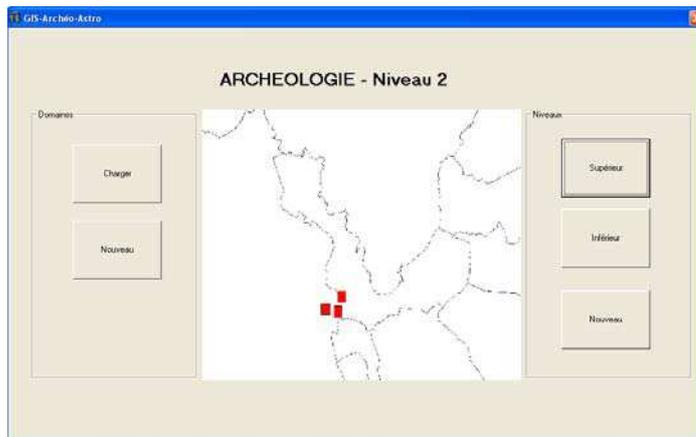


Figure 4 : Decomposition site on 3 sub-sites (Representation R2)

On level 3, by changing the field (transition from the field «Archaeology» to the field «Astronomy »), the user can have access to the functions of tracings and calculation of astronomical values related to the entities of levels 3. In section 5 we give the methodology for computation of these astronomical values.

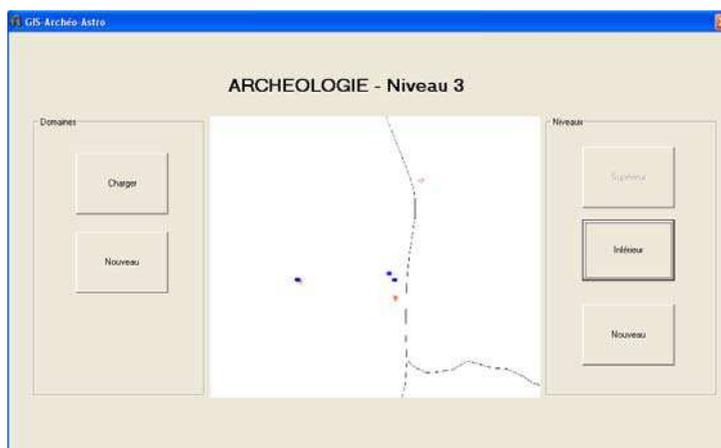


Figure 5: Detailed description of the 3 sites (Representation R3)

6. Conclusion

We presented how the introduction of concepts of fields and levels of abstraction allowed the resolution of problems highlighted within the framework of an interdisciplinary research project led to the University of Corsica between anthropologists, archaeologists and data processing specialists. The definition of the concepts of levels of abstraction of space data as well as the concepts of fields allowed an original structuring of space data. Moreover we showed how starting from these concepts we can offer a generic software infrastructure allowing:

- To manage several fields and levels of abstraction of space data,
- To define or use transfer functions between levels,
- To carry out astronomical analyses between various space data.

The data-processing realization of the various concepts presented is in the course of validation. The software is developed in Visual BASIC what makes it possible on the one hand to implement the various concepts by using a directed design objects and on the other hand to facilitate the integration as of the these concepts in a GIS (Arcview). The validation of the software is carried out within the framework of the interdisciplinary project.

The goal of the project is thus to offer a convivial software environment allowing the development and the use of a GIS integrating the anthropological, archaeological and astronomical data.

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