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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
l'objet est d'offrir un outil informatique puissant aux archéologues ou anthropologues. Ce outil doit être "ouvert" dans la mesure où il doit offrir des possibilités qui se concrétisent avec les demandes complexes. Cela offre au chercheur toute liberté de corrélérer les informations. Nous verrons plus bas que l'archéoastronomie repose sur des études issues de trois domaines distincts : l'archéologie, l'anthropologie et l'astronomie.

En effet, l'espace est pour une société d'oralité le réservoir de tous les inscriptions de son passé, de ses histoires et de ses croyances. Le toponyme permet la restitution de la conscience des gestes, des sons, de la résonance du lieu, de ses valeurs et de ses propriétés, renouvelées et perpétuées de génération en génération.

Le but est de travailler à l'interface des domaines précédents pour tenter de tirer les capacités de l'ESG à être utilisées dans le contexte d'une recherche en archéoastronomie. L'archéoastronomie [RUG 99] est la science qui concerne la découverte et l'étude des croyances et des pratiques astronomiques des anciens. Elle est initialement un outil pour comprendre et connaître les réalisations intellectuelles des civilisations primitives, telles que par exemple, les alignements mégalithiques. Pour aider les archéoastronomers d'une manière ou d'une autre, nous avons facilité l'analyse suivante avec l'ESG : (i) simuler le ciel des anciens et calculer les adresses éphémères, pour ensuite être confronté avec des données préhistoriques (reconstitution des phénomènes célestes par la simulation de l'aspect du ciel à un moment donné et dans un lieu donné); (ii) déterminer des liens géométriques entre les différents sites, (iii) étudier les liens entre toponyme et sites d'intérêt à une perspective archéoastronomique.

Le but est d'arriver à aider les archéoastronomers à définir les informations suivantes en un ESG :
- Localisations GPS de menhirs et dolmens
- Abstractions de ces informations (par exemple un point représenter une alignement de menhirs)
- Il doit être possible de mener des analyses géométriques et astronomiques.

2.2. Gestion des données spatiales et multi-réprerésentation

Les Systèmes d'Information Géographiques (SIG) ont démarré activement à être utilisés en archéologie pendant la deuxième moitié des années 80 [SAU 90]. La capacité de l'ESG à incorporer de nombreuses données, soulignant les liens entre l'espace et la société humaine, a rendu possible de montrer l'intérêt de l'ESG pour mener des recherches dans des domaines tels que l'archéologie [MAR 90] et l'anthropologie [ALD 96]. Selon [ALD 96], l'usage de l'ESG en anthropologie est particulièrement rentable dans les 5 situations suivantes :
- Gestion des données régionales [MC G 96],
- Gestion des données satellites [LOK96, NEY &GRE 99],
- Gestion des données environnementales,
- Simulations [V WES & KOH 96] et
- Gestion des sites [ALD 96].

Concernant plus particulièrement l'archéologie, nous pouvons souligner les utilisations suivantes :
- Définition de modèles pour la localisation des sites,
- Analyse des sites archéologiques via l'ESG et
- Études liées à l'archéologie du paysage [SAU 90].

Les récentes efforts dans le domaine de l'application de l'ESG en archéologie ont rendu possible de mener des recherches significatives concernant la connaissance précise des paysages autour des sites archéologiques [GAF 96]. Il est certain que dans l'avenir, l'ESG sera encore plus lié et associé au travail des archéologues et anthropologues, et réunira aussi des concepts issus de l'intelligence artificielle, de la réalité virtuelle et du modèle multidimensionnel [CLA 95, HAR & SER 95].

La mise à disposition de l'ESG en archéologie ou anthropologie aura lieu dans les régions en fonction des capacités des chercheurs dans le domaine de l'ESG pour faire des progrès dans les problèmes liés à la multi-réprerésentation.

La recherche en multi-réprerésentation peut être classée dans deux types de recherches : des approches connues sous le nom de traitements dirigés utilisant l'algorithmique de généralisation [RUA 99] ou de nombreux approches connues sous le nom de représentations dirigées qui utilisent une base de données dans lesquelles sont stockées les divers niveaux de détail [VAN 98 & ALL 00, SPA 00], [BED 02]. Avec le même type de analyses et de synthèses de ces deux types de recherches, nous pouvons affirmer que la définition de concepts autorisant une combinaison des deux approches rend possible de répondre efficacement aux problèmes mis en évidence dans 2.1. En effet, le chercheur est dans certaines conditions dans l'obligation de rechercher de nouvelles représentations qui n'ont pas été stockées dans la base de données. Il ne peut pas être satisfait de faire uniquement des représentations dirigées. Il doit donc faire appel à des approches connus sous le nom de traitements qui impliquent un processus de généralisation pour générer de nouvelles représentations.
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 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 agreg. 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 agreg 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, affich-azimuth, display-height, affich-decl, calculation-decl

  - **Class TRANSFER**
    - **Attributes**: entity-departure, entities-arrived, transfer
    - **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 astronomical calculations (method CALCUL-DECL). Moreover the following 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 archæological complex. However in order to be able to study this archæological 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, archæology 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, archæology 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.
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.

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.
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.

6. Bibliography


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