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GIS USAGE IN WORLDWIDE ARCHAEOLOGY

1. Introduction

GIS introduction in Archaeology may be dated from the end of the eighties. Until now, adoption and diffusion of GIS in Archaeology has never finished to progress. Ten years later, it is useful to report on the state of the GIS in Archaeology, concerning risers, tools, and applications, and to analyse the success and the weakness of its usage in academic institutions.

Of course, it is sure that, behind the GIS word, are existing various heterogeneous needs and solutions, with in common a graphical information system. It is also evident that main actors are searchers from universities, public or private specialists of Cultural Resource Management (C.R.M.) and field archaeologists (mainly rescue Archaeology), and that their functional needs are certainly different.

But, nevertheless, all these risers are convinced that their archaeological problems must obligatory go through the project of an archaeological information system, using widely graphical management techniques, data bases, and spatial analysis (statistics). The most promising event in Archaeology is that for the first time (after data analysis in the eighties) these techniques are considered by archaeologists themselves as really useful for Archaeology.

2. GIS computer sciences since the last forty years

Graphical display is a late development in Computer Sciences. Computerisation came first, for fast and powerful numerical computations, from the large mainframe of the sixties (Control Data, Cray) to the parallel processors of the nineties. Then, database management was introduced, to interrogate and update large databases, with permanent improving technologies (Codasyl, from 1975; Relational, from 1985; Object, from 1995).

In the seventies, computers in the universities and research centers were mainframe computers, for scientific computations and software development environment. In the available packages, there were few graphic functionalities. Graphic colour monitors were too costly. The printers were plotters, slow and very costly to use (Benson, Calcomp). But it is also in the seventies that the first minicomputers were born, dedicated to real time process management, for supervision and control systems.

The success of microcomputers at the beginning of the eighties, with the Apple miracle, soon followed by the irresistible marketing machine IBM/

Intel/Microsoft, was a real cultural revolution, comparable to the pocket book press for traditional publishing, giving data processing to everybody who wanted it, mainly students and computer fascinated people, at low cost, purchasable by quite everybody, even by poor archaeologists.

Within the new technology of microcomputers, there is still no place for colour and graphics: colour graphic monitors were still too costly, microprocessors too slow and memories too limited. The first graphical features have appeared in the early seventies with large mainframe computers, dedicated to special needs (meteorology, remote sensing/satellite image processing, public cartography, control defence systems, etc.).

In the early eighties, with the success of the minicomputer technology, were appearing the first workstations, and, with them, the first CAD/CAM software products (Computer-Assisted-Design, Computer-Assisted-Manufacturing) giving a major entry for computers in the Engineering offices of the industry market. In the eighties, then, an important development has concerned various technical information systems, as CAD/CAM, remote sensing and image processing, cartography, 2D/3D modelisation, etc.

The first GIS emerged in that general context, as an answer to the technical need of mixing both cartography and data management: management of spatially distributed equipment of private or public technical services (Power electricity, gas, water, district heating, telecommunications lines, transport, etc.), geomarketing, thematic cartography, etc. If the development of the first GIS occured in the early eighties, or even before, in large university research centers, mainly North-American, the migration from mainframe to workstations was very fast in the late eighties, with the Unix standardisation.

Moreover, evolution of microcomputers to personal computers (PC), associated with modern technical evolution (more friendly man-machine-interface, larger memory, more disk storage, more powerful processors), has allowed to implement increasingly sophisticated software in small PC workstations including graphical software CAD/CAM, GIS, Image processing, etc.

3. Archaeologist needs

The needs to understand the spatial dimension of Archaeology is as old as Archaeology itself, with all due respect to modern specialist of Spatial Archaeology. Early in the XIX century, and until now, architectural drawings, artefact distribution maps of archaeological layers, regional cartography of archaeological sites were manually realised with a large worry of quality and accuracy that the last computerised techniques are still not obtaining today. The work, particularly time consuming, was generally given to technicians belonging to archaeological laboratory teams, who have dis-

appeared today, forcing the researchers to do it themself, or to subcontract to low qualified people (students, trainees) obliging to resort to computerised tools.

At the beginning of the third millennium, the needs of archaeologist for graphical features may be found in several independent archaeological information systems:

– Salvage archaeology, operating on area surveys. One of their main aims is site prediction to optimise efficiency (and cost) of field sampling;
– excavation field archaeology, which involves the realisation of numerous drawings, graphics, maps, photographic recording, using 2D/3D reconstruction (x,y,z=t), and sometimes involving virtual reality;
– regional settlement studies, which concern relationships between peopling, landscape, and culture, on a given territory, involving spatial analysis and modelisation;
– Cultural Resource Management (C.R.M.), of which the institutional role is to survey, protect, and preserve the cultural heritage (not only archaeological sites).

These applications, even having between them a common concept of spatial and graphics objects, are deeply different in terms of aim, functionalities and information system design. So no one can expect to find easily a miraculous computerised tool doing everything, even a GIS!

4. The progress in the development of GIS applications in Archaeology

4.1 *Introduction*

Statistical conclusions obtained from different reports need preliminary analysis concerning the eventual bias of information. Even if, for evident reasons, this kind of surveys is never totally exhaustive, the number of answers by country, and the number of countries, having been reported, are giving enough confidence in the selected information to try to extrapolate some statistics from these data. Of course, it is necessary to be careful with the accuracy of the answers, the ambition of the objective, the real progress of the project, the technical and financial resources involved in each application, which could give the same importance and the same reality to idealised and real applications.

4.2 *Number of projects*

Nearly 150 projects, designated as GIS, have been described in the present report. Each country seems today be concerned with GIS projects, between 1 and 100. It seems possible to propose a clustering, with countries

concerned only by few projects (under 5), others concerned by 15 to 30 projects (France, Scandinavian countries, Italy, Spain), and others with more than 50 projects (U.K., U.S.A., Australia/New-Zealand). If we are obliged to propose some world-wide estimate of the number of the projects, an estimate of 400 GIS projects is not today unbelievable.

Such estimate is certainly lower than the results of a survey on data banks in Archaeology made fifteen years ago. What these data banks have become? GIS, if we could consider that GIS are the children of the yesterday data banks, because the need is basically the same, with a more advanced technology! It seems true in the C.R.M. field, where the transition from archaeological site database to archaeological GIS map is a real technological question for administrations, which are concerned by.

And, what is the future for GIS in the next ten years? Certainly, they will progress too. The GIS phenomenon is certainly at the beginning of a long story, and the number of projects would increase at a rate of 25% per year in the next five years.

4.3 *Differential advance of GIS among countries*

It is clear today that Anglo-Saxon countries (U.S.A., U.K., Australia/New Zealand, Scandinavian countries, Holland) have shown more enthusiasm for GIS (60% of the projects) than Mediterranean countries (Italy, Spain, France, etc.), in a slower progress (25% of projects), while central and eastern European countries and other parts of world are only beginning (15% of projects). This is not totally surprising, if we are considering the generally higher interest of Anglo-Saxon culture for methodology and advanced technology in Archaeology (archaeometry, computerised applications, mathematics, etc.).

4.4 *Which are the pilote organisations?*

About 70% of GIS projects are piloted by researchers from different organisations – Universities, Archaeological Institutes, Academies of sciences (CNRS, CNR, etc.) – depending on the organisation of archaeological research in the different analysed countries.

About 30% of GIS projects are piloted by technical services of cultural heritage administrations (C.R.M.). These administrations can operate at a national scale like the Culture Ministry in France, the Royal Commission on Ancient and Historical Monuments (RCHME, RCAHMS, RCAHMW) in the United Kingdom, the Copenhagen Museum in Denmark, or at a regional scale like in Spain, or at a department or municipal scale. Some of the projects are piloted by university teams (University of Rome in Italy), and about 5% are subcontracted to private companies.

4.5 *GIS projects*

About 40% of GIS projects are C.R.M projects, most of them are survey projects associated with the management of an archaeological site map. Only 8% of these projects are designed to produce archaeological risk area maps. 35% of GIS projects are regional settlement searching projects, aimed at analysing links between settlements, landscape and culture. 25% of GIS projects are excavation management projects, often at a large scale. 8% of them are survey and excavations for rescue excavations.

Statistically, Italy and United Kingdom have more C.R.M. projects, while other Anglo-Saxon countries (U.S.A., Australasia, Scandinavian countries) have more developed landscape peopling research projects. In France, it must be pointed out more excavation management projects on large rescue archaeological operations. Such a phenomenon is complex to analyse, and generally has local explanations. In France, for example, the distribution is certainly due to the large grants given to prestigious rescue operations for one part, to the centralisation of the archaeological national map for an other part, and to the weak support given by the C.N.R.S. and the universities to GIS research projects for the last part.

4.6 *Computerised tools*

About 33% of computers for GIS applications are Unix workstations, mainly Sun machines and 66% are microcomputers, mainly PC. The 9% of Macintosh machines seems to be in France the result of the local influence of Mac oriented scholars. It must be pointed out that Unix workstations are generally shared by several applications, and often associated with PC terminals. The technological trend of the computer market is going towards more and more powerful PC workstations operating under Windows/NT.

Software configurations inside computers are particularly rich in various packages, demonstrating once more that the archaeological information system need complex software integration with numerous packages: DBMS, GIS, CAD/CAM, CAP, Statistics, etc.

Concerning GIS packages, 50% are public or public-like software from university research, with low cost diffusion (MapInfo: 24%; Idrisi: 15%; Grass: 11%).

About 40% of GIS users have chosen ArcInfo/ArcView from the software editor Esri. The other 10% are concerning various local solutions. Nobody, save one, has tried to develop a specific archaeological GIS package.

About 25% of the projects are using a CAD/CAM package. AutoCAD has been chosen twice more than Microstation.

About 25% of the projects have a DBMS associated to the GIS. Oracle

is the preferred DBMS, for C.R.M. applications. Access from Microsoft is the favourite for research projects, replacing quickly earlier products like D-Base, Paradox, Filemaker, etc.

4.7 *A typology for GIS applications*

A more accurate analysis of different GIS applications is showing several patterns in the choice of hardware and software, and for applications.

The C.R.M. applications for archaeological site maps are long time institutional projects with enough budget for hardware and software supply, and are managed by a standing team, well trained to needed computerised techniques. In that environment, are found projects using Sun Unix workstations, with DBMS (Oracle) and ArcInfo/ArcView GIS.

The regional landscape settlement studies are generally research projects, with a time schedule limited by the received grants, allowing only small hardware and software supply, and an application developed by the researchers and their students. The computer configurations are PC with public GIS (MapInfo, Idrisi, Grass).

The survey and excavation projects are limited in time, with often important budgets. The management of the computer application varies, from the help of a computer science student to package and support given by a private subcontractor. Computer configurations are generally based on PCs with a DBMS (Access), a CAD/CAM (AutoCAD or Microstation) and a GIS (MapInfo, ArcInfo).

This is why, under a GIS label, are often dissimulated different kinds of applications, using distinct hardware and software tools, around a DBMS, and with only in common, the need to manage various graphic objects: digitalised images, thematic and geographical maps, artefact horizontal or stratigraphical distributions, which will be operated after by spatial analysis methods and statistical programs, most of time with *ad hoc* packages (SAS, SPAD, SPSS, SPLUS).

5. Back to graphical software packages

With so many various and mixed solutions, the reader could be lost while he thought having understood there are software packages solving all his graphic needs.

5.1 *Vector GIS packages for spatial data visualisation*

Vector GIS packages, *stricto sensu*, are software processing superposition of thematic maps of various objects described in associated files.

By example, let us consider the technical management of equipment in

a metro line. The metro line plan will be first digitalised, as the reference plan. At a second level, will be recorded all the power equipment and lines. On a third level, all the telecommunication equipment and cables. On a fourth level, all the security equipment. And so on. Each object has to be recorded and described in a database. All the information is then operated for predictive or repairing maintenance by the technical personel of the metro. Maps, like objects, may be selected partially or totally, and printed depending on the needs. The database and the graphical maps may be easily updated following evolution or repairing works on the lines.

The applications of this kind of product, of which the most used is naturally ArcInfo, are numerous in all the fields of technical management of buildings and installations, thematic cartography (digitalised maps and various equipment plans), geomarketing, etc.

A GIS package is then a software product answering to well defined cartographic functions. The most important technical feature of such a GIS is the processing of graphical information by vector data, well adapted to network graphical mapping (particularly cartography), but not to computations made on graphical objects.

The GIS leaders on the market are ArcInfo (Esri) and MapInfo. The ArcInfo package and its primer ArcView are edited by a private company, Esri, which is assuming evolutions and maintenance of the product. MapInfo, at the opposite, is a software developed, and initially distributed at low price, by U.S. universities, and is a good starter for small budget applications.

5.2 *Raster GIS packages for spatial data manipulation*

A second category of GIS is raster GIS packages, where data are fully digitalised and represented by an image, in place of vectors. The main interest of raster GIS is that the data may be easily operated by quantitative techniques (Map algebraic procedures), and then the GIS package can be completed or interfaced with numerous spatial data analysis software allowing processing functionality such as various landscape visualisation: viewsheds, 3D modelisation, etc. The accuracy of digitalisation is then critical for applications, as for the capacity of storing and processing of the PC.

The most suitable raster GIS used in archaeology are low cost public software Idrisi, Grass, Spans. It is also recently possible to use a vector GIS product and to make some vector to raster data transformation for particular spatial analysis.

5.3 *CAD/CAM packages*

CAD/CAM packages are very widespread software in the industry business, everyday tool for engineering 2D/3D drawings in various product manu-

facturing: cars, aircrafts, electronic equipment, clothes, civil works, houses and buildings, cabling, etc. The software leaders are AutoCAD and Microstation.

The CAD packages are well adapted for 2D and 3D archaeological plans of excavations: sampling maps of survey, excavation drawings, architectural plans, artefact spatial distribution maps, etc. CAD/CAM products unfortunately cannot be used directly and must be customised before by specialists, or integrated in a global archaeology oriented product.

5.4 *(Multispectral) image processing package*

Image processing packages are directly coming from remote sensing applications or satellite image processing, initially reserved to defence applications. The best satellites are supplying a pixel of 10 meters (civil satellite like Spot, Landsat) until 1 meter (military satellite). Software like Erdas, PCI, Spectrum are dedicated to image processing. But a CAP (Computer Assisted Publishing) software like Photoshop from Adobe has already many features of image processing.

6. Archaeological problems and their solutions

6.1 *Survey, preservation and risk prevention of cultural heritage*

Survey, preservation and risk prevention of cultural heritage have for main objects the recording and graphical visualisation of archaeological sites: the archaeological map. A secondary function, essential for risk prevention, is the management of an archaeological risk map, for large (or small) civil works, which could emerge into predictive modelisation of potential presence of sites, and preventive actions of rescue archaeology. The main issues of computerised tools are risk thematic maps, involving a powerful DBMS (to record and update numerous information of site description, environment, administration and references) and a vector GIS on Unix workstations.

6.2 *Survey and excavations of programmed or rescue archaeology*

Actions of surveys and archaeological excavations are needing various plans and maps. They are using vector cartographic data from archaeological map, or other cartographic sources (cadastre, geological maps, landscape maps, etc.), raster data from air photographs, satellite images, or any kind of digitalised images, raster topographical data from laser theodolithe or GPS system. Air and ground survey, core sampling and excavation procedures are elaborated. Plans of artefact surface collecting, archaeological structure or site localisation, artefact spatial distribution are issued.

These data are creating the operation reporting, which is requiring more a multimedia electronic data retrieval system than a GIS. A CAD package (AutoCAD-like), associated with a DBMS (Access-like) is an adapted computerised solution for this kind of needs. Nevertheless, it is not a complete finalised solution, leaving the archaeologist, or the technical support he has been obliged to ask, to develop customised information system (cf. Archeotech SA with a solution based on Microstation and Oracle).

6.3 *Regional landscape settlement studies*

The problematic of the links between culture, landscape and settlements in a given territory is at the origins of numerous researches using GIS in the universities or research institutes. Here, the research is focusing on the recuperation of all possible cartographic data, able to give spatial explanations to archaeological problems: geographical map, involving an adapted digitalisation of contour lines (DEM); landscape map; soil map; geological map; hydrographical map; images from air photographs and satellite images with limitations essentially due to prohibitive prices; archaeological maps; and of course artefact surface surveys.

Here the challenge is not a recording survey or rescue excavation, but spatial intersite analysis and settlement modeling.

The software solution is a raster GIS package, for easy data extraction for mathematical methods of spatial analysis and modeling. Raster GIS like Idrisi, Grass, initially designed for remote sensing, are the most widely used by archaeologists, with interfaces to statistical data analysis packages like SAS, SPSS, SPLUS, SPAD. The availability of a real language of graphical object primitives like Map algebra, available today in Arcgrid from Esri and MGE grid from Intergraph is necessary. The spatial modeling which is using frequently today viewsheds (all the landscape viewed from a single point), various cost-surfaces and 3D landscape visualisation, may arrive at dynamic 3D modeling, matching GIS packages with simulations languages (Stella, SME, etc.).

6.4 *Virtual Archaeology*

Virtual reality software is nevertheless totally different from previous computerised tools, and is needing independent projects, even if they can usefully be based on previous results.

6.5 *Going to only one package?*

The business pressure, resulting from the success of the multimedia computerised applications, are pushing software editors to develop more and more common functionality in their products, very different at the ori-

gins. For example, interfaces are allowing to transfer data from vector mode to raster mode (Arcgrid). CAD/CAM packages have developed GIS modules (AutoCAD), and 3D simulation modules (Modelview from Intergraph). Today, and more and more, the archaeologist will have to face to problems of choice in front of less costly and more functional multiple offers.

6.6 *Pure archaeological problems and software solutions?*

Nevertheless, it is clear that limitations would always subsist due to the specific character of Archaeology: the main problem is to introduce the management of the time dimension in the software. Archaeologists need a 4D graphic and cartographic product. It does not exist today, and probably never. It is for this reason that archaeologist is using GIS with time treated like a thematic level.

7. Theoretical Archaeology and GIS

Is the use of GIS in Archaeology independent of any a priori theory, or dependant of an implicit or an explicit theory? The question has been raised by many scholars in Geography and after in Archaeology seeing GIS applications as an argument of return to positivism and environmental determinism. It is not clear today to be able to answer definitively that question, in differentiating between a theoretical oriented application and a technological oriented software tool. It is sure that many regional landscape settlement studies have been made by archaeologists convinced of some environmental determinism, while other studies have been made free of any a priori theory about the role of the environment. For the first ones, the GIS technology is a decisive tool for such correlation. For the second ones, GIS technology is just a modern information system tool, giving them the ability to separate between cultural behaviour and environmental determinism.

8. Conclusions

GIS usage in Archaeology is perhaps in the nineties the historical event of the computer age introduction in Archaeology, as data analysis in the eighties has been the historical event of the introduction of mathematics in Archaeology. But more than GIS, it would be better to talk about AIS (Archaeological Information System), or AMIS (Archaeological Multimedia Information System), which is covering all the applications integrating graphic applications in Archaeology.

To avoid the same problems of difficult technical acculturation of archaeologists to modern tools, well known in the past, it is certainly necessary to help by some academic strategy the training of young and less young

archaeologists to computerised and GIS techniques, and to focus in each country on pilot projects with enough resources and long term program.

Software products are existing today in the market, pushed naturally by numerous applications existing in various sectors of the society. These products are enough generic to be adapted to the different archaeological needs: Cultural Resource Management, survey and excavations, spatial intersite studies. So, much more than in the past, hardware and software solutions are available at low cost to favour such a technical revolution.

Finally, the development of GIS applications in Archaeology will also develop a new profile of archaeologist: the AIS project manager, at the interface between the traditional archaeologist and the computer specialist. Such a new background could be a fruitful reaction against the excess of specialisation which can be recognised in Archaeology since twenty years.

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ABSTRACT

This paper is an introduction to the IX issue of «Archeologia e Calcolatori», dedicated to GIS in Archaeology. GIS technologies are first put in the context of the Computer Sciences since the sixties. It is shown that the development of the GIS is resulting from a general evolution of computer manufacturing towards both multimedia and workstation solutions. The needs of the archaeologists for graphics and GIS are mainly dedicated to Rescue Archaeology, large site excavations, regional settlements studies and Cultural Resources Management (C.R.M.). The progress of use of GIS in Archaeology since 10 years has been analysed from the 150 projects described in the present volume. It appears the advance for GIS applications in the Anglo-Saxon countries (US, UK, Australia), even if in other countries the success of GIS is growing. It is proposed a global rate of development worldwide of 25% par year. Pilots of GIS applications are mainly research Institutes for 70% and culture heritage administrations for 30%. About 40% of the GIS projects are C.R.M. projects, 25% excavations management projects and 35% regional settlements studies. The computerised tools are Unix workstations for 33% and PC for 66%. About 40% of GIS users have chosen ArcInfo from Esri, while 50% have chosen public low cost software like MapInfo, Idrisi or Grass. The market for GIS applications in Archaeology seems to be shared between vector packages dedicated to C.R.M., raster packages dedicated to regional settlements studies, and CAD/CAM packages dedicated to surveys and excavations. But progressively, the different packages will be adapted to have all the needed functionalities, including image processing and interfacing with DBMS and statistical packages. Finally, GIS applications in Archaeology are not intrinsically theory oriented, even if environmental determinationism has found with GIS a perfect to ol for its needs.