ArchaeoGRID, a GRID for Archaeology

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Abstract- **The approach of modern archaeology to the study of the evolution of ancient human societies is based on the acquisition and analysis of many types of data. It is well known that in archaeology large use is done of digital technologies and computer applications for data acquisition, storage, analysis and visualization. The amount of information coming from remote sensing, from acquisition of 3-D artifacts images by scanners laser, from GPS precise reference of geographical points and from other sciences are increasing at a large extent the amount of data that it need to be stored and made available for analysis. Such data must, however, be analyzed if they are to become valuable information and knowledge. The data analysis use advanced methods developed in mathematics, informatics, and physics and in other natural and human sciences. Moreover the use of Virtual Archaeology as a new approach to the narration and visualization in Archaeology, is expanding rapidly, not only in the museum and archaeology professions, but also in the broadcast media, tourism and heritage industries. The inevitable result of this is an exponential increase of the amount and complexity of information that must be acquired, transferred, stored, processed and analyzed. From another side natural disasters, wars and terrorism created enormous damages to the archaeological heritage and in many case destroyed definitively all information about ancient civilizations. It is urgent a long term project for acquiring at least the archaeological information.**

The paper presents a proposal for an ArchaeoGRID that, using the GRID technology developed at CERN, will develop a GRID capable of fitting the very challenging requests of archaeology.

I. Introduction

It has been underlined from organizations, associations and single archaeologist the necessity of a world wide program for the Archaeological Heritage protection, documentation, preservation and accessibility. In fact natural catastrophes, wars and terrorism, but also any activity for land management can destroy, for ever, not only the physical remains but any archaeological information present in the environmental context. Archaeological material traces are fragile and must be handled with care to reconstruct the "memory" of the humanity history.

As the WEB has been used from the archaeologists for their communication, for accessing database, for realizing archaeonets and review on line, the ArchaeoGRID has the characteristics useful for collecting, storage, accessing and processing very large amount of data coming from excavation and field survey, but also from application of 3D Virtual Reality technologies.

Archeologists use modern information and communication technologies to collect, transmit, classify, process and evaluate the data that are of interest to them. Data are produced in the archaeological site and in the laboratory. Data could be transmitted to distant computing centers for real time analysis, such as simulation and 3D visualization. In fact the archeologist on the site does not currently have access to sufficient computing power to provide the needed data processing. On the other side, data that interest archeologist during his field work are stored in many different locations and the access of the appropriate data is not just a question of collating known data: there may also be potentially useful data which are unknown to the archaeologist that has no current mechanism of finding.

The number of computationally intensive processes that an archaeologist may wish to do is huge. For example, the simulation of the changes over centuries in the shape of a large ancient landscape would take a very considerable time on one computer, or even on a cluster of computers. Modeling an ancient society is like modeling very complex dynamic systems. For these application areas need the development of a new communication and information structure, based on the Datagrid at CERN, to develop an ArcheoGRID of use.

II. The Nature of the Archaeological Information: the Archaeological Record

The archaeology studies any element, artifact and ecofact that have some relation with the life of the ancient societies living in the past on a specific geographic area. During the excavation the archaeologist look at the physical remains and with the same care and interest at the soils where they are immersed. He tries to answer at the following questions:

"what", "where", "when", "how" and "why"[1].

"What" indicates any material and symbolic aspect carrying information on the ancient society life. The esthetic and economical values of finds are not important and the fine and

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precious ones have, in this context, the same significance than the ugly and valueless. Nothing must be neglected during the data collection.

An other aspect that it needs underline is the necessity to link the object, the data, to his spatio-temporal context and answer with the best precision possible to the other two questions: "where" and "when". Out of the context large part of information carried by the finds is lost.

Archaeologists try to answer at "how" and "why" questions by the "narration", by the reconstruction of the history based on the retrieved information.

Each step of this complex research way must be realized in a team where specialists in many different sciences, from anthropology to geography and social sciences, from geology, to botanic and zoology, to biology and genetics, are organized in a scientific collaboration. Archaeology is a multidisciplinary science.

Sophisticated instrumentation and tools for physical, chemical, biological, geological and geographic measurements are used for excavation, field survey and laboratory analysis.

Advanced mathematical methods in statistics, in Geographic Information System (GIS), in mathematical simulation, in 3D graphics and Virtual Reality are used for data analysis and visualization.

Computers and information technology are now used at a large extent because give the possibility to do better and faster what was done before without the computer, like storage data in database, use digital maps and visualize the results. But a more sophisticated use, that employs the full potentiality of computers and of the information technology, is carried out only from a limited number of archaeologists.

It can be concluded that existing archaeological information, and the one collected in the next future, will represent an enormous and complex amount of data, non homogeneous, spread over many sites, often in region with strong social instabilities. The management of these data is the central problem of modern archaeology.

Who collects the archaeological information? The subjects involved in such activity are many and various. They are groups and persons working in large international organizations as UNESCO, that, for his institutional activity acquire information on the archaeological heritage in any part of the world, NASA end ESA by satellite images at high resolution in the visible and infrared bands and by interferometric radar that in dry soil can show underground remains until more than ten meters; archaeologist groups working in Museums and Universities, involved in site excavation and field survey all around the world; municipalities that must care the archaeological parks, important for tourism economy; regional and national government with their organization for the conservation and monitoring of archaeological resources and for organizing excavation campaign; until to the archaeological association that do an important research work at local level.

The large number of different and inhomogeneous subjects involved in collection of archaeological data, the large quantity and complex quality of the archaeological information, the urgency to collect information in many important archaeological area before their destruction, the general demand for a sustainable tourism, the use of archaeological heritage in education and other aspects linked with the archaeological activities push in the direction of realization of a new information structure that give the possibility to organize the multiple subjects in an organization for the realization of a precise project.

A new archaeological GRID seems to be the best approach at these problems solutions.

In fact the objective of European DataGRID project [2] to enable next generation scientific exploration which requires intensive computation, very large storage and analysis of shared large scale data base across widely distributed scientific communities seems to fit well with the objective of an Archaeological GRID.[3] Sharing in this case is made complicated by the distributed nature of the resources to be used, the distributed and inhomogeneous nature of the archaeological communities, the distributed nature of the sites where data are collected, the size of database.

One of the primary goals is to build a data grid for efficient access to very large and increasing datasets in archaeology.

The primary goals are an organization of the data for efficient access, storage of data in widely distributed locations and an efficient handling of entire major archives. It need to remember that at present the finds distributed in museums are a very big number and their 3D digital images by laser will need large dimension storage, with efficient access for data retrieval and mining.

But a first phase of technology demonstration and evaluation using scientific application has given good results. The demonstration of the same ability for an archaeological GRID prototype could be easier.

The multidisciplinary nature of the archaeology needs to be taken into account for a good archaeological GRID design. Data from earth observation by remote sensing with satellite, airplane, balloon, from evaluation of the global and local past climate, from ancient geomorphologic and pedological situation, from paleobotanic and paleozoology, from population genetics, from history of agriculture, of economy, of techniques and of communication ways, from anthropology and social sciences are important in archaeology and must be accessed as the information on the archaeological finds.

This poses the problem for communication between inhomogeneous databases and between different Grids.

III. Archaeogrid as an Archaeological Resource Management System

Management of the archaeological resource represents today very complex problems. Archaeological museums, parks, cities and territories under the protection of the UNESCO, digital archives and libraries need a complex system for preservation and for access. A combination of large database with the known data and continuous surveying can offer the way for solving the large number of problem linked to the management.

Much different expertise in different scientific disciplines and technologies, existing in public and private institution, national and international, need for such aim.

UNESCO in many occasions diffused documents and alarms for preservation of the archaeological heritage. Documents have been written and approved by the majority of the UNO member nations, but not very much has been done.

But today the tumultuous and dramatic events linked to the war and terrorism, but also to the climatic changes or to the construction of colossal infrastructure requires a strong and rapid intervention on the territories interested in such disasters. The example of the war in Iraq demonstrates the necessity of such effort. The ancient sites of Babylon are not completely registered by the archaeological field survey, due to the complexity of the topographic studies and, until now, is unknown the site of the very famous city of Accad, important cultural centre founded in 2350 B.C. It need to remember that, in this region, only 1% of sites have been excavated

This is an archaeological area immense and inexhaustible and an example representing a synthesis of the important reasons that push at the realization of an Archaeological GRID as soon as possible.

The reconstruction of the Iraq could present similar problems if we consider the big environmental impact due to oil extraction and transportation as than all new constructions needed for his economical development.

Management of the Archaeological Heritage requires the storage of a huge amount of information in large database, accessible by the ArchaeoGRID. Data from continuous monitoring of archaeological sites will be compared with the stored data. This will be as a worldwide digital archaeological risk map, useful in many human and economical activities.

IV. ArchaeoGRID as the Information Structure for the Archaeological Research

ArchaeoGRID will be a very powerful structure for the archaeological research. In fact by his use it is possible the acquisition, storage and retrieval of a huge amount of data from field survey, from excavation and from laboratory. It will be also the way to access information produced by other GRID, needed for the archaeological research.

The archaeological knowledge could circulate and new data could be easily incorporate in it. The updating of information will happen quickly.

Circulation of the archaeological knowledge through the use of advanced technological platforms will aid and produce advances in knowledge unification and integration. Before modern computer technology, this goal was not even foreseen by archaeologists. But the formalisation in data structuring and inference rules imposed by computers is an advantage archaeologists should profit in order to obtain a completely new way of producing archaeologically relevant knowledge. According to the objective possibilities of computer technology, different application domains of this technology in the archaeological process are established. Some schools would give advantage to one domain instead of another, but all will coincide with a majority of the practical necessities, which could be supported by the machine: storage, manipulation and data acquisition, as well as graphic, analytic and communicational support.

The precise usefulness of computer technology can vary from one domain to another. The assumption is that the advantage of using ArchaeoGRID, regardless to the immediate usefulness in some particular domains of research, is to advance in knowledge unification and integration through the use of advanced technological platforms.

Computer technology becomes the medium for the cognitive process. The world where paper and pencil where the tools used to generate knowledge have been left. Verbally generated and transmitted knowledge is still useful, but we can go far beyond its limits. Formal knowledge, quantitative or qualitative, expressed in form of concrete data structures and inference rules gives the opportunity to add knowledge from different sources, and to integrate different voices and thinking into a single coherent, but diverse body of information, which can be used in an interactive way, without imposing a single way of thinking.

The archaeological knowledge generated must circulate: the knowledge, which is not used, doesn't survive, and that is the main problem of the archaeology today. The process of incorporating new data in general archaeological knowledge seems to be too slow. Archaeological knowledge is not a unique construction, but a series of stand alone stairways, waiting rooms and halls, containing isolated activities and dispersed results Information must be shared at run time between the field archaeologist and the laboratory technician. And simultaneously, specialists about past societies must be reviewing field data and laboratory results at run time, understanding archaeological data in the field with the help of augmented knowledge. In that case many people can collaborate in the understanding and in the way the archaeologist extract knowledge from the ground, without being there excavating. That means knowledge sharing and knowledge growth. Everyone learns: the archaeologist in the field, the technician at the laboratory, the archaeologist at the university, the public at the museum, the student at the classroom. The idea is to generate knowledge, to share knowledge and to use knowledge, because only through its use, it will build significant relationships between bits of data which may be inutile in their own.

Distance appears to be the main problem when archaeologist is speaking about synchronized activities on the same object, or, in other words, when he uses a specific knowledge. Sometimes, archaeologist accept that objects, information and people have to travel (deleting distance), and that needs some time, and has some cost. Physical impossibility to be on two distant places simultaneously, make him to use only one knowledge location (deposit, source, object) at the time. Only in front of radical situations of urgency or material impossibility to be there, he is obliged to find solutions.

Telearchaeology, in its basic sense, may be defined as the use of telecommunications to provide archaeological information and services. Two different kinds of technology make up most of the telearchaeology applications in use today. The first, called store and forward, is used for transferring digital images from one location to another. A digital image is taken using a digital camera, and then sent to another location. When archaeologist is not using images, he can store and forward any other kind of data files.

The idea is quite simple: send images or data from the field to another place for diagnosis and interpretation. For example, readings of magnetic prospection on site, taken by archaeologist, forwarded to expert geologist, turn back in a form of analysis and profile interpretation.

The other relevant practice of telearchaeology is two way interactive television, which is used when a face to face consultation is necessary. Consider the case where the archaeologist needs some geological consultation to understand the stratigraphy or deposits him is excavating. Videoconferencing equipment at both locations allows a real time consultation to take place. There are many configurations of an interactive consultation, but most typically it is from a research center to an archaeological site, between different archaeological sites and different research centers. Telearchaeology bring knowledge when and where it is needed, essentially annealing the distance

Fig.1 – Mediterranean Sea in X-VIII centuries B.C.

factor in archaeological knowledge exchange.

Of course, the idea of telearchaeology is to use telecommunications software and hardware to share knowledge. The greater the number of archaeologists using shared knowledge, the greater the quantity of new knowledge will be generated

The following example illustrates the dimension and the complexity of the problems that are the final study aims object of the archaeology: the origin of the city in the Mediterranean area between the X-VIII centuries. [4]

The event, the urbanization process, is so relevant that for Etruria it is known as the "Villanovan revolution". Phoenicians and Etruscans during this period built urban centres in many sites of the Mediterranean area, starting from Phoenicia and South Etruria.

In fig.1 the large geographical extension of this area is shown and therefore the dimension and complexity of the archaeological problem.

As it known the information came from the field survey and excavation of the archaeological region and site and by laboratories where any type of remain is analyzed.

The archaeological record is done by answers to questions like what, where, when, how and why. The stored data are spatial data associated to the archaeological time. An archaeological GIS including time will be the needed geographical database, which will contain any data from remote sensing, GPS, field survey and excavation, Virtual Reality simulation and from laboratory analysis and historical archives.

An archaeological space can be defined as a sequence of finite states of a temporal trajectory, where an entity (ground surface) is modified successively, by accumulating things on it, by deforming a previous accumulation (for instance, by spreading) or by direct physical modification (building, excavation). Archaeological sites should be considered as the result of successive and overlapping modification steps. Any element of the ground surface will be represented by image (map), which pixel position will be defined by the two spatial coordinate and by the time. In the case of excavation a volume element will be defined by the three spatial coordinate and by the time (voxel). At any voxel (pixel) are associated measured (or estimated) values of anthropological, ecological, geographical variable $w = w(x, y, z, t)$.

Natural and human processes modify physical space, and as a result it is possible to distinguish phase or modification step*s*, which can be used as analytical units. A phase is a homogenous region in space, delimited by a well defined discontinuity or boundary. It easy to understand that the number of variable connected with the voxel properties is very large.

Spatial discontinuities have three main properties: geometry, topology and texture. A wall, a pit, a garbage accumulation are phases or distinct regions of the archaeological space, which can be defined not only in terms of their own properties, but also in terms of the differences with neighbouring phases. The archaeologist needs to distinguish where observed discontinuities or boundaries begin and end, that is what are the proper borders of an occupation floor, or the original shape of a pit, where pottery sherds are accumulated, or where an animal carcass has been broken into bones. Therefore, archaeological excavation cannot be reduced to the mere unearthing of artefacts and ruins, but an exhaustive documentation of an archaeological space in terms of a finite set of spatial variables. The purpose is to characterize observed discontinuities in terms of distinct components or relevant units with uniform value of shape, size, texture, composition. However, a phase cannot be defined only in terms of their boundaries. They should be analysed as the presence-absence of some qualitative spatial variable, which is a feature which has positive value if it is present and negative value in case of absence. Observed discontinuities between phases can also be expressed in terms of quantitative variables. Quantitative variables exhibit a variation in value throughout spatial regions. Variables such as geomechanical properties, mineral grades, material accumulations, soil morphological features, or any other property of sedimentary and depositional units and archaeological contexts, can be sampled or measured in terms of real, numerical values. Analysis is done to establish how qualitative and quantitative variables vary significantly from one location to another. Visual model [5] is used for the spatial analysis of phase correlation to understand how distinct formation process influence the spatial and temporal discontinuities observed through the site. What happens in one location (temporal or spatial) is the cause of what happens in neighbouring locations? One possible effect of spatial causality is the similarity of values in neighbouring locations. Obviously, it will be analysed all effects probabilistically related to the spatial or temporal location of the cause

A similar discussion can be done for the pixel of any type of image and map useful for the description of environmental and social variables. Image from remote sensing, any type of maps containing information about geology and geomorphology, idrography, land use e land cover, paleoclimate, paleofauna and paleoflora, resource dislocation, will give information about the interesting variables.

The analysis of these complex set of data require complex method and large computing power, but is necessary if it want take in account all the information existing on a specific problems. Such very complex problems could be analyzed using the ArchaeoGRID.

IV. ArchaeoGRID as the way for the exploitation of archaeological information and knowledge

Some of the final users that could be also members of a Virtual Organization are institutions and companies working in education, entertainment, cultural heritage management, cultural tourism, and agriculture and land urbanization.

In many case these activities have a considerable economical interest, as in the case of agrarian and land urbanization companies. In fact, they need detailed information about the archaeological situation for the territory where will operate, a map of archaeological risk, for excluding sites from their territorial plan. Entertainment companies, TV and cinema are doing large use of the archaeological information. Virtual ancient cities and landscape are created using the 3D graphics and Virtual Reality technology for a use like a virtual place where the movie action is settled. For these uses it will need an archaeological validation, if there is an interest in the diffusion of a correct knowledge of our past history.

International and national institutions, national and regional government, municipalities, whose institutional task is the preservation and the management of the archaeological heritage, will find in the archaeological GRID the needed tool. ArchaeoGRID will place at their disposal resources otherwise difficult to access.

V. Conclusions

Effective and seamless collaboration of dispersed communities, archaeologists first, public institutions and then companies will be enabled by ArchaeoGRID with the ability to run large-scale applications aggregating thousands of computers, for very wide range of applications and the transparent access to distributed resources from desktop

The term e-Archaeology has been coined to express these benefits. The ArchaeoGRID can act as unifying agent of the archaeological knowledge. Archaeological knowledge building is a collective work, a dynamic series of tasks and processes. The explanation process needs knowledge as a raw material, and this knowledge doesn't exist in mind of one individual archaeologist. It is distributed in the community of researchers, on a global scale. To be able to interpret data, every researcher needs a previous knowledge on which he will make a specific reference.

Other benefits of such an archeological system are 3D visualization of ancient buildings, cities, landscapes; archaeological risk maps with the identification of currently unknown areas of potential archeological interest; educational material; new possibilities for archeological tourism.

Is clearly futile to imagine that a single computer could cope with the challenges of e-archaeology, which entail simultaneously realities at local, regional, national and international levels.

Only a distributed approach using ArchaeoGRID can hope to approach these challenges and that is why a Grid for archaeology is not just a fancy idea: it is a necessity. ArchaeoGRID will be the good structure for production, management and exploitation of the Archaeological Information and Knowledge

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