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A Virtual Research Environment for Archaeological Data Management, Visualization and Documentation

Abstract: The development of data management systems to store and make use of the heterogeneous archaeological datasets is very significant nowadays. This allows the preservation of the information and offers new management possibilities, such as the immediate connection of different kinds of data for analysis, or the digital documentation of the site for its improvement. Within this scope, this paper aims to present a Virtual Research Environment for archaeological sites. It is based on open source software modules dedicated to the Internet, to avoid users needing to be familiar with software and to permit them to work from different computers. Our VRE has three objectives: digital archiving of archaeological datasets, data inquiry through different interfaces notably clickable maps and 3D models, with attractive visualization and communication of the information. The tool proposed is compatible with every kind of archaeological site. Some experimentation has been done on sites managed by the Service of the National Sites and Monuments of Luxembourg.

Introduction

Cultural heritage documentation includes the use of computerized techniques to handle and preserve the information produced. In archaeology, numerous documents have been produced for years without computerized means. It is now necessary to preserve them numerically, to be able to combine them with the new types of representations of the monuments that can be done currently (3D models for instance). In the archaeological domain, particularly, data computerization gives solutions to specific problems by allowing inventory actions to save, represent or understand the features. Archaeology is an erudite discipline where the knowledge increases in complexity, referencing the previous documents already gathered. The quantity of data produced during the working of a site can thus quickly become huge. Archaeological datasets consist of primary information, concerning the archaeological objects or configurations, and of secondary information referring to the primary information including documents that allow us to know these documents, publications with artefacts descriptions and comments, or image collections. It is then required to develop systems that create relationships between these numerous and heterogeneous data. For instance, by establishing relationships between the primary data, such as a ceramic, to the secondary data, information retrieval and research is made easier.

Proposition

To produce such a system it is necessary, first of all, to create a database to document this data. The majority of the databases currently used in archaeology are relational, because the structure and the relationships of excavation data can be successfully modelled in this type of databases (RICHARDS 1998). These databases have to contain all of the characteristics generally used by the archaeologist in his interpretative reasoning. Also the characteristics which do not relate directly but allow us to have a more precise view of the document, or for those which could be of value in the future. Therefore, the description of the feature that is recorded in the database is at least as rich as the report from traditional publications (GINOUVÈS / GUIMIER-SORBETS 1978). To record the context or metadata of the data is as important as it is to record the data itself. The database that we propose for archaeological documentation records data and metadata in the XML (eXtensible Markup Language) format and allows to insert the data automatically into a MySQL database. XML has been chosen because it is a standard of the W3C (WWW Consortium) for data description, and because it includes the registration of metadata about the data that is to be preserved (to have secondary information about the primaries). The system is very flexible as it allows the user to choose the metadata he wants to attach (according to an archaeological standard e.g. CIDOC CRM (DOERR 2003)).

There is a need for the development of an information system that has to provide an enrichment of the information recorded in the database, while permitting the immediate access of the data. An information system is a combination of the diverse types of data accessible through various interactive consultation systems. We propose an information system based on open source software modules dedicated to the Internet, which aims notably:

- to process graphically several pieces of information derived from very different kinds of surveys, as a selective superimposing could be of great value for the interpretation of the information;
- to combine elements selected in diverse graphs or models for the generation of visualizations in synthesis maps or 3D models. For example to be able to interpret in a new way the historical changes of the archaeological site;
- to present images and their connections with the concerned texts from the database, to lead to a complex system in which the integrated processing of texts and images would be possible to be viewed simultaneously;
- to search in the dataset through views of the data, or through diverse search engines by data types, keywords or images.

Thematic and interactive treatments are then achievable, principally on spatial and temporal criteria.

These treatments provided by the information system are necessarily combined with visualization systems that allow the viewing of the results of the data extractions. The means of visualization of Cultural Heritage information are numerous in order to allow visual interpretation of data through representation, modelling or animation, which is rarely possible in traditional paper publication. Visualization techniques are constantly evolving. They are most frequently based on 3D modelling used notably for museum presentations. The principal drawback of the types of 3D models used in archaeology nowadays is that these models are “empty”. The idea is to produce 3D models that can serve as research interfaces to access different kinds of information, notably in coupling them

with web procedures (scripts). Our system has been carried out this way. We have produced interactive maps and 3D models that work like web interfaces to obtain views of the database records. The system is closely connected to research the work of P. Drap (DRAP ET AL. 2005), who has notably developed a system integrating photogrammetric data and archaeological knowledge. The clickable representations are 2D images or vectors created in SVG (Scalable Vector Graphics) from scanned or vectorial drawings, and 3D models produced in VRML (Virtual Reality Modelling Language) or X3D (eXtensible 3D), for a full compliance with the W3C recommendations. The data was created by topographic, photogrammetric or laser scanning surveys.

Finally, the creation of a system working on the Web provides a tremendous opportunity to link distributed resources and to make unpublished material widely available (RYAN 1995) as well as uncommon material like detailed fieldwork data, large quantities of photos and archive drawings, vector graphs or 3D models. The division between publication and archive could thus be removed, even if there is still a big challenge to control the way in which the Internet is used in regard to the discoveries, quality controls and copyrights. The use of the World Wide Web network permits the communication of the archaeological data in a very comprehensive way, more so even than traditional publications. Aims of the Web information system are to assist the digital archiving of the documents, their inquiry and their processing by everyone, both professionals - archaeologists, surveyors or architects - and the general public. Different types of access to the data are available depending on the nature of the user of the system. Representations adapted to museum displays (public attractive) have been done as well as interfaces permitting to update the data directly from the 3D models, for the needs of the site managers. Moreover, open source software modules allow easy accessibility for all users, and above all permit us to propose a system independent from any commercial software.

Next, we propose a Virtual Research Environment¹, which has the following objectives:

¹ Term introduced by the Joint Information Systems Committee (JISC), which manages research and development programs in the use of ICT in teaching, learning and research to build knowledge. Particularly, it supports a project called virtual research environments program. A VRE is an online environment dedicated to support collaboration (i) in the management of a research activity, (ii) the discovery, analysis and curation of data or information or (iii) in the communication and dissemination of research outputs.

- complete digital archiving of archaeological datasets,
- innovative data inquiry notably through clickable maps and 3D models,
- attractive visualization and communication of the site information through thematic and interactive interfaces.

This tool notably combines survey, modelling and imagery data. Our purpose is to highlight how such a system can offer new possibilities for the management and the dissemination of these data, in particular those coming from archaeological sites.

Modelling of the VRE

To understand how the Web information system that we propose has been implemented, it is interesting to present its conceptual model. The conceptualization of the system is based on the requirements of the user. It is necessary to establish this first because these needs define the outlines of the system to be modelled and make clear the objectives needed. Also they allow to identify the main functionalities of the system. In the next sections, we describe the essential steps of the modelling: the identification of the needs of the users and of the processes of the system. This is followed by the definition of the entities and interfaces of the VRE.

Needs of the Users and Processes

The modelling of an information system is guided by the needs of the different elements of the system. The elements are the external entities (users, files) that interact with the system. A user can consult or modify the state of the system, and in answer to the action of the user, the system supplies a service that corresponds to his need. For our VRE, we have identified the following elements:

- files and software: system administration, application software, archaeological site data
- physical users: administrator, member (user who has rights to act on the data), visitor

Once users log on, we can identify and structure their needs. These needs are finally what the archaeologists can expect from a system dedicated to the online easy management and dissemination of datasets coming from the working of archaeological site data. They make up the detailed counterpart of the objectives of the VRE quoted before.

From a simple visitor's (data consumer's) point of view, the expectations are:

- to visualize the data in different ways: in catalogues, by reaching directly the data connected, by views that aggregate different attributes, from the metadata corpus, in thematic and interactive interfaces (clickable maps and models);
- to do flexible search across the diverse data: using data types, keywords or images;
- to combine elements selected in diverse graphs or models to generate visualizations in synthesis maps or 3D models, in order to see historical changes of the site;
- to configure the use of the system (e.g. language); to have access to help files, simple schemes of the VRE tool box, answers to frequently asked questions, or to contact the support.

From the point of view of a site manager (data provider), the needs are:

- to access the system in a secure way (login and password to be able to do modifications on the data);
- to administer his archaeological site: to add a site record (from existing files or not); to generate standard exchange files of the data (to collaborate with other teams for instance), to make global backup of all data files, to delete a site record;
- to store his data on a server (upload of images, maps, models, videos...);
- to generate new interactive data from his initial 3D models or maps (process of automatic anchoring);
- to manage his data: the addition of a data, addition of existing types of data or of new types (originals or imported), also the modification of the structure of the metadata, definition of default values for the metadata, suppression of data types;
- to access the data in different ways (via catalogues, by accessing directly the connected data, through views aggregating different attributes, or from the metadata corpus, and thematic and interactive interfaces (e.g. clickable maps and models)). This enables data to be edited, updated or renamed, duplicated, deleted as needs be;
- to do flexible search across the diverse data: via data types, keywords or images;
- to combine elements selected in diverse graphs or models for the generation of visualizations in synthesis maps or 3D models, in order to see historical changes of the site;

- to configure the use of the system (language, configuration of the pages); to have access to help files, simple schemes of the VRE tool box, answers to frequently asked questions, or to contact the support;

And finally the administrator needs to:

- administer the information system and its applications (thematic and interactive interfaces, search engines, views, etc.);
- administer the server parameters and the databases;
- administer the rights and roles of the users.

The formulation of these needs is essential to conceive a system really dedicated to the user needs, in our case the archaeologists or site conservators. Indeed, they have particular expectations regarding a system for the management and the dissemination of their very specific data, and they are not necessarily experts in computing (the simplicity of use is thus very important). Moreover, from these needs ensue the processes of the VRE, i.e. all the internal activities of the system aiming to answer the users' needs. For instance, the process corresponding to the need "to combine elements selected in diverse graphs or models for the generation of visualizations in synthesis maps or 3D models" can be formulated as "generate representations". This process concerns the visitor as well as the member, and is put at disposal of these users through a menu in the main interface of the VRE (see Fig. 3). The same principle has been used to offer menus (corresponding to each type of user) aiming to answer their needs. These menus (see left part of Fig. 3) were created after identifying the entities and the interfaces required.

Entities and Interfaces

The entities of an information system are the objects that the workers utilise. The workers are those who interact, communicate and work together to execute the system processes. The entities are then considered as the diverse study classes of the VRE that permit the execution of the processes of the information system. A class is an abstract type characterized by properties (attributes and methods) common to a set of objects. It also allows the creation of objects that have these properties through a process named instantiation. The classes of our system have been divided into three

categories:

- the entities (data): place, period, document, object
- the internal workers: site, database
- the external workers or "interface workers": user, support (administrator)

To sum up, a class consists of attributes, methods and an instantiation process. The attributes can be considered as the columns of the tables of a database or as the nodes of an XML file. They are for instance the metadata about the entities. The methods ensue from the processes of the VRE that we have identified previously. They are what the user can do and what can be done on the entities. The example of the class "Document" with one of its sub-classes "3D Model" is given in Fig. 1. A sub-class inherits the attributes and the methods of the main class and adds some extensions.

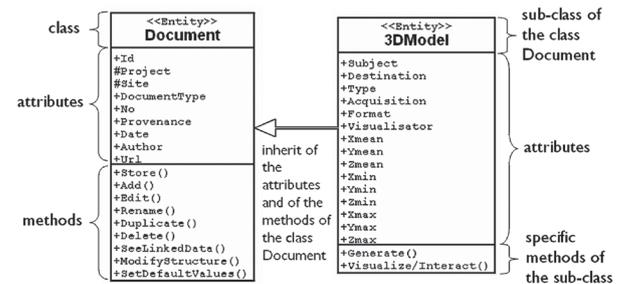


Fig. 1. Class "Document" with one of its sub-classes "3D Model".

The following interface types necessary to access the information managed by the VRE have been defined:

- list (catalogue of the data)
- thematic (by places and periods)
- interactive (2D and 3D)
- views (creation of table views, display of data corpus)
- search (by data types, keywords, images)
- generation (combination of elements selected in diverse graphs or models for visualising the synthesis of 2D maps or 3D models)

This allows representation of the global diagram of the classes of the VRE, also showing their diverse interfaces (Fig. 2). This schema represents the structure of the VRE for archaeological data management that we have developed. It is flexible and allows modifications to add new functionalities to the system. For example, new classes or sub-

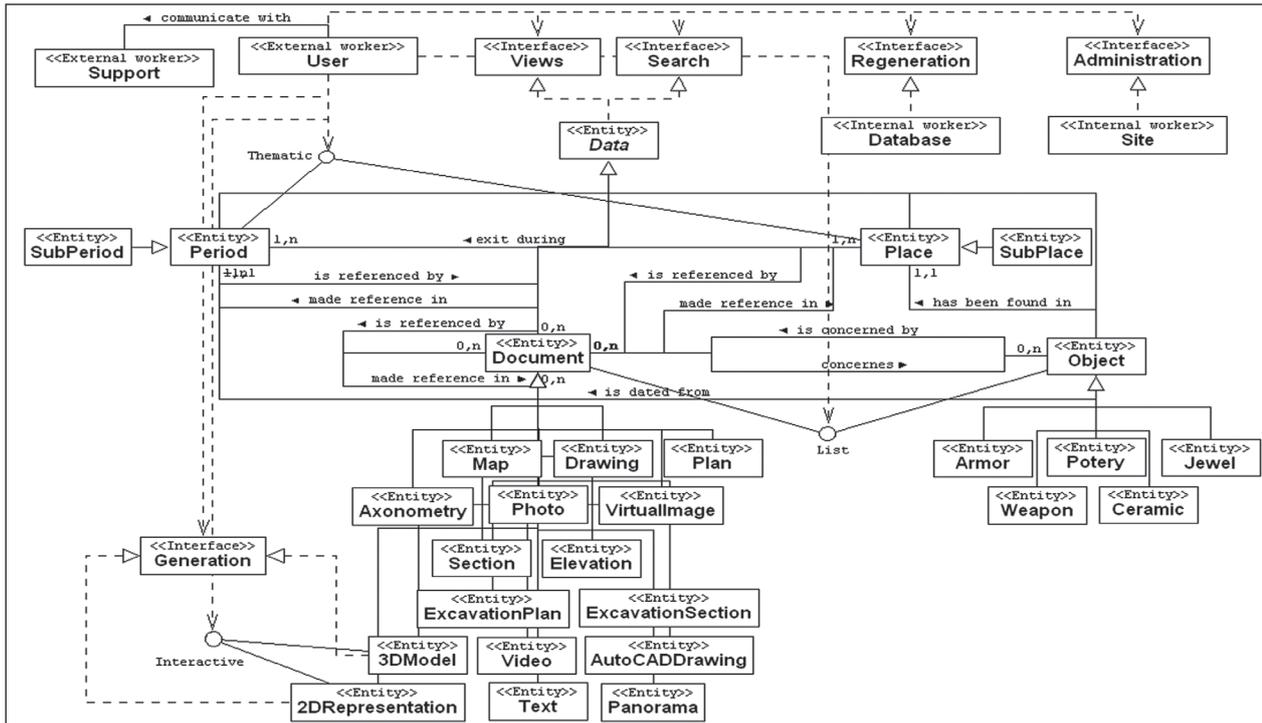


Fig. 2. Global structure of the information system developed.

classes of the already existing entities can be created. As shown in the diagram, the system permits the management of very different kinds of documents and archaeological objects. The types given here are examples. We can imagine managing documents or objects of any nature. Likewise, the proposed interfaces answers the needs of the archaeologists recognised before. However they can be completed by others to offer new possibilities of visualization or interpretation of the data. These interfaces are seen in Fig. 3 (menus on the left).

Finally, we will give an example of the functioning of the system that explains the use of 3D models and 2D maps as interfaces to access the data recorded in the VRE.

3D Models as Privileged Interfaces to Reach the Data

There are several types of formats to provide 3D models on the Internet. The most commonly used are VRML (Virtual Reality Modelling Language, the oldest), X3D (eXtensible 3D) and COLLADA (COLLABorative Design Activity). X3D is the successor to VRML, ISO standard for real-time 3D computer graphics that offers the ability to encode the 3D scenes using an XML syntax (according to

the W3C recommendations). COLLADA aims to establish an interchange file format for interactive 3D applications, and defines an open standard XML schema for exchanging digital assets among various graphics software applications. For the simplicity of visualization we have created and displayed our models in VRML, because the plug-in Cortona VRML Client (ParallelGraphics) is more flexible to use (in HTML frames for instance) than X3D plugins. However, to obtain models compliant to the standard of the W3C, the VRML code needs to be rewritten with XML conventions and descriptive elements to convert it to X3D format. (Converters are available). The 3D models included in the VRE have been produced from historical documents (for the models of the past phases of the site) or from surveys (notably laser scanning). The modelling can be done in any software that can export in VRML or X3D (for instance Maya or SketchUp). Processes are then programmed in PHP to make these models interactive, in order to put anchors in the models that allow to click on diverse elements to access data through an URL link. Scripts with "routes" created in JavaScript or VRMLScript ensure that the clicked elements are highlighted permitting for instance to change the colour of the chosen part of the model. Now, the user can navigate freely in the model, zoom in, choose viewpoints, and so on, to see the parts in which he is interested. In addition, he can

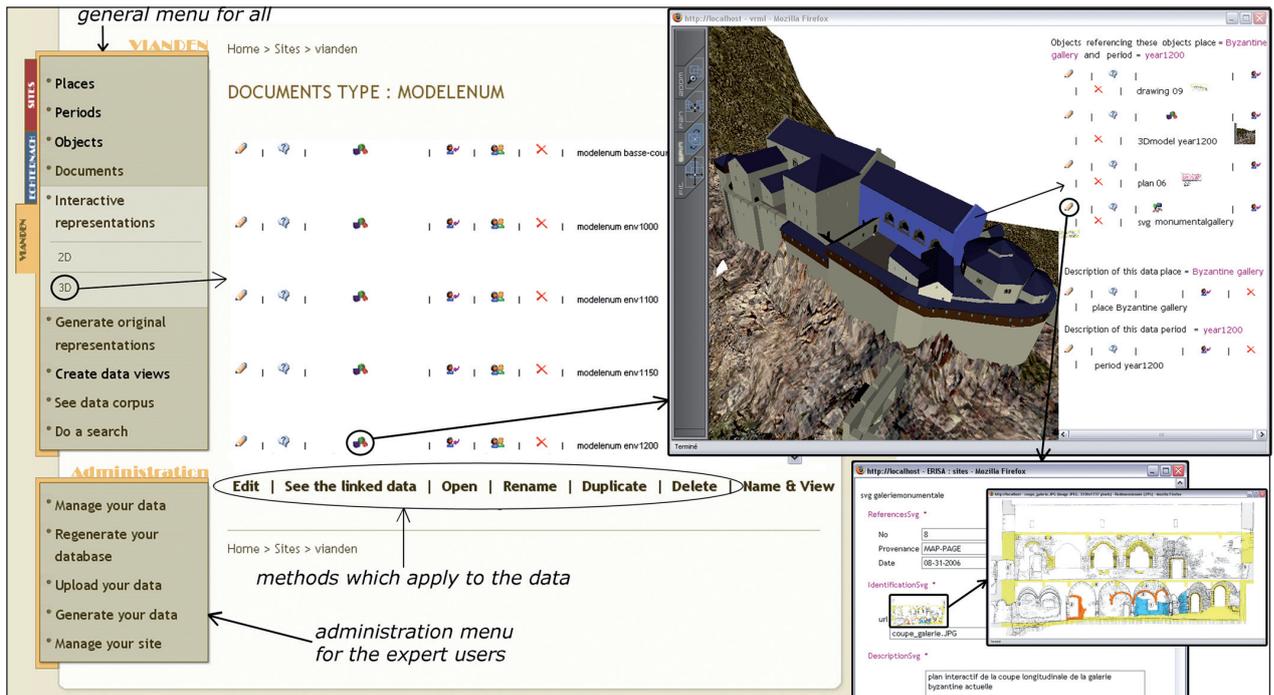


Fig. 3. 3D interactive interface allowing access to the data linked with the chosen place.

click on a place within the modelled site, to access all the documents and objects that have been recorded in the database and that concern the place he has chosen. The queries that are achievable through the clicks on a 3D model are spatial queries, but if we navigate in a historical model (model of the site during a given period), we will also access only the data making reference to both the place chosen and to the period of the model. Spatio-temporal queries are then also available, to find specific information recorded in the VRE through the navigation in the 3D models.

Fig. 3 gives the example of a 3D model corresponding to the historical reconstruction of the Vianden castle during the 1200s. It has been done by the MAP-CRAI laboratory of Nancy (France). This model is mainly accessible through the “Open” button available on the interface. On this model, a place called “Byzantine gallery” can be seen and clicked on. This example shows the possibility of a query on a combination of period and place. First click on the place “Byzantine gallery” on the model of the year 1200 which gives the relevant documents referencing this place and this period simultaneously. Afterwards, these documents can be edited or manipulated. This then allows the updating or modification of the data directly from their 3D representations.

A similar procedure is available to access the information recorded in the VRE through 2D representations. The system allows the user to examine deeply and to interact with 2D maps generated in the format SVG, which is the XML formulation of 2D vector graphics. The possibility to create 2D interfaces is useful to complete the 3D interfaces, because often archaeologists are more used to working on 2D representations than on 3D models. Therefore the proposed VRE gives the possibility to create and to explore both 2D interactive graphics and 3D interactive models, while permitting diverse visualizations and multiple types of navigation through the information.

Conclusion

Having established our propositions for a system dedicated to the online management and dissemination of datasets based on archaeological site documentation and reconstruction, we created a conceptual model of an appropriate Virtual Research Environment. This modelling allows us to see in a generic way how the VRE works and how it is possible to implement it on different platforms. The essential point in this statement is the listing of the needs of the different users to whom the VRE is dedicated, and the processes that were carried out in the system to address their needs. Thus, the Web

information system described in this paper allows to record, present and query data of any Cultural Heritage site. This VRE has been created to offer solutions to site managers, while avoiding the need for them to be software-driven in their conservation and communication work. The full XML choice for textual and graphical representations permits relevant interactions. The use of 2D graphics and 3D models as user-interfaces to the data permits the linking of purely documentary data and metadata to geometric representations. We have connected very different types of data to emphasize new research possibilities and new information exchanges between diverse sites for instance, to be able to draw conclusions by cross-check. Moreover, the data is available through the Internet which is not only a step towards visualization but also towards innovative and interactive communication. Our final aim is to create a simple and widely accessible tool for all the site managers, who wish to be able to efficiently manage the quantity of data produced, while representing it through the use of VRE which can act simultaneously as a virtual storefront for the communication and the e-publication of their findings.

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