The ARANO SDI. A spatial data infrastructure for the rock art of Northeast Africa

Introduction

The work discusses the concept of using a spatial data infrastructure (SDI) as a digital information system (IS) appropriate for sharing archaeological information between different research groups. SDIs situate such groups within the same cooperative framework. The methodology employed in the construction of an operational example, the ARANO SDI, is also discussed. The potential of SDIs in the development of ISs covering archaeological heritage is highlighted against the backdrop of the digital divide separating the rich North and the poor South (Ramonet 1996, 2004)[1].

Within the framework of digital information and communications technology, an IS should reflect as reliably as possible the reality it attempts to describe (Fig. 1). However, in practice it can go no further than the modelling of more or less rich and exhaustive conceptual schemes within the domain of the data described (ontology in the information context). Many facets of reality remain outside an IS, and attempts to incorporate them would only lead to the system approaching the size and complexity of reality itself, rendering it unmanageable (as unmanageable, for example, as the maps made by the cartographers of the Empire imagined by Jorge Luis Borges, which coincided completely with reality, Borges 2005: 119).

An IS is generally composed of data and actions involving these data – analogous to the nouns and verbs of language. The different ways of conjugating these verbs in order to act on these nouns are known as paradigms of digital thought. The ideas organised by the nouns are data metamodels. Nouns and verbs, data and actions, are interrelated via different architectures. Simplifying to the maximum, a trinitarian idea of each part of an IS can be adopted (Table 1). The development of data metamodels was linked to the appearance of different digital thought paradigms. In the 1960s, transactional architectures accessed hierarchically organised data via

[1] One of the aims of the doctoral thesis *DEL PANEL A LA HEGEMONÍA. Nuevas teorías y tecnologías para el arte rupestre del Noreste de África* (Fraguas Bravo 2007) was the creation of the first unified body of rock art of the selected macroregion that was easy to use and freely accessible by all researchers involved in the study of this archaeological heritage. The context in which this work was undertaken conditioned the work itself and influenced the perspectives from which it was approached. The granting of a pre-doctoral grant to the *Departamento de Prehistoria de la Universidad Complutense de Madrid* required the study of the recent prehistory of the Blue Nile area, home to some of the rock art studied. Other grants and work visits to the laboratories of the *Consejo Superior de Investigaciones Científicas* (CSIC) allowed knowledge of information systems to be applied to landscape archaeology, an area of study undertaken by the *Grupo de Investigación en Arqueología Prehistórica y Social* of the CSIC. This work was undertaken at the old Digital Imaging and Sensing Laboratory of the *Dept. de Prehistoria* and at the facilities of the new Landscape Archaeology and Sensing Laboratory of the *Centro de Ciencias Humanas y Sociales*.

'*Goto*' languages (Dijkstra 1995 [1968]). In the 1990s client-server architectures appeared that inter-related relational databases largely via structured-procedural languages (Dijkstra 1995 [1968]; Kernighan 1978; Tanenbaum 1990). Currently there is a movement towards navigational architectures involving many clients and servers inter-relating semi-structured databases via object-oriented languages (Beck and Cunningham 1989; Rubin 1992; Booch 1994; Fraguas Bravo 1994; Quirós Casado 1994; Fraguas Bravo 1997; González Pérez 1999).

2. Digital thought, data metamodels and inter-relational architectures

Nonetheless, there is no single line that necessarily links one paradigm of digital thought to a data metamodel and inter-relational architecture. For example, Lisp, which was formulated in 1956-58 and was one of the first high level languages, followed the structured-procedural paradigm and was oriented towards lists. Yet the current extensible stylesheet languages (XSL) XPath and XSLT are also oriented towards lists. It would seem that there is nothing new under the sun.

Digital thought paradigm	Data metamodel	Inter-relational architectures
'*Goto*'	Hierarchical or networked	Transactional
Structured-procedural	Relational	Client-server
Object-oriented	Semi-structured	Navigational

Table 1

The '*Goto*' paradigm is characterised by absolute jumps in the execution flow, and can still be useful for small programs with only a few hundred lines of code. The structured-procedural paradigm emphasises the actions to be performed. The object-oriented paradigm begins to resemble human thought, leaving the flow of the program to the interaction between objects that encapsulate attributes and methods; these methods are employed to undertake actions that make use of these attributes. A good example of the hierarchical metamodel is the directory-file tree of Unix-Linux or DOS-Windows. The relational metamodel is based on the theory of mathematical sets and predicate logic. This model organises data as file tuples that in turn are divided into columns. The semi-structured metamodel allows computers to adapt to information rather than the other way around, as occurs in the relational metamodel. In the transitional architecture setting, computer terminals request, via a transaction, data from the custodian system which undertakes the entire extraction as well as the preparation of the data. In the client-server architectural setting, however, the roles of the client (data processor) and server (data provider) are separate. In the navigational setting several clients can consume information from several servers, process it, and provide it to other users. Good example of this are the so-called *Mashups* in which the work performed by a team is distributed around the world (or at least the digital world) and can be equally shared.

The body of rock art mentioned above was organised as an SDI based on the object-oriented and structured-procedural technological paradigms, semi-structured databases, and navigational client-server architecture. The pillars of an SDI are information, technology, human resources and legislation (Guerrero, I. personal communication). All are important, but this work concentrates primarily on technological aspects. Technologically speaking, an SDI is a service-oriented architecture

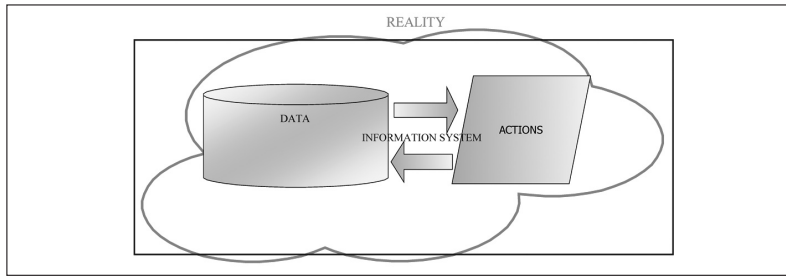

Fig. 1 – Diagram showing the overlap between reality and information systems.

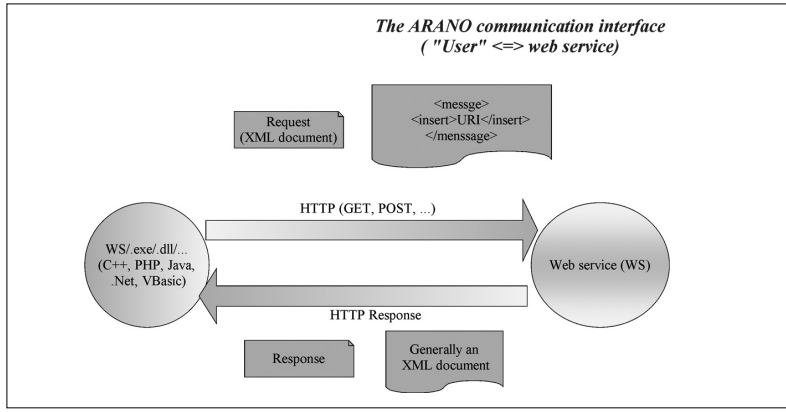

Fig. 2 – The ARANO communication interface.

(Muro Medrano 2006) - a web application. Colloquially, an SDI could be known as an interoperative Geographic Information System (GIS) on the Internet. Meeting standards regarding the metatagging of information and public protocols allowing access and data consumption (either by humans or machines) facilitates the interoperability of an SDI (Fig. 2). Metatags basically consist of profusely describing the different data files, for which an international standard exists: ISO 19115, *Dublin Core Metadata Initiative* DCMDI[2]. The core of an SDI is necessarily supported by agreements such as the SDI Africa Initiative, which is backed by the *Economic Commission for Africa* (ECA), the *Global Spatial Data Infrastructure Association* (GSDI) and EIS-Africa, and which enjoys the collaboration of the *International Institute for Geoinformation Science and Earth Observation* (ITC)[3].

[2] Given the complexity of these standards, the *Núcleo Español de Metadatos* (NEM 1.0) was developed for Spain as a minimum series of required metadata, a subset of the ISO 19115. Different utilities exist for the generation of metadata (such as *CatMDEdit*, which is in the public domain) that are adapted for use with the complete ISO standard or the NEM subset.

[3] Another example is the agreement between the European parliament: INSPIRE (*Infrastructure for Spatial Information in Europe*). This initiative of the European Commission materialised in the directive 2007/2/CE.

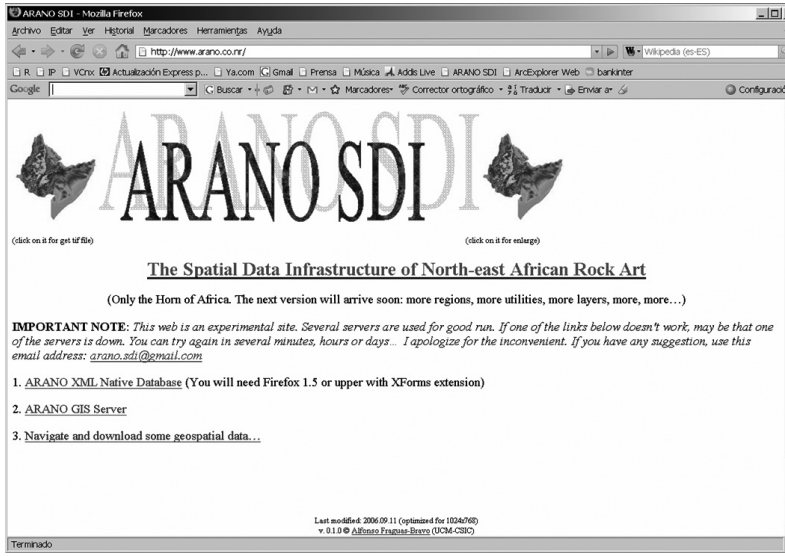

Fig. 3 – The home page of ARANO geoportal.

Given the interest of this work in combating the inequalities of the 20:80 society (the world's rich 20% consume 80% of its resources), the SDI proposed is available as Free Software. Further, given that one of the convictions behind this work is that the collaborative rather than the individualist model of technological development is richer in terms of the advances that can be made for humanity as a whole, the functional architecture of the proposed IS is designed so that information can be distributed over multiple machines around the world, thus fortifying collaboration between different research centres. The different research groups could provide content of different types, such as texts, photographs, services, satellite images etc., allowing teams in poorer countries to enjoy the full technological potential already acquired by rich nations, while bringing researchers in richer countries closer to the African rock art sites being studied by local teams. The key to sharing is the existence of public protocols for access to the information stored.

The technical platform for the proposed SDI is the Internet. Uniform resource identifiers (URIs), chains that unequivocally identify network resources, can localise either data or programs. Access can be gained via URIs to data and services that consume data. Put simply, different services and data are located behind URIs. An SDI can incorporate services that use a web server with applications designed to facilitate the provision of other services, a geographical server providing different layers of geographical data, and a native XML database motor. Since URIs are occasionally localizers of universal resource locators (URLs), data can sometimes be consumed by thin clients such as web browsers. For example, the URI and URL of the proposed SDI is: http://www.arano.co.nr/.

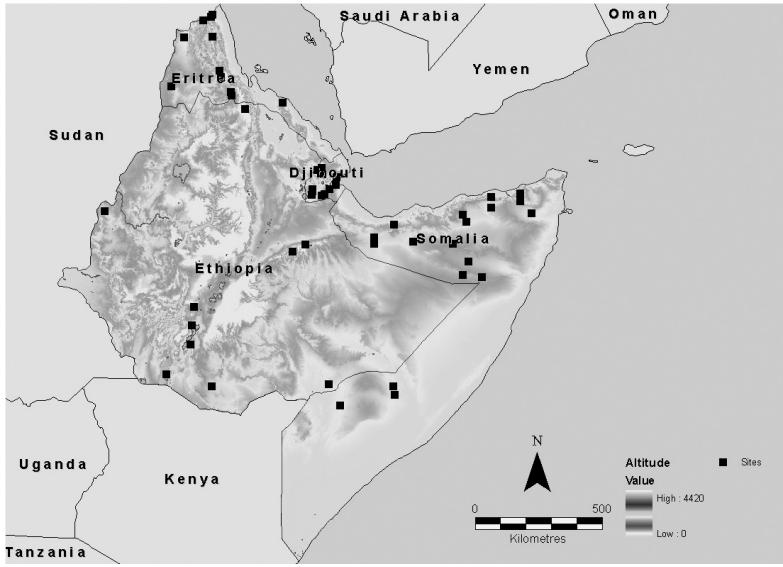

Fig. 4 – Distribution map of the Horn of Africa rock art.

3. The rock art of the Horn of Africa: digital corpus

ARANO SDI aspires to become the SDI holding information on the location of Northeast African rock art (Fig. 3). Currently, the body of information available corresponds to 203 sites in the Horn of Africa, the easternmost area of the geographical region contemplated (Fig. 4). The majority of the sites in this area contain representations of bovids (Breuil 1934; Brandt and Carder 1987; Joussaume 1995; Bouakaze-Khan 2002; Fraguas Bravo 2007), probably domesticated (Fig. 5). None of these paintings have been absolutely dated but they are conventionally situated within the first three millennia BC.

Currently, the IS is formed by two large blocks: 1) consultation services and the updating of a native XML database that codifies the information for each site using AranoML (an XML modelling language); 2) services for accessing different geodata (e.g., a layer of points showing the exact sites of rock art) following the protocols of the *Open Geospatial Consortium* (OGC): *Web Map Service* (WMS) to obtain maps, *Web Feature Service* (WFS) for vectorial data, and *Web Coverage Service* (WCS) for raster data for the different information covers held by the ARANO server.

The functional architecture of ARANO (Fig. 6) is based on series of URIs that locate documents pertaining to each archaeological site (using the language AranoML), different images of the rock art, services that allow users to interact with these files, and WFS, WCS and/or WMS that allow the use of geodata. All these URIs refer to URLs currently held by a single physical server, but there is no technological reason why they should not be held on different servers.

Fig. 5 – Paintings in the shelter of the Geel (Somalia) (Gutherz *et al.* 2003: fig.5).

Different types of software were used to implement the ARANO SDI, including the *Apache Tomcat* server program and the web development framework *Apache Cocoon*, on which is deployed *Arano-catalog* (which provides web update services and consults the rock art site database), *Arano-local* (a web application that allows human users to interact with these web services), and the geographical server program *Geoserver*. *Apache Cocoon* is an application support structure that focuses on the publication of XML and XSLT files; it is written in Java (Fig. 7).

The future development of the proposed IS includes its presentation to researchers in this field, as well as to those who might be interested in it as a means of cataloguing new sites; an international conference is being organised with this end in mind. From a purely technological point of view, the information available is being switched to a native XML (eXist) database.

Conclusions

In conclusion, the use of Free Software and Open Source in the design and implementation of the ARANO SDI, and adhesion to the international standards governed by the OGC, facilitate access by poorer countries to geo-referenced information. The conclusions of the *AfricaGIS2005* conference (Tshwane, South Africa) recognise the opportunity provided by geospatial information for the development of Africa (*Conference Recommendations* 2005). Certainly, the dissemination of knowledge regard-

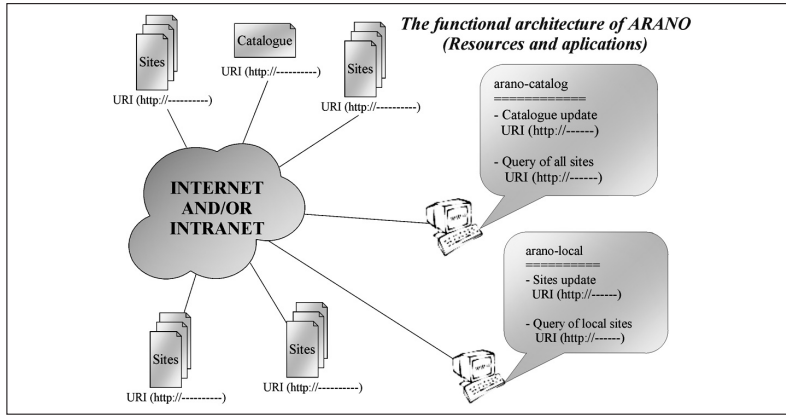

Fig. 6 – The functional architecture of ARANO.

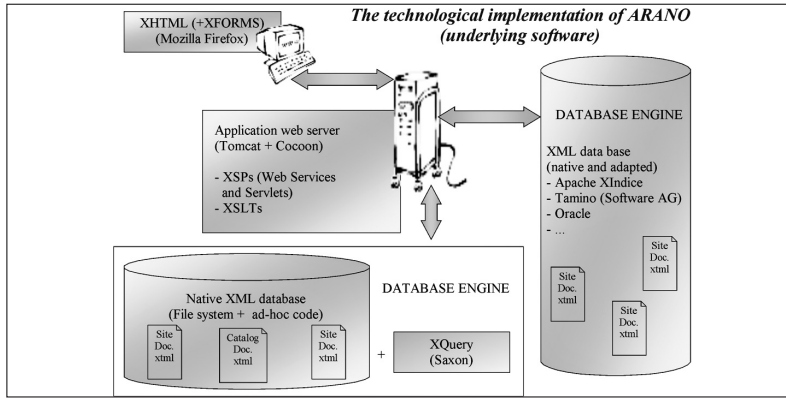

Fig. 7 – The technological implementation of ARANO.

ing cultural heritage should be a right in the intellectual development of this continent. The implantation of SDIs such as ARANO for other archaeologically studied areas and periods would facilitate further access to information and better distributed research and collaboration, providing an opportunity for more egalitarian participation in the generation of knowledge by countries with unequal economic resources.

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Alfonso Fraguas Bravo
Instituto de Historia
Centro de Ciencias Humanas y Sociales - CSIC
afraguas@ih.csic.es

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Methodological proposals for Near Eastern Archaeology. Tell Mozan (Urkesh) and Çatalhöyük: comparison of two complementary experiments, from planning to publication

Introduction

Near Eastern Archaeology currently presents a complex methodological outline, both from a conceptual point of view as well as a technical one. We can identify two prevalent trends: the first one has been developed around the European culture of the "historical-contextual" school, the second one is a kind of "anthropological" approach born from the American tradition. Both have the merit of having produced over the years many different experiments and results of considerable methodological impact (Matthews 2003).

However, we should point out the fact that, except for a few cases, the traditional field literature, in particular that concerning excavation reports, tends to leave out the speculative dimension which is the base of the strategy that precedes the work itself. Archaeologists are not always effective in identifying the informative potential of their excavations, especially where the web edition is concerned. This fact calls attention to the problem of the value of our subject on a social level as well as an academic one.

This paper offers a comparison and a critical essay about two archaeological experiments which were particularly innovative in relation to systematic research and publication of the results: the Tell Mozan (Urkesh) project, in north-eastern Syria, and the Çatalhöyük project, in the south of Turkey. These two cases are interesting because they represent complementary methods and results and offer us an opportunity to review the differences between scientific and popular publications which are not always held in due consideration, especially in light of the opportunities deriving from the use of the open-source platform and the presence of new web sites dedicated to Near Eastern archaeology.

Tell Mozan (Urkesh): the "grammatical" principle in the data processing system called *Urkesh Global Record* (*UGR*) and its real time publication

Tell Mozan is identified as the ancient city of Urkesh; it was occupied starting in the Halaf period and reached its greatest moment of prosperity during the second half of the III millennium (2350-2100 BC). Since 1984 the site has been excavated by the University of California under Buccelati's direction.

The strategy presupposes a scholarly organization of data. The conceptual approach has been developed around the principle that archaeological data are similar to grammatical elements, therefore they must be constructed on a grammatical model. This is useful not only for understanding them in their individual components as a static identity in the ground, but also in their mutual relationships as dynamic elements of

deposition. This "atomistic" conception presupposes that each element must be documented after being observed the first time using a set of pre-defined parameters.

There is a considerable difference between this kind of application of grammatical categories and the use of a codification system: only the first one allows us to acquire a correct understanding of a single element in the light of its context and in relationship with all the other elements that are related with it (Buccellati 2006, *pro manuscript*).

This method has brought about the creation of a formal management system called *Urkesh Global Record*, based on the use of a common vocabulary which is shared by all the members of the mission. In the field, this means that each observation needs to be registered physically using pre-printed forms according to parameters defined by the application of the model of the grammatical categories of reference. Afterwards, the work in the lab consists of re-writing all the existing traditional paper format documentation in the digital format of an ASCII program (currently some commercial programs like *Excel* and *Note Tab Pro* are being used), and then saving it in the server used for the final on-line data entry. Each file must include:

– the excavation area;
– the current data, when it was entered into the system and the initials of the person who acquired the documentation on the field;
– a short definition of its contents;
– the extension of the file.

In this way the document acquires a level of transparency that makes it possible for the document to be found at any time and traced through all the fundamental stages it has crossed during the long process of registration, including the various authors and their observations.

The final result is the creation of a *UGR* browser edition composed of a central page of work with two lateral columns of different colours; the left column has been created to facilitate access to the archaeological information in a traditional narrative format and the right one gives all the grammatical instruments of the system needed to enter the primary archaeological documentation, like that produced in Tell Mozan (Fig. 1).

For example, if we click on the individual constituent "*feature*", the web page will show us the whole list of *features* which have been entered in the chosen area, afterwards we can select one of them and the system will give us not only the documentation about our *feature* as a single element, with all its qualitative and quantitative proprieties, but also the hyperlinks in relationship with all the other components (Fig. 2).

For each constituent we have all the information about its specific definition created during the first observation in the field; the picture made *in situ* that best represents its characteristics; a brief description of it; the data concerning its spatial location created by the use of the direct survey, and also its temporal deposition, acquired with the use of Harris matrix.

One of the most important aspects of the *UGR* is the possibility it offers to implement it in real time, i.e., while the excavation is being conducted: this represents a conceptual and practical revolution in terms of archaeological publication, because it

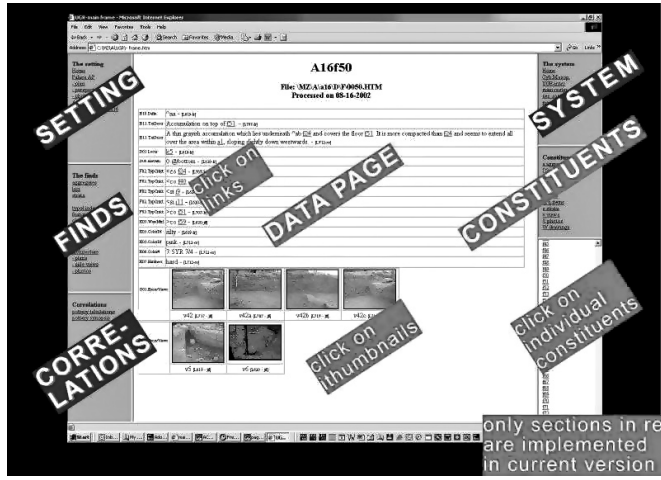

Fig. 1 – The *Urkesh Global Record* browser edition: the general web page structure.

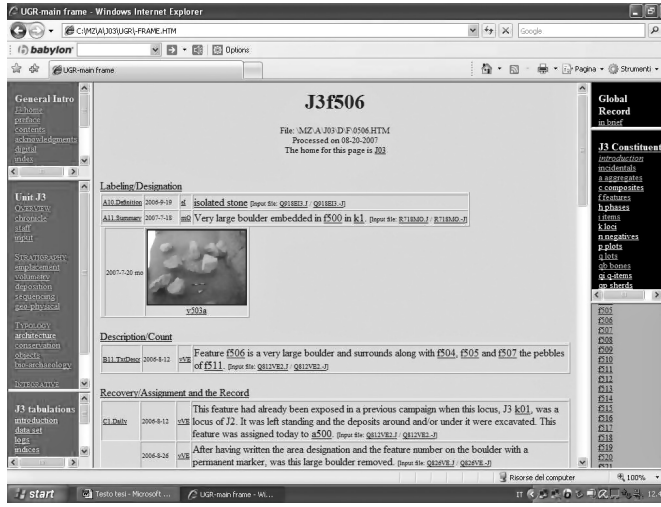

Fig. 2 – An example of browsing in the work page generated by the *Urkesh Global Record*.

permits to produce a correct and immediate documentation which is ready for use; it also eliminates the traditional academic dichotomy between primary documentation (preliminary reports) and the final one (final narrative interpretation), as well as the logistic and economic problems connected to the traditional paper format.

The Tell Mozan web site is both an exhaustive instrument which allows specialists to access complete archaeological documentation, as well as an easy vehicle of communication to reach the wider public, thus demonstrating that these different types of users are not incompatible.

This narrative expansion produces two very positive effects: the first one consists in the possibility of updating the contents in any moment, without costs; the second one, is the dynamism by which people can move within these two kinds of typologies, from the excavation reports to the site presentation, based on the their particular study requirements.

The case of Çatalhöyük: the "reflexive-multivocal" method from the point of view of the database management system and multimedia publication

The archaeological site of Çatalhöyük is one of the most ancient sites in the Near East, with a Neolithic occupation which begins 7400 BC. Its particular combination of customs is evidence of a strong symbolic expression of the community which inhabited it, and this fact has directed research to the ethno-anthropological field. The particular nature of the site can explain the success of the Post-Processual theories, which is the main interest of Ian Hodder, excavation director for the University of Cambridge since 1996. His approach is totally different from the first one we have discussed: in this case we can recognize a relativistic data vision, with a contextual point of view which insists on the fluidity of the archaeological interpretation, precisely because the past is considered as a product of the present.

Based on these principles, synthesized into Hodder's *motto* «Always momentary, fluid and flexible» (Hodder 1997), the *höyük* is contemporarily excavated by different international teams of archaeologists, each of which has the opportunity to put into practice its personal method based on their various backgrounds, which differ as much for the theoretical-intellectual traditions as for the direct experiences on the field.

From a practical point of view, the Çatalhöyük experiment presents a very problematic exercise in terms of internal structure of the data and their general availability: when we decide to adopt a complete decentralization of the decision-making process, the concrete problem is the way to harmonize a similar quantity of different data into a single archive system. Without a shared language, in fact, most of the data end up fragmented in a chain of different files that is never able to reflect the correct stratigraphic and interpretative excavation process, nor does it allow the implementation and correction of the data themselves.

For this reason they have opted for the use of a common database, even if the first model presented a series of inconsistencies in systems, applications and platforms, because of the diversity of meanings used by the specialists in the various fields. The final database now in use is a relational model which has finally produced a correct re-configuration of the different data, with a form of common access. Like all databases, this one also has precise requirements of fixity and codification. The advantages it currently offers on a practical level are exactly the same as those that every other computer archive can give us: the possibility of making a rapid and up-to-date search on all aspects of the excavation (Fig. 3). It should be pointed out that the internal mechanism that characterizes the database is very rigid, so it inhibits a truly flexible and polysemic functioning, and it does not reflect the conceptual and technical development of the stratigraphic excavation.

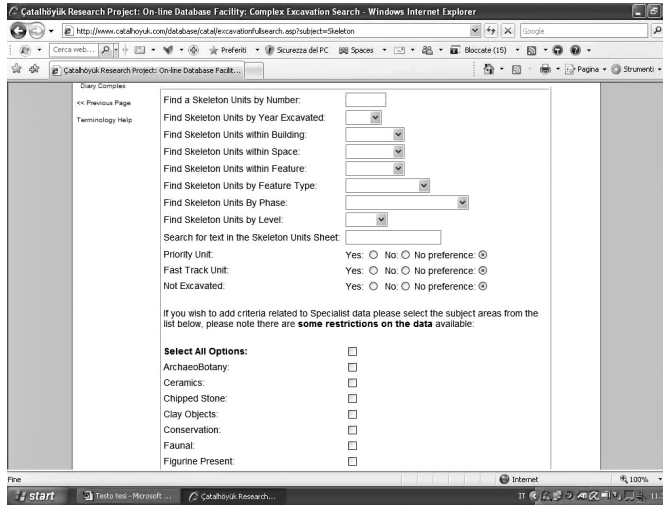

Fig. 3 – An example of interface for the advanced search in the Çatalhöyük on-line database.

As in the case of Tell Mozan, the documentation here is also accessible on-line, almost in real time. The modalities are clearly different, because they suffer from the effects of the problems previously described. In the on-line database, directly available on the Çatalhöyük web site, the work appears juxtaposed instead of organically linked, so that each area of reference is disconnected from the others because an evident dishomogeneity in the languages of the documentation and presentation of the results persists.

The primary results for Çatalhöyük have been achieved by the application of the "multivocal" approach to the socio-anthropological field of study, which has produced a remarkable impact on the way the figure of the archaeologist and his fields of expertise are being considered. This popularizing of archaeological subjects makes use of some exceptionally innovative means, like the use of 3D animation, the creation of an echo-museum *in situ*; and collaboration with a group of graphic designers to create field documentation which is both technical and artistic.

A critical comparison: advantages, limits and some alternative proposals

The comparison of these two methodological experiences encourages us to postulate some proposals which could be useful in overcoming the limitations described for each case and, if possible, in obtaining advantages by combining their different strengths.

A) On a theoretical level: in the case of Tell Mozan the method reveals a clear semiotic impression which represents a valid alternative both to the aseptic rationalism generated by the Processualism, as well as the post-modernist positions which would contrast it with an equally aseptic intellectual relativism.

The strategy is a result of constant feedback between the evidence observed in the ground and the formalization of the grammatical categories used to register them. These should not be interpreted in a deterministic way because they are susceptible to alterations resulting from objective needs of documentation. In light of this, the grammatical instrument makes the entire range of the observed phenomena accessible, from their variants to their variables, and gives us a series of parameters which arer very useful in adapting our strategy to a series of heterogeneous situations. Grammatical data processing helps show us the complete documentation process, it enables us to return to the stratigraphic chain and to the archaeologist's work, and it makes us aware of what has been recorded and published.

What seems to represent a diametrically opposed point of view is the method applied by Hodder during the Çatalhöyük excavation: in this case the approach is typically Post-Processual and contextual, almost affirming the impossibility to acquire a real knowledge of the past, because it is perceived not only as dependent on the archaeological context of discovery, but also on the social-cultural context in which the archaeologist is working in the present (Hodder 1986).

In this case we must object that the decentralization of decision-making can often lead not only to the absence of a rigorous criterion during the strategic operations, but also to a kind of refusal in terms of acknowledgement of the personal responsibility at the moment of the final interpretation, so the theory of "flexibility at all costs" runs the risk of generating a series of disconnected entities of documentation that are very difficult to manage.

B) On a practical level: in the case of Çatalhöyük, it should be pointed out that the potential of a database applied to archaeological documentation has been overestimated, thus creating some unfulfilled expectations. When a database keeps its primary nature as a data matrix organized into a tabular format, its advantages are limited to bringing a series of logistic functionalities, which are not at all structural, so it does not have a lot to offer on the methodological level; on the contrary, when this tool is re-elaborated implementing complexity and thus conceptual flexibility, it can meet the demands of stratigraphic representation in a very useful way, also in relation to on-line publication as a cognitive instrument.

Though recognizing the value of the *UGR* method, it should be mentioned that this is only now beginning to utilize new ways to popularize Near Eastern Archaeology. During my last study season in Tell Mozan (July-August 2007), I pointed out more than once that almost all of the principal obstacles to the fluid utilization of the system are related to a single cause:

1) When we need to adapt our categories to some kind of new situation, we end up generating an infinite chain of repeated items and redundant data; correction and elimination of this data from the system takes up a lot of precious time for the archaeologist. A large part of these repetitions in a specific web page, each of them with a different file heading for author and data, is generated automatically because each file has to go through a very complex process with many programs and multiple re-writings.

2) In the field of graphic documentation most of the problems derive from a very restrictive use of AUTOCAD: almost all the surveys are direct, without the help of

a total station or any kind of geo-references. The metrical data obtained this way are re-written on the respective digital work pages, and processed in AUTOCAD in a simple script form. Not only is this modality insufficient with regards to the potential that the program can offer to the archaeological documentation, it cannot even give back a detailed and referenced graphic representation.

3) There is an objective difficulty to entering into the *UGR* previous documentation which was produced before the creation of the current system, when the grammatical paradigms were not in use as they are in today's model.

4) The complexity of the system does not allow an immediate understanding of its functioning for people who do not have sufficient familiarity with it.

Most of these problems are not caused by the semiotic approach itself, but by its practical application through the use of inadequate programs, especially if we consider that the traditional ASCII input has stayed the same, at the least with regards to data entry since 1994.

In my opinion this kind of data processing only needs the application of some new technologies, without any alteration of the methodology that inspired it. For example, a valid alternative to be considered would be the use of the markup meta-language XML; in fact, this is preceded by a phase of document recognition in order to organize a model resembling as much as possible the real aspect of its source, coherent with the paradigms we have seen for the grammatical structure, and therefore it is adaptable to the semiotic-linguistic theory applied in Tell Mozan.

Besides these functional and structural advantages, there is another one related to the perspective of long term conservation and fruition of digital memories. While the de-materialization of paper archives has made the development of the informative nature of documents possible, it has at the same time made their long term function as historical memory less perceptible than in the past. These general considerations are more serious when they are attributed to the specific typology of the archaeological archives, because in this case their material number is very small, and they are not saved and reproduced adequately in a sufficient number of servers, with the consequence that they are much more exposed to the risk of definitive data loss.

XML seems to be the best solution in semantic, functional and economic terms, and the most adapted to reflect the particular requirements of transparency and reproducibility of the archaeological data process.

Some other proposals are also needed in the field of image management, which we have seen to be one of the most restrictive. In my opinion, the main problem in this case is the fact that the graphic item is introduced into the documentation with the same criteria as a textual one; in other words, instead of being directly processed into the respective CAD/GIS field, the item is destined to a limitative digitalization through a series of stages from the previously cited commercial programs to a script format readable in CAD. The model which is auto-generated in this way gives us a wrong image of the real archaeological item, because it ignores the detailed parameters that a correct metrical documentation is able to create with respect to the context that surrounds it, so this process is dubious also from an interpretative point of view.

The informative potential of the document has not been fully developed. The elimi-

nation of this practice in favour of an organic and coherent combination of AUTOCAD and GIS could be a positive turning point in terms of quality and significance of the result, because we will be able to interpret it based on perfectly real canons of observation, and we can question it with truly interactive modalities.

C) On a popular level: comparison of these two methods has also shown us different ways to approach the various situations which are related, for different reasons, to the excavation itself. We know that the archaeologist has to relate to the institutional, political and socio-cultural context in which he is working; it is, in fact, in these aspects that the "multivocality" expresses itself best.

In the case of Çatalhöyük, the strategies and the languages used during the different experiments in site representation produced a series of communication modalities never before applied to the archaeological reality, which have been very positive from a functional point of view as well as a cognitive one. In this context, there is room for experiments like a conservation program which is a real form of non-invasive musealization *in situ*; the development of new tools for graphic documentation (like artistic drawings, virtual animation, etc.) more open to a sensorial knowledge of the past; the involvement of local people in the management activities and ethno-anthropological site presentation; the educational programs for adults and children.

All these projects represent a resource with considerable educational value, as well as an opportunity to affirm the value of the archaeological subject also from a social point of view, in terms of public participation in the discovery. Hopefully, experiments like these can also be reproduced in other similar Near Eastern contexts.

Conclusion

The examples we have seen give us two significant messages: the first one, from a methodological point of view, because we must be aware of the importance of programing an archaeological excavation in virtue of its information potential from the very beginning; the second one, on a popular level, to re-think the publication in terms of something new, able to go beyond the limits of the traditional narration in favour of different possibilities of communication.

The transformation from a traditional paper format to a digital one is associated with the consequent reorganization of the original text: this does not mean a standardization of the languages because this perspective, apart from its unlikely realization, would involve a homogenization of the variegated universe of study, nevertheless it can contribute to find some guideline to formulate an understandable web language, which could be an answer for the more substantial archaeological questions, durable and usable on every platform.

In this context, we can cite some interesting examples of archaeological portals dedicated to the Near East which are useful for popularization: for example, the ETANA and OPENCONTEXT projects are two permanent archives which contain, and make available, numerous excavation reports, editions of ancient and modern texts, monographs, dictionaries, trade magazines and various other materials of public domain. This gives the archaeologists the possibility of utilizing an editorial service and of ordering software suitable for their requirements, while

they are being encouraged to publish their excavation reports on-line in real time or seasonally, and at a reasonable costs.

The academic and cultural advantages of these resources are basically three: accelerating the publication of archaeological research making the excavation data available in real time, and making the institutions and the general public aware of the Near Eastern cultural heritage.

From a humanistic point of view, it should be mentioned that these new media have an important impact on the social and public component of the archaeological discipline, in particular in the oriental context, in which it has a primary function of consolidating the natural links between the past and present of the human community which is related to the archaeological site, consciously or not.

The archaeologist can contribute actively to achieving these goals when, within the range of his competence, he takes responsibility for investing economically and intellectually in different resources: from the involvement of the local people, to the development of educational activities and knowledge of the web tools.

Eliana Iorfida
Dipartimento di Scienze dell'Antichità "G. Pasquali"
Università degli Studi di Firenze
eliana.iorfida@libero.it

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Visualising Pozzuoli: digital models for reading imperial architecture

Introduction

With its long tradition of trade contacts with the eastern Mediterranean, coupled with the productivity of Campania, Pozzuoli (*Puteoli*) rapidly became a centre for technical and commercial expertise. It was the principal port of the Capital in the late 3rd and 2nd centuries BC and maintained its function as a port of Rome at least till the 3rd century AD (Frederiksen 1984).

Pozzuoli was also a 'packet port' for travellers to the east and the principal place of arrivals and departures for officials, embassies and ordinary travellers. The inherent dynamism of Pozzuoli is compounded by the drastic landscape changes that have taken place over time, the port being located in an area renowned for its volcanic activity, the most notable of which is the phenomenon known as *bradyseism*.

The research context

This paper forms part of a doctoral research question that has as its primary focus the concept of the Roman townscape and its relevance to ports. Specifically it re-evaluates the concept of the Roman imperial urban image as constructed by the public monuments at Pozzuoli. This concept raises the following questions: as an affluent port town serving a very specific commercial role, how was this singular Imperial image applied to Pozzuoli? Did the constant influx of foreigners contrast with the image of unity that the Emperors wished to project or was it amalgamated into the town's infrastructure? How much of Pozzuoli's townscape was conditioned by the practical needs of a port and how much of it by the desire to assert imperial influence in the area?

The chosen methodological approach towards the idea of imagery is a physical re-creation of the visual themes that will be explored; in this case the prominence, visibility and the monuments' visual impact on incoming vessels and their relationship with other architectural components (such as residential areas) together with the experiences these buildings may have generated on the town's population. Pozzuoli, with its richness in archaeological remains coupled with its unique geological setting, is an ideal case-study.

The following sections shall discuss briefly the two main aspects of the proposed methodology. These are the modelling of the terrain using GIS and the process of recreating volumetrically the monuments using digital technologies.

Recreating the coastal landscape

The Phlegrean Fields constitute an expansive area of relatively small scale and superficial volcanic activity likely representing the remains of a larger volcano,

most of which has been eroded away. The pressures of steam and gas have lead to further formations of lesser craters and short-lived eruptions. The Phlegrean Fields were as famous in antiquity as they are today, for their frequent and impressive geothermic phenomena, associated with volcanic activity. These phenomena are to be found in the form of geothermal springs and fumaroles, the most famous of which is *La Solfatara* (Scherillo 1977).

Another phenomenon which has had the most far reaching consequences on the geography and history of Campania and which is indeed almost unique to the region is the vertical coastal movement known as bradyseism (Scherillo 1977). This involves the relatively rapid rising and sinking of the coastline caused by the pressures of subterranean gas and steam. The intervals between oscillations amount to centuries and the amplitudes as much as several metres (Paget 1968). Although this activity has been detected elsewhere, it is the clearest and most studied in the *Campi Flegrei* (Frederiksen 1984).

Geo-archaeological data now allows us to accurately map the bradyseismic events that occurred in the Phlegrean Fields, at least for the last 2000 years. These have been summarised as follows: *A*) the Roman-era coastline between Pozzuoli and Baia is currently submerged at 10m below sea level. *B*) Geo-morphological data attests to the rise of level of the ground of about 6-7m above sea-level. *C*) The archaeological remains drowned as a result of these movements have been dated from the 1st century BC to the 3rd century AD and were still in use at least till the 4th century AD (Varriale 2004). Further confirmation of these bradyseismic events is the more recent study that took place in Pozzuoli. Christoph Mohrange and Nick Marriner collected fossilised marine organism samples, which were then radiocarbon dated. Various episodes of sea-level changes in Pozzuoli were then identified amounting to a total rise of sea-level of 17m since Roman times (Morhange and Marriner 2006).

The storage and manipulation of terrain data is one of the tasks for which GIS is most frequently used. Elevation data and its derivatives, such as Digital Elevation Models (DEM) have been increasingly adopted as tools for various analytical techniques including the simulation of natural processes such as flooding and erosion (Wheatley and Gillings 2002). Examples used in the field of geological research indicate that DEMs are now commonplace in the study and interpretations of the submerged coastlines and in the monitoring of seismic activity. A GIS database set up to store, process and interpret the seismic data from the Island of Ischia (Cubellis *et al*. 2004) and more recently, a DEM created to identify and interpret the submerged coastline of the Phlegrean Fields Caldera are examples of such work (Aiello 2007).

With these examples at hand, there is thus little need to underline that the recreation of Pozzuoli's original Roman landscape (using a GIS dataset and a DEM) is of primary importance to the development of the research project in order to understand the environment within which the 1st century AD monuments formed part of. Undoubtedly, any proposed method will start with the collection of the various available datasets, including bathymetric data, contour and fossil data, all of which are currently available.

Drawing on the current geological techniques for the modelling of submerged landscapes and with the inclusion of archaeological data, which may also act as an indicator of past geomorphologic changes, the identification and implementation of a methodology may thus be possible.

Visual techniques for the re-creation of monuments

The theory, critique and practice of the idea of visualisation and digital visualisation techniques in archaeology, have long been studied and discussed, particularly in more recent years. There is an increasing corpus of literature dealing with a multitude of aspects in the field archaeological computing amongst which are the transparent methodologies for presenting the past, the impact these methodologies have had on the interpretive process and the dangers of computing techniques potentially dictating archaeological methods (Earl 2006). The realisation and constant critique of such aspects has in turn led to numerous successful applications of computer visualisation techniques to archaeology, many projects of which have been executed carefully and methodically whilst remaining self-aware of the potential caveats (Favro 2006).

Of relevance to this project are the questions asked by Diane Favro such as: what did Romans 'see' when they looked at the city? What visual repertoire did they draw upon (Favro 2006)? Similar questions have also been asked by John Clarke who explores visual representations in the lives of Romans whilst including digital reconstructions to highlight aspects of the visual impacts the location and decoration of monuments would have had on the viewer (Clarke 2003). Virtual reality models allow researchers to simulate the viewing experience, or at least parts of the viewing experience, in scaled environments, considering sequencing, viewing angles and a multitude of other factors such as acoustics light and time (Favro 2006).

This is the reasoning behind the choice of re-creating digitally the 1st century AD monuments of Pozzuoli and the creation of animations as a methodology to generate and perhaps answer the contextual questions that will inevitably arise. The reconstruction has been carried out by gathering the extensive available documentation such as maps, plans and reports on each individual monument. The project then proceeds with a generic volumetric reconstruction of the monuments together with any surrounding architecture, in order to understand their initial spatial relationship. Thereafter, the necessary details are added to the main monuments in order to enhance them photo-realistically. The analysis would then create various views and real-time animations of the possible panoramas and vistas that may have been encountered on sailing into and moving around Pozzuoli.

Questions about commercial need versus imperial patronage would be answered by analysing if it was commercial buildings or imperial monuments that first came into view when entering the port, whether public monuments covered or were covered by commercial buildings, which edifices were most prominent/impressive, which architectural elements were observable only from a particular angle and which buildings could only be encountered when on land.

Software

The project is currently making use of four main, commercially available software packages. The initial digitising of the contours for the terrain model as well as the plans and elevations for the building reconstructions is being undertaken using AutoCAD© 2007 (Autodesk). Any *.dwg* and *.dxf* files that are created are imported into both ArcGIS© 9.1 (ESRI) and 3DStudioMax© 2008 (Autodesk).

The creation of the DEM using the imported contour lines is carried out with the *Spatial Analyst* and *3D Analyst* extensions available in ArcGIS. The plans and elevations that have been digitised in AutoCAD are also imported into Autodesk's 3DS Max whereupon the volumetric reconstruction takes place using the AutoCAD files as guidelines. Considerable use of layers is being made throughout the project as this enables distinction, selection and visualisation of the models through every stage of their creation. The ability to create and import layers between software packages is also proving to be essential for the ease of the current work-flow.

The architectural materials are added using a combination of digital photographs and available pre-defined textures. The landscape recreation software Vue Infinite Xtreme© 6 is designed for the rendering of the natural environments. Detailed natural landscapes with high-resolution terrains and realistic vegetation quickly reach huge polygon counts, Vue is designed to handle billions of polygons with ease and allows for rendering even within 3DS Max.

To conclude, in 1998 G.J. Novitski stated eight reasons for creating digital historical models, only two of which were related to research (Novitski 1998). Nowadays, there has been a considerable shift; digital modelling like all tools both shapes the usage and thinking as well as reflects the current knowledge production. The reactions and criticisms of scholars across disciplines instigate the comparative assessment of methods and literacies. One cannot help but agree with Diane Favro (2006) who succinctly summarises the role of visualisation with the following: «More re-creations [of ancient Rome], regardless of the medium, will convey more interpretations, more states of knowledge and more evaluations, both of the past but of us as scholars. As research on the gaze has shown, the eyes of the beholder not only see, but are seen in turn».

Elizabeth De Gaetano
The University of Southampton
betta.degaetano@gmail.com

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For information visit: http://www.hgis.org.uk/HGIS _ conference/index.htm
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For information visit: http://arheologija.ff.uni-lj.si/aarg/indexAARG.html
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Athens, GR. 15-18 September 2008
For information visit: http://www.cidoc2008.gr/cidoc/site/Home/t _ section
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