

# A GIS tool box for Cultural Heritage. An application on Constantine, Algeria, historical center

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## Abstract

A GIS toolbox, available on the Internet, dedicated to cultural heritage, archaeology and urbanism is proposed in this paper. Dedicated to heterogeneous data visualization, the tool box is designed for the end user, developed with the GeoTools package, an open source Java library for 2D cartographic visualization, JavaView and VRML for the 3D visualization and XML technology (XML schema, X Path and X-Query) in connection with SQL compliant software as MySQL for database access and querying. We present an initial application on the Constantine historical center developed in the framework of an international project with partners from Algeria, Italy and France. After a presentation of the main objectives of the project we'll discuss the tools used, the Internet accessibility and the flexibility of the proposed system.

## Keywords:

GIS, java, XML, open source, 3D visualisation, cartography, urbanism, cultural heritage, archaeology.

## 1. Introduction

We present here a GIS toolbox, developed using a set of free software packages, in order to present several data aspects on a web browser.

In the frame of data management for cultural heritage and archaeology, urbanists, historians, archaeologists are the new users of Geographic Information Systems. As the use of GIS software is not always easy for a layman, we decided to develop a web interface with GIS functionality, that is easy to manipulate, is inexpensive, and is dedicated to the visualization of a set of heterogeneous data linked with geo-referenced data.

The goal was to use free software, have quick access via Internet, 2D and 3D visualization and textual data all linked to one web interface.

The work is divided into two main steps: the data collection and elaboration made by professionals and the consultation step on the Internet. The first step is carried out by computer scientists, architects, urban planners, archaeologists, and photogrammetry experts, using commercial software such as AutocadMap™, Photo-modeler™, etc. The second phase, dedicated to consultation, is designed for the end user.

It's available on the Internet, developed with the GeoTools package, an open source Java library for 2D cartographic visualization, JavaView and VRML for 3D

visualization and XML technology (XML schema, X Path and X-Query) in connection with SQL compliant software such as MySQL for database access and querying.

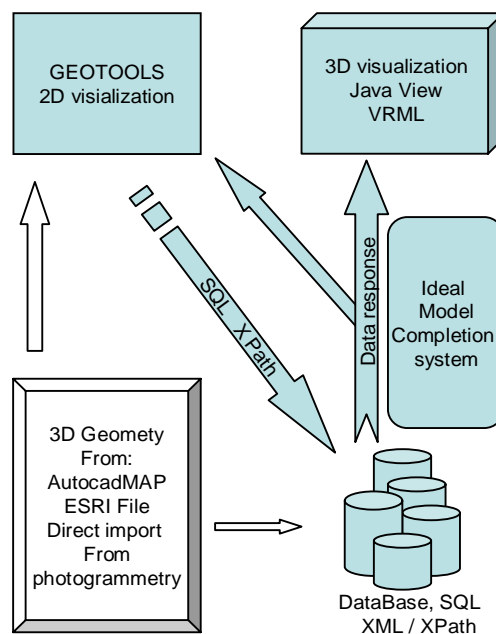


Figure 1: GIS toolbox synoptic view.

The GIS toolbox presented here is dedicated to cultural heritage and archaeology. We present a first application on the Constantine historical center developed in the framework of an international project with partners from Algeria, Italy and France.

## 2. The application to the Constantine historical center

The Master Plan of Medina of Constantine is introduced in a program – in cooperation between Italy and Algeria, begun in May, 2003, promoted by the Ministero degli Esteri Italiano, by the Università di Roma Tre, by the Ministre de L’Habitat et de L’Urbanisme Algerienne and the “Wilaya du Constantine” and with the participation of the French CNRS laboratory MAP. This program

provides a definition for a common project between the two countries, finalized by the recovery and revalorization of the historical patrimony of the ancient city of Constantine, characterized by a very unique morphology of the terrain.

This city is currently heavily degraded, 28% of its buildings are collapsed or abandoned, 18% are in serious condition. The infrastructures, the power grid, the water and sewer systems, are deficient, in contrast with the continued presence of most of the city’s commercial and handcraft activities, and of a few buildings of cultural interest, including some mosques and the Palais du Bey.



**Figure 2:** panoramic view of Constantine.

### 2.1. The project framework

The Master Plan was structured according to a Geographic Information System, based on its cadastral properties, key elements for definition of the data. This system was based on a computerized reference cartography, at 1:500 scale, digitizing the maps on paper, among which are: a map from 1985 (1:1000 scale), the pages of the French Calastre of 1847, a period of occupation and destruction of the old city (1:500 scale), several tourist maps and six aerial photographs, produced in 1998 (1:4000 scale) and used in aerial-photogrammetric reconstruction.

Georeferenciation was performed using the information base whose coordinates was derived from a dwg-format file, the altitudes being deduced from aerial-photogrammetry, provided by the Algerian partners, at 1:2000 scale. The digital base was obtained by comparing the various maps, taking as reference, when still existing today, the elements present in the cadastral map of 1847, the perimeter of the buildings, the geometry of the private courts, and the definition of their properties, assuring maximum reliability and precision of details. Afterward, the modified parts were integrated through

the updating of the maps and the analysis of the aerial-photogrammetric model.



**Figure 3:** map, 1985.



Figure 4: map, 1837.

The geometric base with indications of buildings, roads and level curves constituted the two-dimensional support in order to define the 3D model of the terrain of the entire area, created using the Autodesk 3Dstudio Max 5 software package. The model was then partitioned into sections both horizontal, useful for level curves, and vertical, necessary for profiles of the terrain.

The map of the GIS, created using the Autodesk Map 6 software package, refers to the digitalized and geo-referenced cartographic base, following a structure divided into four levels of analysis, corresponding to the following tables of a database: BATIMENT, PARTCAD, ILOT and SPAZ\_PUB.

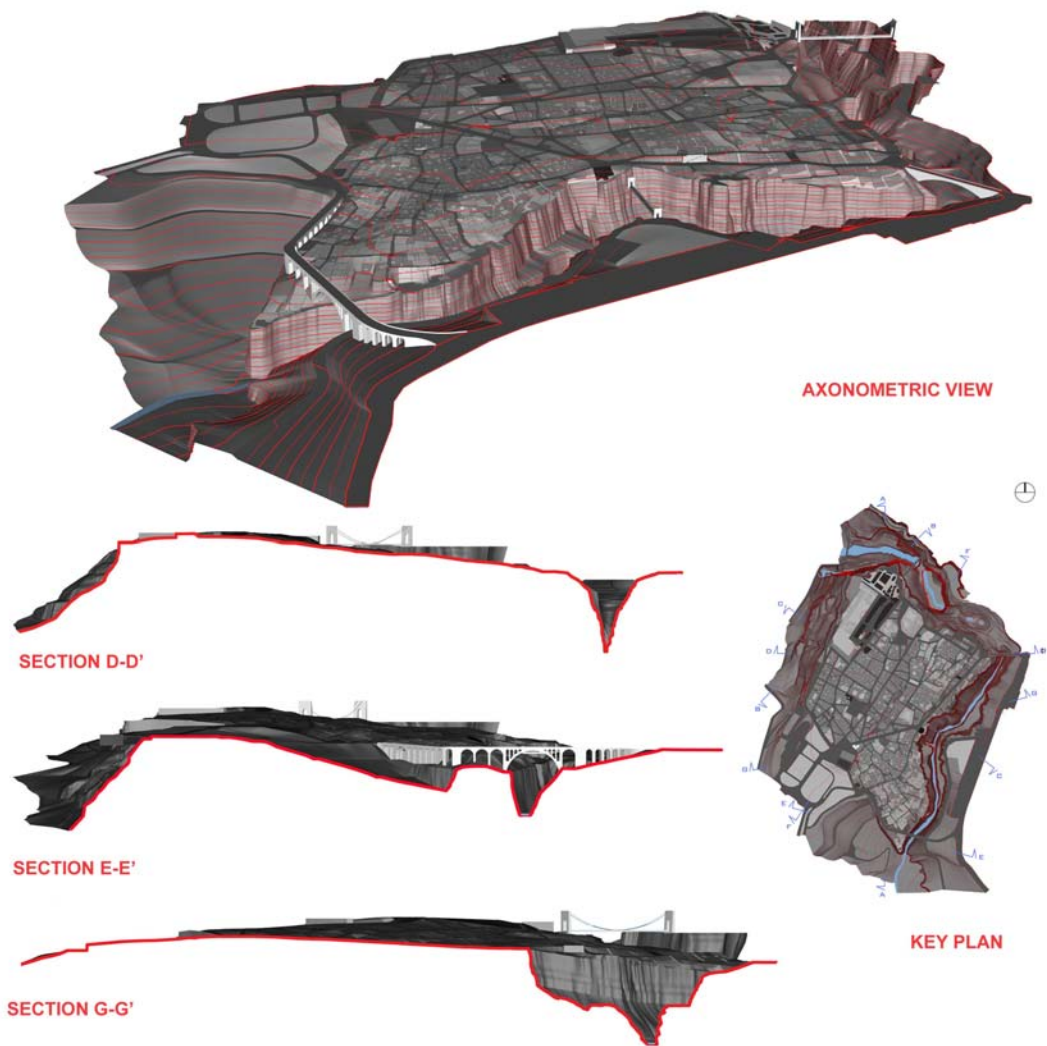
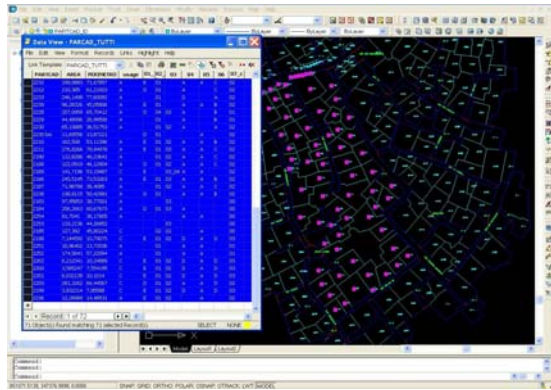


Figure 5: 3D modelling.

For each level, topologies were defined (polygons identified by a centroid and an identification number), to which relevant data was linked in database tables. The principle topology is PARTCAD, for which the perimeters of the cadastral particles are delineated, numbering around 2000, each with an ID for reference; the topology ILOT refers to the blocks, also numbered; SPAZ\_PUB defines public spaces, streets and piazzas, along with their toponyms; and BATIMENT delineates the constructed parts, inside each particle, excluding the courts and free spaces, indicating those which are covered and their height.



**Figure 6:** Cadastral survey.

Each topology is associated with a database table, which has a key field and a series of fields containing data relevant to the chosen element, such as for example designated use, occupancy for a cadastral particle, or density of inhabitants, number of inhabitants per room, and per block. The structure of the elements and of the database linked to them allowed for an overlay to be executed among the various levels/topologies, in order to obtain cross-linked information (for example, it is possible to obtain regarding a given cadastral particle, the block in which it is located, the road or Derb [internal road] that it borders, its area and perimeter). The insertion of statistical data in various fields of the database was performed directly in Autodesk Map, displaying the topology of interest in the data entry.

Once the database was defined, it was possible to obtain elements by generating them directly from the system, through a topological query, that displays the individual values in the fields.

The single, two-dimensional topologies of the cadastral particles of a few sample buildings, were linked to three-dimensional objects, that define the volumetric properties and aspects of the roofing.

These 3D elements were produced through photogrammetric processing of the aerial photographs, using the Photomodeler software package, and an initial 2D

elaboration that describes properties of the roofing (flat, single or double pitch, height of the eaves and of the summit), of a single building



**Figure 7:** table 2.



**Figure 8:** 3D building modelling.

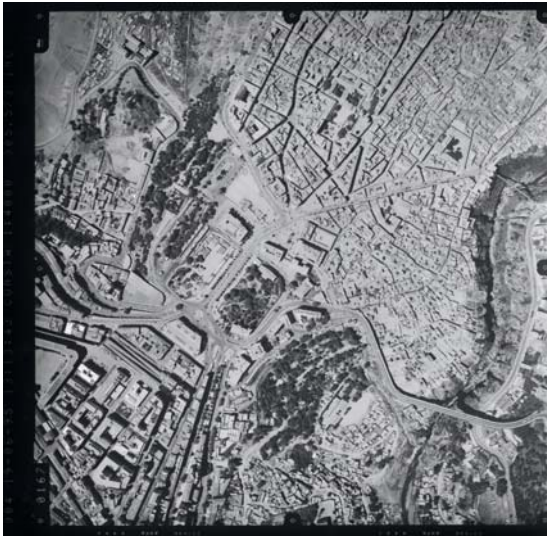


Figure 9: Aerial photography for planimetric data.

### 3. GIS for cultural heritage and archaeology

For many years Geographic Information Systems have become common tools for archaeologists who see in this technology the alliance between the huge amounts of information collected in the field and graphical representation which supports their analysis. The GIS graphical representations most often originate from cartography, that is to say the merging of vectors, images, and symbols into 2D visualization tools. The old culture of chart reading (see Christian Jacob's book on this subject, [15]) is very useful in the use of GIS and probably one of the obstacles in the way of a truly 3D GIS. As a matter of fact, even though representations are not completely realistic, the strength of the GIS is linked to the symbolic cartographic representation of the data offering a synthetic expression of the data analysis. [10,11]

If the 2D representation is sufficient to demonstrate the archaeological work concerning an urban scale or larger, applied to a period for which traces of the elevations do not exist, it is far from being the same when one is studying a building. The need for a 3D representation is then of primary importance and as is a global understanding of the study revolved around that kind of representation. The context of this work concentrates on only one tool, a data management system using XML and SQL, a 2D and 3D visualization system, a 3D measuring tool, and an object modelization of the study area is then set-up.[4,6,7,9]

#### 3.1. XML formalism

From an architectural and urbanistic point of view, we propose the XML data structure to represent the data. This is a convenient way to share data with other applications for two categories of reasons:

- Considering the heterogeneous data to manage, a XML structuring is a good opportunity to manage it within a single document.
- It is then possible to elaborate a request on the whole set of data and write a simple and automatic publication in HTML or PDF.

The XML document structure allows for different kinds of data indexing:

- An intuitive way, by interactive navigation,
- A simple way such as keyword searching,

The second category of reasons is the intrinsic interoperable structure of XML documents. The document structure is described in a separate file that allows the user to search the document and retrieve only the relevant information.

#### 3.2. XML and XML Schema: a language dedicated to structured data

Since the early development stages of the Web, the W3C consortium (<http://WWW.w3c.org/>) has developed many technical specifications for the Web infrastructure as a W3C commitment to promoting interoperability. This means encouraging *universal access* to make the Web accessible to all, *semantic Web* to develop a software environment that permits each user to make the best use of the resources available on the Web and a *Web of Trust*.

Among these efforts, "the XML 1.0 Recommendation (published in February 1998) was the first step towards the next generation Web, allowing each community to design languages that suit their particular needs and integrate them harmoniously into a general infrastructure based on XML" (<http://WWW.w3c.org/Consortium/>) The XML specification (Extensible Markup Language, 2000) describes "a syntax created by subsetting an existing, widely used international text processing standard (Standard Generalized Markup Language, ISO 8879:1986(E) as amended and corrected) for use on the World Wide Web". For this, "XML documents are made up of storage units called *entities*, which contain either parsed or unparsed data. Parsed data is made up of *characters*, some of which form *character data*, and some of which form *markup*. A markup encodes a description of the document's storage layout and its logical structure. XML provides a mechanism to impose constraints on the storage layout and logical structure". The XML language defines the concept of well-formedness and validity: a well-formed document simply respects the XML way of structuring elements whereas valid documents respect some constraints on document structure. ([22, 23, 24, 25])

The XML Schema specification (XML Schema Part 0, Part1, Part 2, 2001) is built atop the solid foundation provided by XML and provides a way of defining in a

separated document (written itself in XML) the structure of entities, their data types, the relationships between these entities and constraints as well. The so-called schema gives thus the conditions for a given document to be declared valid with respect to this schema.

### 3.3. Access to XML information

XML is a good way for information representation because it can manage heterogeneous data and it is very flexible, but access to the information present in a XML file is not trivial. The W3C implemented a solution to address parts of XML documents, which names XPATH and was presented in 1999. XPATH allows navigation through the XML structure of a document by representing it like a tree. We can traverse this tree to reach various parts of the XML document and thus the information which it contains. The principle of XPATH is simple, each part of an XML document has an address which is made up of all markers containing this part, formalized by a specific grammar. This address is called XPATH address. Like XML Schema, XPATH is now a W3C standard and is fully implemented by several applications. To obtain more precise details or examples on how XPATH functions, refer to the site of the W3C.

XPATH provides a means of traversing XML documents but a system of requests, like SQL queries for databases, must also be set up. This system is called XQUERY. XQUERY is the extension of the capacities of a query language like SQL to heterogeneous documents, like XML documents. It is based on the FLWR principle (flower delivery) which is a format of queries: FOR ... LET ... WHERE ... RETURN. The FOR part allows for the joining of documents, like the FOR of SQL. The LET part allows for declarations of variables, and also can be another FLWR query. The WHERE is the equivalent of the SQL WHERE, adapted to the XPATH address. The RETURN is present because XQUERY is a functional language and each query must return a result. With XQUERY, XML has a query language and can be used for data management. Although XQUERY is constantly under development, many applications rely heavily on it and its use does not pose any problems.

## 4. The 2D visualization system

In developing the 2D visualization system, one of primary object libraries that were employed is known as GeoTools.[17] It was originally created at the University of Leeds in 1996, and represents one of the leading, continually evolving open source Java libraries available today for developing GIS applications. It consists of a set of library classes, designed with the concerns of rendering geometrical and geographical data in mind, and it provides a multi-layered system allowing for the creation of geographic objects containing high levels of complexity.

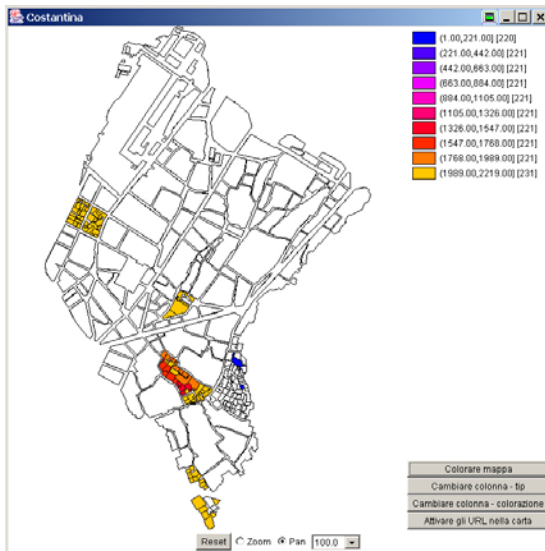
For a quick idea of the kind of structuring it provides, within a given View of the geographic data object currently loaded, there can exist a multitude of Themes, each of which has associated with it one of many possible types of Layers (eg. PolygonLayer, MixedLayer, etc.) each having its own set of capabilities aimed at offering rendering options appropriate to the Layer type in question. Also configurable within each Theme are shading and highlighting tools, which lend themselves to creating map renderings which show features and aspects related to the map, for example quantitative data such as elevation, area, or qualitative data such as names of streets or piazzas. Highlighting tools allow for the user to indicate one or more objects of interest to query or retrieve stored data about. Since, databases that accompany these geographic data objects usually contain multiple tables or columns, another useful map browsing technique we included in our application, which is facilitated by the GeoTools packages, is the ability to view on-the-fly the contents of a given column for a given shape by placing the mouse pointer over it.

The ability to associate with a given geometric form a wide variety of information concerning the underlying site in question, as well as information related to rendering options, permits powerful applications to be created using these tools. Its creation and free distribution, therefore, constitute an added level of capabilities and options available to the those wishing to create geographic visualization software systems. Among the various operations that may be of interest to the researcher who works with documents containing geographic or architectural data objects, of primary importance is the ability to provide accurate and scaled versions of these objects, as well as permitting user interaction with the forms, through query transactions that aim at giving in-detail information concerning a given area within the document.

This querying system can take the form of text based commands directed at, for example, finding all shapes within the document representing the architectural site or geographical location that satisfy a given number of constraints, (eg. find all amphorae whose volume falls within a given range; or find all locations in the site map under examination that have a surface area above some threshold), however, they can also be formulated via direct interaction with the document being visualized, by means of mouse commands executed over the regions of interest. Thus, as the levels and complexity of embedded data tied to these objects grows, the ability to retrieve such information in an intuitive and practical manner is enhanced by the capabilities provided by its immediate retrieval.

Furthermore, such information need not reside locally, but instead can be distributed and accessible using Uniform Resource Locators (URL) whose contents are

viewed in Internet browsers, which permits extended quantities of documentation to be attributed to the map, often in ad hoc timeframes. Such enhanced and facilitated interaction with these geometric data objects, renders as a consequence, the over-reaching task of formulating interesting ideas about these documents easier.



**Figure 10:** 2D cartography with Geotools.

Regarding the file format used to store the maps, the information tied to the elements in the map and possible links to data sources reachable via URLs, the choice of using shapefiles has several practical advantages. Created by the Environmental Systems Research Institute, Inc. (ESRI) as a standard in the representation of geometrical data objects of many different kinds, shapefiles have reached a level of popularity that is reflected by the existence of many conversion tools capable of producing files conforming to the shapefile format from a variety of rendering systems formats. For example, shapefiles can be created by exporting data to a shapefile using ARC/INFO®, Spatial Database Engine™ (SDE™), or other similar applications. They can be created directly from the digitization of shapes using software packages, or they can be produced from raw numerical data having been read into a program, as is the case of the application we produced.

A shapefile contains non-topological geometry and attribute information for the spatial features in a data set (topology attributes must be generated and rendered using information contained in the databases that accompany the shapefile using the multi-Theme, multi-Layer system described above). The geometrical aspects of each form within the map represented by the shapefile take the form of arrays of coordinate points, whose significance is dependent on the shape type. Since they are free of topological data structures (these are loaded sepa-

ately and as needed), they offer both rendering speed advantages as well as editing advantages. Perhaps the one limiting aspect of the shapefile format, is that they can contain only one type of shape within a given shapefile, although this presents no issues of concern for our application. Shapefiles can support point, line, and area features. Attributes, topological references as well as links to external data sources are all held in a dBase® format file (dbf). Each attribute record has a one-to-one relationship with the associated shape record. Given the separation of raw geometric coordinate information from attribute and topology information, our application allows for the insertion/deletion of either shapes or attribute columns.

While the shapefile format has the ability to store geometric forms of a variety of types, such as 3D polygons and 3D arcs, as well as the possibility of ascribing data in the so-called M-dimension, used for giving scale or measure data to the object in question, the development of GIS interaction tools that this article describes necessarily limited the range of compatible shape types to 2D arcs and 2D polygons. For some shape types, such as Point and Multi-Point, the reason for their exclusion results from the simple fact that rendering them and locating them using the mouse is impractical. Since a primary means for identifying an element of interest is by clicking in its region, these categories pose problems since they have zero areas. Besides, they are rarely of use in representing geographical data sets. The other category of shape types supported by the shapefile format, that were not implemented into our application, are the three-dimensional shape types, since this tool is specifically designed for use with 2D objects.

Being able to provide additional information regarding a given element within the display naturally brings up questions as to possible forms which it can assume, as well as the issue of locating the data, since at the moment of loading a display, it is neither plausible nor desirable to load all linked information associated with the display (since some of that data could result in the querying of geographically distributed databases). Furthermore, allowing for the possibility of auxiliary information arriving from various sources, it becomes indispensable to provide for access to these sources, without regard for their format. This is why the dBase® (dbf) file that accompanies the shapefile plays a fundamental role. It can contain simple character or numerical data about the shape it points to, but it can also contain URL links (editable by the user on a per-shape basis) which allow heterogeneous data forms to describe the map in question.

The Java programming language was chosen primarily with its platform independency in mind and ease of integration with networking, but also due to ever-increasing amount of development that can be found of

packages like the GeoTools libraries, and other visualization and rendering libraries, that ultimately made the task of producing GIS applications feasible reducing the production and debugging times involved with respect to some other development languages available today. Regarding speed of execution concerns, there are currently very few spots in our application that constitute bottlenecks due to large amounts of data processing, however, they do not pose problems since none of the functionality currently implemented is intended to have real time execution requirements.

## 5. 3D visualization

The importance of the visualization of a three-dimensional model for cultural heritage and archaeology at the scale of buildings no longer needs to be demonstrated. For instance, see Paul Reilly from 1990 in an article entitled "Towards a virtual archaeology" published in the Computer Applications in Archaeology conference proceedings in Southampton, which clearly described the interest in the elaboration of a three-dimensional model and its visualization. Since then, this aspect has largely been studied and many theoretical studies on the 'reconstruction' of the past have been undertaken. On this subject see the synthesis of Juan A. Barceló [1].

There are not many ways to visualize dynamically a 3D model on the web, the choice must be made between VRML and a custom application in Java. Each of them has its advantages and disadvantages, and we choose to use both of them.

### 5.1. The Limitations of VRML

The VRML three-dimensional imaging language is well adapted to simplified and quick visualization.[21] Coupled with a script language such as PHP, it also allows a simple and efficient link to a relational DBMS for consultation or an XML database access. Within these limits of use, it fulfills perfectly its job and research projects which employ it, for example, the virtual museum project dedicated to the evolution of a city developed by Maria Elena Bonfigli and Antonella Guidazoli [3]. It is also used with a sound Java2D interface, such as the educational work in the GIS from Kate Moore, Jason Dykes and Jo Wood at the University of Leicester.

Nevertheless, VRML suffers from a lack of portability, the fact that a free and efficient viewer has not yet been developed for Unix, and especially from an enormous lack of flexibility for dynamic updating of three-dimensional models.

### 5.2. The Opening of 3D tools in JAVA

A Java3D library can therefore be used directly from the model development language. The link between the graphic representation and the model becomes then intimately close and it is possible easily to consider a bidi-

rectional link between the model and its graphic representation, also between a persistent object manager, the acting object and its graphic representation.

The choice of a visualization tool in Java was made, in this project, between two possible solutions:

- Developing a tool on Java3D library developed by Sun and distributed for a majority of today's computer systems. The Sun Java3D library is a set of very useful and convenient tools for developing a VRML-like visualization tool. Being a high level library dedicated to visualization, in order to use the product the final user must install Java3D on the client computer in order to use the Sun runtime library.
- Using a tool written directly in Java, without any runtime resources to install. There are several tools available on the Internet, one of the most complete and efficient of which is JavaView, see the web site [18]. JavaView has an open class library for advanced mathematical visualization. Its class library can be used and extended for specific use while always profiting from the advanced 3D visualization capabilities. As it's written directly in pure Java the final user does not have to first install a specific library.

We are currently developing a set of mechanisms, extending the JavaView library, based on the object approach to offer to objects a dynamic behavior for their graphic representation. This approach will also allow for visualization on the web of relations linking the objects.

## 6. X-Echo: The query system

The GIS must allow an interaction with the data attached to the objects represented. These data are often stored in different places and cannot be embedded in the application containing the GIS. This is particularly the case in the field of archaeology where the databases relating to the sites and the objects found during the excavations are stored on the servers of organizations of research. Each user must request access to the data desired from the authority which stores them in order to use them. We propose in this work a system of automatic publication of information which can be used in a simple and effective way without requiring a heavy installation and especially compatible with the current formats of storage of information. To this end, two goals are significant. First, the data must be usable in a formalism independent of their methods of storage. Second, access to the data must be technically simple and not involve great complexity for the users. We propose here an Internet usable application based on the principle client – server. This application allows access to various sources of information in a transparent way, for which the XML formalism is sufficient for both queries and publications of results.



The user only interacts with XML documents. In fact, requests for access to data have a XPATH form and the responses to these requests are in XML, to which transformations can be applied. Figure 11 shows the general operation of our system. We explain here the processing of a request in order to expose the general behavior of our system. In our case, the application is a GIS software package, and the data provided by the source is information relating to an object pointed to in the GIS. In order to retrieve data, the user sends a query via a web connection to a server using our system. This query takes the form of an XPATH command and depends on the chosen XML publication formalism of the source of information. Once sent to the server, the query is translated to produce a new query; conforming to SQL formalism with the aim of being used for querying the data source. The server, using JDBC, proceeds to the interrogate the data source (ODBC, ORACLE...) and returns the results in a classic tuple form. The system then carries out the XML formatting of the tuple results according to the model provided by the user at the time of the query. Once the results are in XML form, they are returned to the user.

In a more technical way, the server carrying out the queries and publishing the results is in reality a set of Java servlets. This set is divided into two parts: on the one hand, the reception and processing of user queries and on the other hand, access and publication of the data. The processing step of the user's query is managed by one servlet which makes it possible to transform queries in XPATH format into SQL queries usable to work on the conventional data sources. The access and publication steps are made around a cocoon pipeline. Cocoon is a servlet which allows the publication of data conforming to XML formalism by performing various transformations to a data flow. These transformations are assembled into a set called cocoon pipeline. The creation of the data flow is the work of a generator which will query the data source by using the user's query and will produce a flow which is processed by the remainder of the pipeline. In the pipeline, transformations guided by XSL style sheets transform the flow to give it the formalism desired by the user. This formalism can be a simple XML file, usable as entered for an application, or publications in different formats, like PDF or HTML for a more traditional user.

Our system has many advantages. The management part of the data is done on the server. The client needs only to be able to formulate a query to the server and to store the results of it. A simple web navigator or a custom application respecting the interface of the query allows the complete use of our system. It can be used in places where it is difficult transport many pieces of equipment (such as excavation sites). For the server part, the principal advantage is that it is not necessary to modify the data stored in order to set up our system of

publication. This is very useful if the data are present in huge quantities or if they must not allow modifications. For these principal reasons, our system is perfectly suited to the needs for this project.

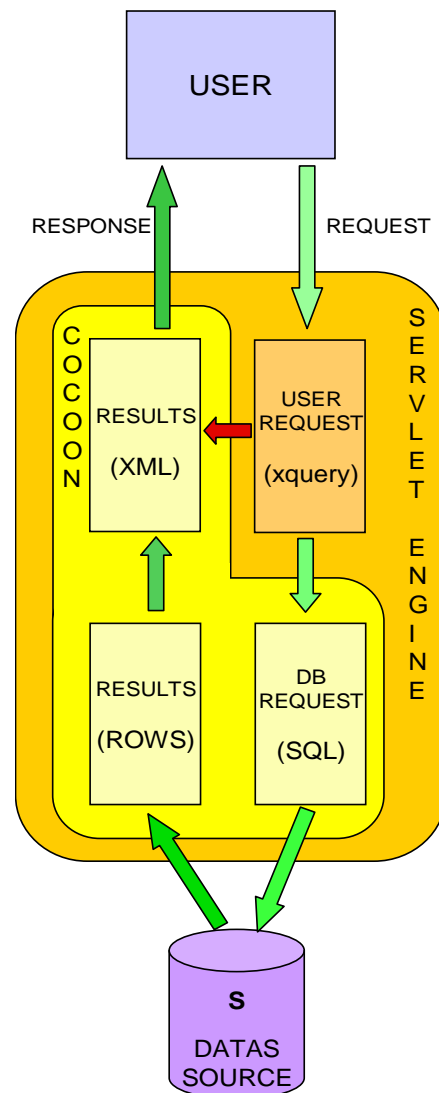


Figure 11: Synoptic X-Echo component schema.

## 7. Conclusion and future work

Data management, an omnipresent problem in cultural heritage, is dealt with in two ways: the first is purely textual and non graphic data, and the second is based on the object geo-referential point-of-view. These two approaches, in the project presented here, are accessible on the Internet.

We have presented here a generic GIS toolbox. It is composed of a set of free software libraries linked to-

gether by a common Java interface. The three main components of this tool are all written in Java:

- The Geotools library for 2D visualization and simple query of object properties. This library uses the shapefile format from ESRI™ and is entirely written in Java.
- The JavaView library for 3D visualization. Also written in Java it allows a simple and efficient 3D visualization and a set of very convenient tools for 3D analysis, meshes, 3D rendering, mathematical functions for volume, surface computation, picking and dynamic updating.
- The X-Echo project, developed at the MAP-GAMSAU laboratory, based on XML technology in charge of query analyzing and data formatting.

These tools have been developed for cultural heritage and archaeology. A first experimentation was done in the framework of an international project for analysing urbanistic data of the Constantine historic center. This project, started in May, 2003, is managed by the Italian Ministry of External Affairs, the University Roma Tre, Italy, The Ministry "de L'Habitat et de L'Urbanisme" of Algeria, the Wilaya du Constantine and with the participation of the French CNRS laboratory MAP.

### 7.1. XML and a patrimonial Information System

The three-dimensional model, and more generally the graphical representation, as an interface to the data formalized in XML allows the purely documentary data (references, observations, photographs) to be linked to several object graphical representations. This graphic expression of the object relies on the data (position, orientation, dimensions) and on the generic knowledge of the object (theoretical shape, default values, relationships between various objects, object destination and use, historical aspect). The three-dimensional model is a relevant interface between the user and the collected data. [5]. The resulting data, generated in XML, allows both a simple and automatic publication of the results to different media, and a way to elaborate a query on the whole set of data.

### 7.2. Data evolution problems

The data evolution problem becomes crucial as soon as several measurement methods are involved, or different source are used to establish the final data. For example, in our case, we use a map from the central administration made in 1985, an old map drawn in 1837, photogrammetry using old photographs for which we do not have camera parameters, direct on site observations. During this time the city changes, buildings disappear, others are constructed, but in general most of them have changed in some way or another. This revision problem is clearly identified in the context of GISs [12, 14] but it remains somewhat more complex in our case.

We must manage data coming from both photogrammetric measurements and other more or less direct manual measurements. All of these measurements are incomplete and represent the same object at different moments in time.

This work about reversible data fusion and revision, from the different data sources existing in this project has been started this year thanks to collaboration with Prof. Odile Papini, SIS laboratory, University of Toulon, France. ([2, 13])

### 8. Acknowledgment

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### 9. References:

1. Juan A. Barceló Visualizing what might be. An introduction to virtual reality techniques in archaeology. VIRTUAL REALITY IN ARCHAEOLOGY, Edited by Juan A. Barceló, Donald Sanders, Maurizio Forte. Published by Archéopress PO Box 920 Oxford OX27YH, 2000.
2. [Benferhat, Dubois, Lagrue, Papini, 2003] Benferhat S., Dubois D., Lagrue S., Papini O. « Making revision reversible : an approach based on polynomials » *Fundamenta informaticae*, 2003. (To be printed)
3. Maria Elena Bonfigli, Antonella Guidazzoli, A www virtual museum for improving the knowledge of the history of a city VIRTUAL REALITY IN ARCHAEOLOGY, Edited by Juan A. Barceló, Donald Sanders, Maurizio Forte. Published by Archéopress PO Box 920 Oxford OX27YH, 2000.
4. L. Càmara, P. Latorre. Information system on heritage conservation., *Archives internationales de photogrammetrie et de télédetection*. Vol. XXXII. Tome 5C1B CIPA International symposium – Göteborg – 1997
5. Cantone - Naples University 'Federico II', Franco Niccolucci - Florence X3D and the future of Virtual Archaeology Computer Applications and Quantitative Methods in Archaeology Conference CAA 2002 "The Digital Heritage of Archaeology" 2-6 April, 2002 Heraklion, Crete, Greece
6. Pierre Drap, Luc Long, Anne Durand, Pierre Grussenmeyer "From underwater photogrammetry to a web integrated documentation system: the case of the 'grand ribaud f' Etruscan wreck." CIPA 2001 International Symposium, Potsdam University (Germany) September 18 - 21, 2001.

7. Pierre Drap, Luc Long, Anne Durand, Pierre Grussenmeyer "Un système de gestion de documents hétérogènes dédiés au patrimoine archéologique et gérés sur le réseau Internet. Le cas de l'épave Etrusque du Grand Ribaud. BDA'2001". 17<sup>ièmes</sup> Journées Bases de Données Avancées. 29 octobre - 2 novembre 2001 Agadir, Maroc. Actes publiés sous la direction de Noredine Mouaddib CEPADUES-EDITIONS, Toulouse. ISBN 2.85428.570.0 pages 353-362.
8. Pierre Drap, Pierre Grussenmeyer, Gilles Gaillard; "Simple photogrammetric methods with arpenteur. 3-d plotting and orthoimage generation : the I-MAGE process." CIPA 2001 International Symposium, Potsdam University (Germany) September 18 - 21, 2001.
9. Pierre Drap, Emmanuel Bruno, Luc Long, Anne Durand, Pierre Grussenmeyer; "Underwater photogrammetry and xml based documentation system: The case of the 'Grand Ribaud F' etruscan wreck", ISPRS COMMISSION V SYMPOSIUM Close-Range Imaging, Long-Range Vision 2-6 September, 2002, Corfu, Greece
10. Kristin Leukert, GIS-internet architectures XIXth Congress of the International Society for Photogrammetry and Remote Sensing (ISPRS), Geoinformation for all, Amsterdam 16-23 July 2000. Int. Archives of Photogrammetry and Remote Sensing, , Vol XXXIII, Tome IV-B commission IV, pp 572, 579.
11. Claire Reeler, Beyond GIS: Artificial Intelligence in Archaeology Applications of GIS: Proceedings of Colloquium II, UISPP XIIIth Congress, Forli, Italy, September 1996 Johnson, I. & North, M. (eds) 1997. Sydney University Archaeological Methods Series 5.
12. [Peled, Raizman, 2000] A. Peled, Y. Raizman, "Three-dimensional digital photogrammetric update of the israeli national gis data base" XIXth Congress of the International Society for Photogrammetry and Remote Sensing (ISPRS), Geoinformation for all, Amsterdam 16-23 July 2000. Int. Archives of Photogrammetry and Remote Sensing, Vol XXXIII, Tome IV-3, pp 443, 448.
13. [Papini, 2001] Odile Papini "Iterated revision operations stemming from the hystory o fan agent's observations" Frontiers of Belief Revision M.-A. Williams and H. Rott eds. Applied logic series. 22. Kluwer Academic publishers. Pages 279-301. 2001.
14. Zhongchao Shi, GIS database revision --the problems and solutions XIXth Congress of the International Society for Photogrammetry and Remote Sensing (ISPRS), Geoinformation for all, Amsterdam 16-23 July 2000. Int. Archives of Photogrammetry and Remote Sensing, Working Group IC WG IV/III.2, pp 494-501.

#### References from book:

15. Christian Jacob, L'empire des cartes. Approche théorique de la cartographie à travers l'histoire. Bibliothèque Albin Michel, Histoire. Paris, 1992. ISBN 2-226-06083-9.

#### References from websites:

16. ARPENTEUR, an ARchitectural PhotogrammEt-ric Network Tool for EdUcation and Research; <http://www.arpenteur.net> (version 2.0, 31 May 2001)
17. The GeoTools Web site: <http://www.geotools.org/>
18. JavaView, The JavaView Project. <http://www-sfb288.math.tu-berlin.de/vgp/javaview/index.html>
19. OpenGIS Implementation Specification: Coordinate Transformation Services (Revision 1.00) Open GIS Consortium, Inc., OpenGIS Project Document 01-009. 12 January 2001. <http://www.opengis.org/techno/implementation.htm>.
20. OpenGIS Simple Features Specification For SQL (Revision 1.1), Open GIS Consortium, Inc., OpenGIS Project Document 99-049. 5 May 1999
21. [VRML, 97]Virtual Reality Modeling Language , The VRML Consortium Inc., Information technology – Computer graphics and image processing – The virtual Reality Modeling Language (VRML), ISO/IEC 14772-1:1997 <http://www.web3d.org/Specifications/VRML97>
22. Extensible Markup Language (XML) 1.0 (Second Edition), W3C Recommendation. eds. Tim Bray, Jean Paoli, C. M. Sperberg-McQueen and Eve Maler. 6 October 2000. <http://www.w3.org/TR/REC-xml>.
23. XML Schema Part 0: Primer, David C. Fallside, ed., W3C, 2 May 2001. <http://www.w3.org/TR/2001/REC-xmlschema-0-20010502/primer.html>
24. XML Schema Part 1: Structures, W3C Recommendation. eds. Henry S. Thompson, David Beech, Murray Maloney, Noah Mendelsohn <http://www.w3.org/TR/2001/REC-xmlschema-1-20010502/>
25. XML Schema Part 2: Datatypes, W3C Recommendation. eds. Paul V. Biron, Ashok Malhotra <http://www.w3.org/TR/2001/REC-xmlschema-2-20010502/>