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GIS tools for comparing historical and contemporary landscapes through local maps series

Keywords: GIS; cartographic heritage; digital libraries; on-line accessibility; multilingual and multiformat databases; historical landscape.

Summary
Our Project of the GIS based Spanish Ancient Cartography e-Library was firstly presented in the 3rd Workshop of the ICA Commission on Digital Technologies in Cartographic Heritage (Barcelona, Spain, 2008), and afterwards in the Conference on Virtual Systems and Multimedia Dedicated to Cultural Heritage VSMM'08 (Limassol, Cyprus, 2008). Since then we have applied some of the GIS tools to the study of the evolution of some Spanish landscapes between the 15th and the 19th centuries. By means of the georeferencing of the map images and the use of tools such as transparency and the geometric transformations, we have superposed the ancient maps and views to a composed map of the same areas of the First Series of the Mapa Topográfico Nacional 1:50.000 dating from the second half of the 19th century. The conclusions show that the changes in the landscape involve not only the geographic elements, but also the land uses, the landmarks and the boundaries, as well as the road and the urban frames.

Introduction

The GIS based Spanish Ancient Cartography e-Library has been created according to the strategies of the Council of the European Union about Digital Libraries. The Project has been already presented in the 3rd Workshop of the ICA Commission on Digital Technologies in Cartographic Heritage (Barcelona, Spain, 2008) (Chías and Abad 2008) and in the Conference on Virtual Systems and Multimedia Dedicated to Cultural Heritage VSMM'08 (Limassol, Cyprus, 2008) (Chías and Abad 2008a).
Since then we have developed some digital tools for the analysis of the accuracy (Jenny 2006) of the historical maps, as well as for demonstrating the technical virtuosity of the cartographers as a guarantee of the reliability of the information that they depict (Blakemore and Harley 1980).
This information will be lately applied to the study of the historical changes of the landscape and will serve as a decision support (Jobst 2006).

The digital maps in the cartographic databases

Ancient cartography, as well as old pictures, drawings and photographs, has not been used traditionally as a reliable source of information about the history and the evolution of the land- and the townscape. Those graphic materials have been usually considered as 'second order' documents, mainly because of the difficulties that their interpretation can sometimes involve (Harley 1968) due to the different conventions that are applied in each case by the cartographer.
But this is not the only reason why cartography is so seldom used in the historical searches, for there are other problems related to the difficulties of their localisation and visualisation that have to be considered.

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Although we find it is not essential to have an exhaustive knowledge of the context of each map to get a meaningful interpretation of it (Skelton 1965, 28) (Andrews 2005), it is necessary to achieve some basic specific concepts on the theory of the cartographic expression and design (about map projections, symbols or representation of relief, for instance), because the lack of them can hamper the right interpretation of the document and twist the results of the investigations (Vázquez Maure and Martín López 1989: 1). Nowadays, "digital cartography and the history of cartography are not yet comfortable bedfellows" (Fleet 2007: 102).

Our project of a digital cartographic database accessed through GIS is related to, but distinctive from the history of cartography, and aims to integrating digital technologies with the cartographic heritage, thus providing new approaches and new audiences for the history of cartography.

To define the contents of our cartographic database we have applied the ICA's Working Group broad definition of cartographic heritage as "anything of cultural value inherited from maps and accessible to a broad public community", as well as the wide sense concept of a cartographic document of Harvey (1980: 7), and Harley and Woodward (1987: I, xv-xxi) that includes all kinds of maps, plans and charts at different scales (architectural, urban and territorial scales), as well as pictures and bird's-eye views (Kagan 1998: 18) (De Seta 1996), with no restrictions due to techniques, functions or origins.

We have designed a methodology that applies the modern digital technologies to the history of cartography and:

- Helps to establish new relationships.
- Provides an easy access to images to make analysis and comparisons.
- Shows the map distribution on the different archives.
- And finally allows to reconstruct the historical landscapes and the history of the territory through old maps.

Although this is one the main targets of our project, the final one is to spread the old cartographic treasures that compose a relevant part of the Spanish cultural heritage, that actually remains unknown to the public and even to a great number of specialists (Chías and Abad 2006; 2008).

Briefly we can expose our main targets as follows:

- To diffuse and relate the contents of the various Spanish archives to provide the study of the old maps and plans giving a broad overall view, to be applied to the deep study of the historical evolution of the territory and the landscape at different scales.
- To enlarge the available information about ancient cartographic documents, not only through the metadata of each image, but also with other contents located either in particular or non digitised collections.
- To enlarge the possibilities of the traditional searches on the databases through the queries that are useful through the GIS tools, that include issues as metric and geometric accuracy.
- To use the new technologies to study and diffuse the cartographic heritage through Internet.

The use of the new information and communication technologies

The digital technologies were formerly used by other disciplines (archaeology and historical geography) and had practical non-academic applications (town planning, librarianship).

Among the possibilities of the digital images, the new computerized methods and digital technologies have brought an explosion of the scope and potential of the digital cartography, allowing and encouraging the interaction with early maps with the aim of furthering our understanding of their content in all its aspects. But they also introduce new ways of connecting early maps with other kinds of information, inviting us to use new forms of presentation and making easy a speedier transmission of

images the world over. This is particularly interesting for the creation of the European Space of Information.

On the other hand, the digital cartography is not a loss, but a useful tool in the traditional scholar research (Fleet 2007: 100). But it remains as a central theme of discussion the way the digital technologies may be of particular value to historians of cartography, deepening on subjects as:

- How digital technologies are already providing access to early maps (and related materials) through a range of methods, including: improved reproduction, electronic facsimiles, websites, new forms of presentation and integration, and new forms of digital preservation and archiving (for instance, by using photogrammetric techniques in seaming together images of large maps to create more authentic facsimiles), dynamically integrating maps with other information using the web, applying new ways of visualizing and presenting early mapping, and associating new metadata as structured summary information about a cartographic source to encode data on and about historical maps.
- The digital technologies that are allowing new ways of understanding the content of early maps, allowing the digital analysis of map geometry and the use of digital transparency techniques focused on the cartometric analysis of early maps, the reassessment of the projections used in 15th and 16th centuries nautical charts, based on a study of navigational practices, technologies and texts, or the use of precise methods and mathematics behind the transformations of old maps in various geo-referencing projects.

Digitization

The map images included in the databases are born digital materials as well as digitized maps.

Obviously, it is not easy to access to an original big size and small-scale map that is sometimes composed by several printed sheets; and it is also complicate to see properly the symbols employed in the map and read its texts when it is imposed to handle a reduced hardcopy or a low resolution digital image. The technical specifications about digitization that we have used have been already discussed in our contribution to the Workshop on Archiving in Digital Cartography and Geoinformation (Berlin, Germany, December 2008), and are resumed in the following tables.

Main characteristics:

- Sketches or engravings, monochromatic lines, can be reproduced in black and white.
- It is fundamental to preserve the scale: if it is no original graphic scale, a standardised one must be included.
- Assemblage: multiple sheet maps, plans or sketches

Kind of Files to be preserved, diffused and visualised	Format relationship	Format and resolution	Chromatic model	Compression	Weight (medium average)	Framing and orientation	Colorimetric profile
Net ink lines, print paper	1:1	TIFF, 300 dpi	Black and white	LZW	0,6 Mb each A1	Full frame, reading sense	NA
Light pencil lines	1:1	TIFF, 400 dpi	Black and white, paint diffusion	LZW	12 Mb each A1	Full frame, reading sense	NA
Very light pencil lines or highly coloured background	1:1	JPIF, 300 dpi	RGB	JPEG, quality factor 8-12	7 Mb each A1	Full frame, reading sense	Gray gamma 2.2

Table 1. Linear monochromatic maps and plans.

Sometimes digitisation has been primarily used to preserve the existing original and analogue materials (that can be degrading), but digitisation and preservation are strongly interrelated and therefore have to be considered together. Specially in case of rare works (as several maps are), consultation of the digital copy can replace the physical manipulation of the original, which will add to its longevity.

The risk of losing digital material has been taken in account in our digitisation programme, because digitisation without a proper preservation strategy may become a wasted investment.

Main characteristics:

- Coloured sketches or engravings, printed or manuscript, that must keep the colour information, as well as the paper texture.
- It is fundamental to preserve the scale: if it is no original graphic scale, a standardised one must be included.
- Assemblage: multiple sheet maps, plans or sketches.

Kind of Files to be preserved, diffused and visualised	Format relationship	Format and resolution	Compression	Weight (medium averaged)	Framing and orientation	Colorimetric profile
Preservation File, Size < A0	1:1	TIFF, 300 dpi	LZW	90 Mb each A0	Full frame, reading sense	RGB or CIE Lab
Preservation File, Size = A0	1:1	TIFF or JPEG, 300 dpi	LZW or JPEG, quality factor 12	55 Mb each A0	Full frame, reading sense	RGB
Diffusion File	1:1	JFIF, 200 dpi	JPEG, quality factor 8-12	12 Mb each A0	Full frame, reading sense	sRGB
Visualisation File	Variable, max. 480 pixels in the largest dimension	JFIF, 72 dpi	JPEG, quality factor 8-12	0,05 Mb	Full frame, reading sense	sRGB

Table 2. Colored sketches, drawings, maps and plans.

The image open formats are based upon norms and standards whose specifications are public. We have only considered different formats of preservation and diffusion when images are born digital material in the University of Alcalá, and can be diffused in a high definition version as there are no copyright issues. We always indicate the file format, including the version (for example, TIFF version 6).

The image files are named: FFFXX_NNNNNNNN_T.EXT, where:

- FFF: Archive ID, max. length 5 characters; provided by each archive.
- XX: Internal ID of the collection; length 2 characters.
- NNNNNNNN: File ID that includes a geographical reference (province); variable length from 1 to 20 characters, from A to Z or from a to z, without accent, includes (-) but not the rest of characters including (_), that is used to separate the different ID groups of the image.
- T: image format on screen: V = illustration, T = 1/3 screen, P = full screen, 2 = high definition (2.000 x 3.000 pixels), 4 = high definition 4.000 x 6.000 pixels, H = high definition (more than 4.000 x 6.000 pixels).
- EXT: extension of the format: JPG, GIF, TIFF, PCD…
  - Example for an image of the Archivo de la Real Chancillería de Valladolid, Spain: AChV_00743TO_4.tiff

We have combined the two possibilities of relating the metadata and the image file by including the essential metadata (as are the image ID, Title, Archive and Date of digitisation) inside the digital file, while the rest of the metadata are stored in other external databases.

The Image file metadata is a dataset that informs about other data in order to support their search, management and preservation (Dublin Core Norm). They can be descriptive (Subject, Description, Author, etc.), technical (format, digitisation options, etc.) and administrative (copyright, etc.). There are two possibilities of relating the metadata and the image file that are the external storage or the inclusion of the metadata in the file. We have decided to combine them by maintaining the essential metadata (as are the image ID, Title, Archive and Date of digitisation) inside the digital file, while the rest of the metadata are stored in other external databases.

Regarding storage support and infrastructure, optical devices have been chosen due to their capacity, durability, reliability, accessibility, volume, stability, and cost, among other qualities.

Contents and structure of the databases

As we must restrict the temporal and the geographical subject of the contents of the cartographic databases, we firstly decided to include all the historic documents that have been drawn before 1900, mainly because along the 20th century the cartographic production and techniques have very much increased in many senses and its study should be carried separately. Secondly, the spatial restriction has

been imposed to the search and we decided that the cartographic database should concern the actual Spanish territories (Chías and Abad 2008a).

Assuming all those circumstances, the former stages of our search are focused on finding, studying and cataloguing all kind of cartographic documents that are preserved in the main Spanish collections, archives and libraries as the Biblioteca Nacional de España (Madrid), Biblioteca del Palacio Real (Madrid), Biblioteca del Monasterio de El Escorial (Madrid), Biblioteca de la Universidad de Barcelona, Biblioteca de la Universidad de Salamanca, Real Academia de la Historia (Madrid), Real Academia de Bellas Artes de San Fernando (Madrid), Archivo Histórico Nacional (Madrid), Archivo General de Simancas (Valladolid), Archivo de la Real Chancillería (Valladolid), Archivo del Centro Geográfico del Ejército (Madrid), Instituto de Historia y Cultura Militar (Madrid), Instituto Geográfico Nacional (Madrid), Museo Naval (Madrid), Institut Cartographic de Catalunya (Barcelona) and Archivo de Viso del Marqués (Ciudad Real) among many others, as well as in local and ecclesiastical archives.

Universidad de Alcalá — ANCIENT SPANISH CARTOGRAPHY e-LIBRARY

Id	3 **Library** ICC	**Signature**	RM. 23384
Subject	Toledo; Guipúzcoa; Cádiz, bahía	**Date**	1584 .s. XVI
Title	"Carpetaniae partis descr. 1584; Vasconiae, sive Guipuscoae regionis typus; Sinus Gaditanus, nunc baia de Cadiz / hanc insulam perlustrasse, et sua manu depingebat [...]"	**Kind of Document**	Topographical map
		Size	430 x 550 mm; 1 sheet
Author	Georg Hoefnagel, Abraham Ortelius		
Scale	Toledo 1:250.000 / Guipúzcoa 1:300.000 / Cádiz 1:100.000. Graphic scales in miles.		
Map projection	Plans. Without graticule. North at the upper side of the sheet.		
Technique	Copper engraving. Hand coloured with aquarell. Support: print paper.		
Description	Three maps: at the upper side, left Toledo (inside an 170 x 240 mm rectangle), right Guipúzcoa (inside an 170 x 230 mm rectangle); at the lower part Cádiz, inside a semicircle of a 470 mm diameter, that partially invades the other maps. Dutch and latin text. Decoration: two medals with an archer and a ship; titles in three cartouches.		
Short history	Included in the "Theatrum Orbis Terrarum", printed by Ortelius in 1598 in Antwerpen. The fist edition was the 22 May 1570, dedicated to King Philip II of Spain, and engraved by Hans Hogenberg. Other editions: 1577, 1578, 1579, 1606, 1612, 1624.		
References	Martín López 2002 / van den Krogt 2007 / van der Heijden 1995 / IGN 2000 / La Imagen 1982 / Woodward 1987 /		
Image			
Other remarks	"[...] Georgius Hoefnaglius Antverpian." There is another copy in the same ICC Archive (RM. 6777) of the 1606 edition, not coloured.		

Figure 1. A file of the cartographic databases (soon at www.ielat.es).

The next step was to construct the relational databases over a commercial compatible platform. They have been designed as multilingual (there is already an English and a Spanish version) and open to allow including new registers in the future and even adding new fields or tables, to update the contents to the new needs without damaging the existing ones. Moreover, the concept 'relational' implies the possibility of crossing the data of the different tables and reducing their weights, making easier the data management and the queries.

According to this, our methodology includes three main tables, that are the following:

- 'Cartography', that contents all the registers concerning the cartographic documents and follows the ISBD Norms of cataloguing.
- 'Bibliography', that includes the complete bibliographical references that appear in the field *Bibliography* of the table 'Cartography'.
- 'Libraries, Archives and Map Collections', is the table that includes the complete references of the collections that have been visited, and that appear just as an acronym in both *Collection* and *Signature* fields of the table 'Cartography'.

The three tables have been designed sharing at least one field that allows crossing the data files and economizes data length in the databases.

The design of the table 'Cartography' joins both the descriptive and the technical data about each document, joining the perspectives of the historian and the cartographer.

The datasets of the ancient maps include actually more than 5.000 files, that are continuously being increased, updated and distributed in the servers by geographical units.

Preservation, online accessibility and diffusion

A digital copy of a document does not necessarily guarantee its long-term survival: all digital material has to be maintained in order to keep it available for use.

The main causes for the loss of digital content are the succession of generations of hardware that can render files unreadable (although the solution is the development of systems capable of accessing the disks using emulation techniques), the rapid succession and obsolescence of computer programmes and the limited lifetime of digital storage devices. Unless data are migrated to current programs or care is taken to preserve the original source code, retrieval of information may become very costly, if not impossible. This is specially hard for the 'closed' data formats (those whose source code is not publicly known), that we have avoided.

That is why we have decided to use simultaneously two platforms (PC and Mac) and compatible software for both, as well as open systems, always according to the PREMIS (Preservation Metadata for Digital Materials) Working Group Report (version 2.0).

Nowadays the web-based digital resources are quite frequent as a way to preserve and diffuse the cartographic heritage as well as to access to the modern cartography (Zentai 2006; Livieratos 2008).

Previous experiences as the one implemented on the Greek region of Macedonia (Jessop 2006) or the GIS-Dufour (Egil and Flury 2007) have shown the potential of GIS and its accessibility through the web.

Under current EU-law and international agreements, material resulting from digitisation can only be made available online if it is in the public domain (in a narrow sense, refers to information resources which can be freely accessed and used by all, for example because copyrights have expired) or with the explicit consent of the right holders. The transparency and clarification of the copyright status of works is very relevant to us.

As a matter of fact, our digital library is in principle focused on public domain material, and as digital preservation implies copying and migration, it has always been considered in the light of IPR legislation

(Commission 2005): the digitised funds of other libraries are precisely quoted and respect the conditions that have been established for consulting the documents by the right holders; and we must neither set other supplementary caution that restrict the access to the different data sets, nor establish different access levels. We also provide the links in case that the documents are included in other cartographic databases that can be accessed through Internet.

The GIS implementation

The open GIS is supported by a commercial platform that includes a complete and easy to use computer-aided mapping module in a vector format that is a standard with the maximal compatibility, although the connection with the databases must be established through an ODBC protocol.
The possibility of drawing our own vector cartography inside the GIS not only avoids the problems derived from the import of graphic files through the *dxf* format, but allows an easy definition of the base maps, that only need to make a clear definition of the graphic features that must be digitised and of the strategies that must be followed to compose the base maps.
Each ancient map is referred to a point or a polygon and a centroid, depending on the territory they represent. Points are used generally in town plans or views; centroids are mainly used to identify the maps that represent the different territories.
Obviously, a single centroid can be related to more than a map, and the different possibilities are simultaneously shown in a first screen; afterwards the different documents can be chosen separately.
On the other hand, the contours of the different documents are drawn and referred to their own centroids: then it is quite easy to see the way the maps and plan overlap each other, what allows to perceive rapidly the portions of land that are covered by different maps and which are the historical periods when they have focused the attention due to different targets.
This system and structure has been the most useful and fits with the strategies that we have previously planned to get the most varied and personalized information of the GIS.
Our methodology has increased the possibilities of the usual queries that a GIS brings, just formulating them to the different databases separately or even crossing them; but to ensure the proper display of the cartographical information we have designed a filling card as one of the main printable output ways.
This filling card includes also the adequate links to access to other e-libraries or references as it has been above mentioned.
Obviously, traditional outputs as thematic mapping, statistics, lists or reports are also available, but the possibilities that the hypermedia concept brings on getting personalised information of the different data sets are an added value to the traditional queries system.

GIS tools for the study of the landscape evolution

Digital technologies and particularly Geographic Information Systems (GIS) allow new ways of integrating early maps with other information making the 3-D visualisation more accessible, realistic and impressive, or combining historical maps and associated textual and numerical information to achieve a spatial analysis of agricultural productivity and its relationship with the landowners through integrating cadastral and statistical information; two examples can be quotated: the *Gregoriano Cadastre* (Orciani et al. 2007) and the old cadastral maps of Utrecht (Heere 2006), both focused on a deep knowledge of the reconstruction of the old properties.
The possibilities that GIS tools and georeferencing bring to the study of the geometric content and accuracy of the early maps are specially interesting.

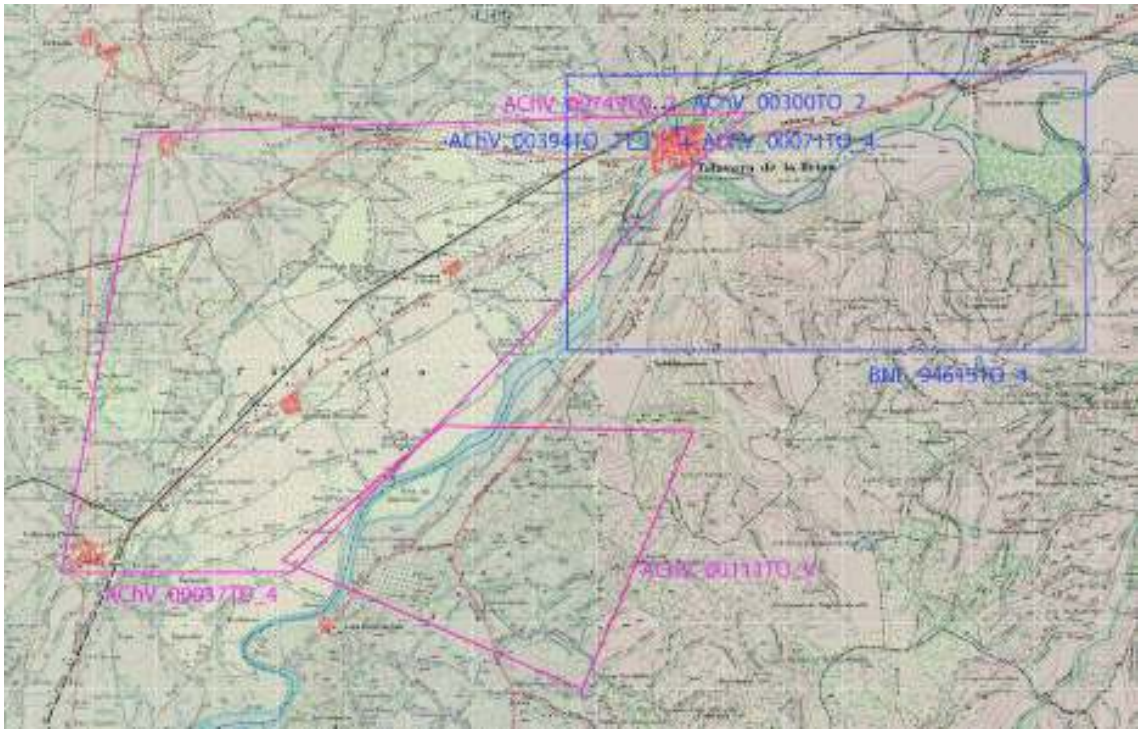

Figure 2. A detail of the cartographic base of the GIS, showing the different areas covered by some ancient maps. In red: 17th century maps; in blue, 18th century maps. As a background is reproduced a composed map of the same areas dating from the second half of the 19th century. It is taken from the First Series Mapa Topográfico Nacional 1:50.000, from the sets in the Instituto Geográfico Nacional, Madrid. Reference grid, 1º latitude and 1º longitude

Figure 2 shows some of the ancient local maps and views that have been joined from the different Spanish archives and libraries, and that depict the surroundings of the town of Talavera de la Reina (Toledo, Spain).

Each map can be identified by the name whose encoding specifications have been already exposed.

As we use a vector GIS platform, the georeferencing of the ancient maps can be related to the polygon that identifies the boundary of the area covered by the image and its corresponding centroid, or even related to a point whose coordinates are accurately defined, as in the case of the views.

Once the different maps are accurately georeferenced and located, it is possible to place as a background another georeferenced raster cartographic base that is an image that provides a better understanding of the territories that are being studied. Both maps share a common coordinate system.

With the aim of comparing the ancient local maps with the situation that is depicted in the Mapa Topográfico Nacional (National Topographical Map series, 1875), we have planned to follow two main strategies: the use of geometric transformations and the application of transparencies to the images of the ancient local maps (Boutoura and Livieratos 2006).

Applying some geometric transformations (scaling, rotating, stretching…) to the local maps it is possible to fit both images. We have used as control points the geodetic bases of the Red Geodésica Nacional (National Geodetic Frame), that in this case are placed in the towers of the churches.

Applying the transparency it is possible to superpose the images of the ancient local maps to the raster map base and to find the different landmarks and the features that have been depicted in both documents.

Case Study: the landscape of Talavera de la Reina (Toledo, Spain)

Among the set of local maps we have chosen the 1767 local map of Talavera drawn by Antonio Plo, because it has a graphic scale and a simplified compass rose. The consistency of the scale on the whole

surface of the map is an important quality in order to transform the oldest map to the reference topographic map of the 19th century.

Figure 3. Antonio Plo, *Plano de la Villa de Talavera*, 1767. Biblioteca Nacional de España, Madrid.

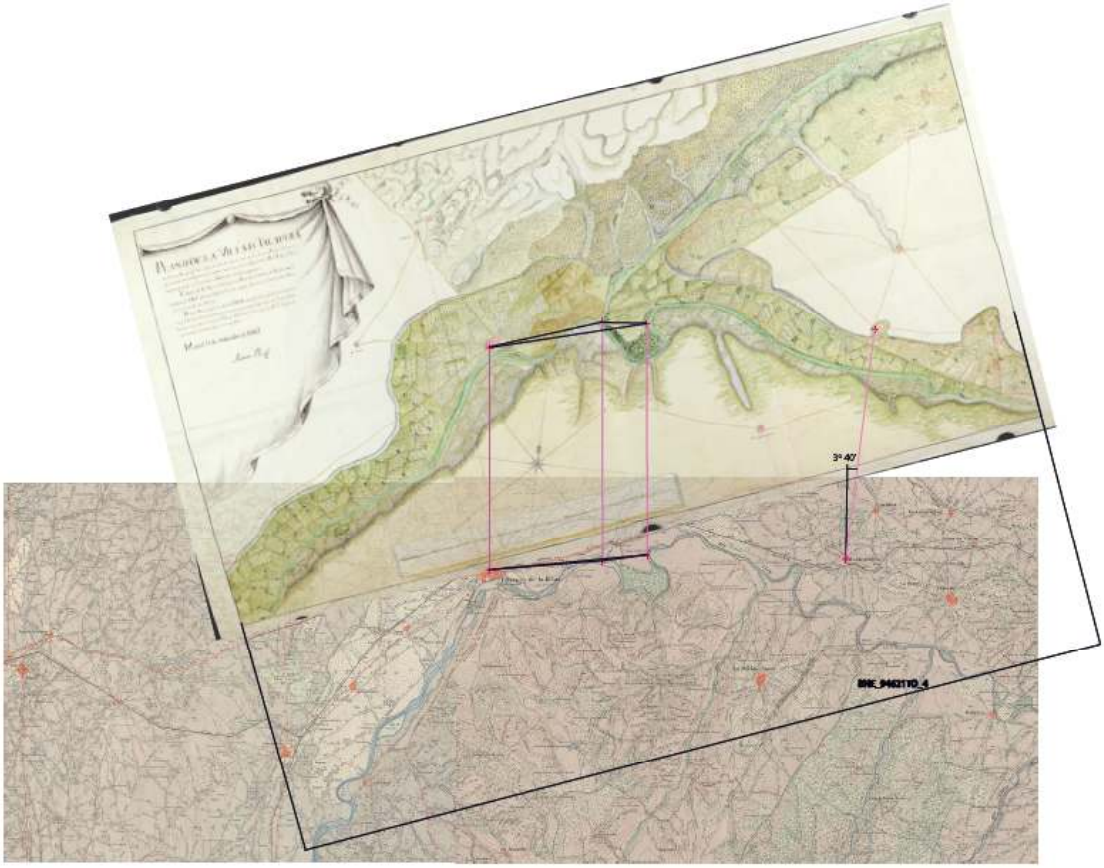

Figure 4. The river Tajo in 1769 and in 1875: the comparison made through transparency, stretching, rotation and superposition of both historical maps show the lands that risk to be submerged.

On the other hand, Plo had used the triangulation methods of surveying that should provide an adequate image of the territory.

According to Jenny (2006), the accuracy of the old maps has been established through two sets of control points and the sharing of the common coordinate system of the 19th century map. We have then transformed the 18th century local plan of Antonio Plo to the polyhedral projection over the Struve ellipsoid of the Mapa Topográfico Nacional (MTN, 1885 former edition) that had the origin of longitudes in Madrid (Martín López 2002).
The application of the scale factor and the rotation angle should determine an affine transformation. But the control points have revealed that the triangles of the local maps and the MTN were not affine, and that other control points did not superpose. Those facts demonstrate a lack of accuracy on the 1767 map and of the surveying techniques employed by Plo.
A second kind of transformations based on conditions which force the points on the local map to be transformed to fit exactly to the corresponding control points (point based warping transformation) (Balletti 2006) was not applied in this case.

Conclusion

According to the initiative of the Council of the European Union about the European Digital Libraries as a common multilingual access point to Europe's digital cultural heritage, and considering the ancient maps and plans as important cultural materials, we have developed an innovative GIS based methodology in ancient cartographic documents, whose essential values are:

- To create new cartographic relational, multiformat and multilingual databases that organise and unify the information that different archives and libraries have elaborated about their different funds, as well as to incorporate the dispersed and unknown documents that belong to non-digitised collections. This new information follows the ISBD Norm, and joins and completes the different approaches of the librarian, the historian (Edney 2007) and the more technical of the cartographer.
    - The new databases join both already digitised materials and new information that we have directly produced in a digital format. These circumstances allowed us to get some mechanisms that facilitate the digitalisation of maps, to identify problems and to monitor bottle-necks (as those that appear handling big size maps).
    - They allow also to preserve the original materials, that are usually fragile.
- The open GIS surpasses the usual operability of the traditional multiformat databases as it enlarges through the queries the way to access to the different kind of data. But we have also disposed a new and personalised way to access to high resolution digital images of the documents by applying the hypermedia concept.
    - Our methodology provides an easy and successful electronic integration of metadata and text, graphics and numerical information about early maps.
- On-line accessibility and diffusion through the Internet, as a response to a real demand among citizens and within the research community, always paying attention to the full respect to the international legislation in the field of intellectual property.
- This new methodology has been created aiming to be an open one that allows being implemented in all countries of the European Union.

The ancient Spanish cartography e-Library provides an easy access to all the maps and plans referred to a definite territory, and their study can give a complete information about the land uses, the road frame, the geographic features and the urban morphology, among others.
The digital techniques provide some interesting tools to transform the digital images and to begin different comparison processes depending on the particular targets of the search.

The affine transformations, as well as the application of transparencies to the local images, make possible the superposition of the maps. Other transformations are also available, but they should be applied depending on the particular aims of the search.
This way it has been possible to get some essential information about the evolution of the geographical features and the human constructions along more than a hundred years.
The main variations that have occurred in the geographical features and the landscape can be focused on the changing meanders of the river Tajo, that evidence the risk of flood in the adjacent plots. This is particularly important if we consider the already existing tendency to invade the river's bed with cultivations and constructions.
It is also important to notice that the road construction has followed the historical paths and has been usually superposed to the old routes.
The urban frame of the town of Talavera has also grown increasingly, while the old villages that surround the main town remain almost invariable or even decrease.
Finally we must remember that the differences in reliability between maps, or even between different parts of the same map, are not only due to the surveying techniques, but also to their original function. An adequate use of the image transformation techniques in comparative methods can ensure the success of the analysis.

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Both are inscribed into our searchers' guidelines on the investigation of the cultural heritage through the application of the most innovative technologies, as GIS and multiformat databases, that set up an essential basis for the knowledge of the history of the territory, the landscape and the town. Since a decade our team is engaged on setting up different useful methodologies that are being implemented in the Technical School of Architecture and Geodesy of the University of Alcalá.

References

Andrews, J.H. (2005). Meaning, knowledge and power in the philosophy of maps. In J.B. Harley, *The new nature of maps. Essays in the history of cartography.* Baltimore, Maryland: The Johns Hopkins University Press: 21-58.

Balletti, C. (2006). Georeference in the analysis of the geometric content of early maps. *e-Perimetron* 1 (1): 32-42. Viewed 20 February 2009, <http://www.e-perimetron.org/Vol_1_1/Vol1_1.htm>

Blakemore, M. and J.B. Harley (1980). Concepts in the History of Cartography. A review and perspective. *Cartographica* 17 (4): 1-120.

Boutoura, C and E. Livieratos (2006). Some fundamentals for the study of the geometry of early maps by comparative methods. *e-Perimetron* 1 (1): 60-70. Viewed 20 February 2009, <http://www.e-perimetron.org/Vol_1_1/Vol1_1.htm>

Chías, P. and T. Abad (2006). A GIS in Cultural Heritage based upon multiformat databases and hypermedia personalized queries. *ISPRS Archives* XXXVI-5: 222-226.

Chías, P. and T. Abad (2008). A GIS in Ancient Cartography. In *3rd International Workshop – ICA Commission on Digital Technologies in Cartographic Heritage*. Barcelona: ICC, 290-296.

Chías, P. and T. Abad (2008a). A GIS in Ancient Cartography: A New Methodology for the On-Line Accessibility to the Cartographic Digital Libraries. In *VSMM 2008. Digital Heritage. Proceedings of the 14th International Conference on Virtual Systems and Multimedia. Full papers,* M. Ioannides, A. Addison, A. Georgopoulos y L. Kalisperis (eds.). Limassol, Cyprus: VSMM / CIPA / ICOMOS, 125-130.

Commission of the European Communities (2005). *i2010: Digital Libraries*. Brussels.

De Seta, C. (1996). L'iconografia urbana in Europa dal XV al XVIII secolo. In *Cittá d'Europa. Iconografia e vedutismo dal XV al XIX secolo.* Napoli: Electa, 11-48.

Egil, H.R. and P. Flury (2007). GIS-Dufour: historical maps as base in a geographical information system. In *Paper and poster abstracts of the 22nd International Conference on the History of Cartography,* M. Oehrli (ed.). Murten: Verlag Cartographica Helvetica, 196.

Fleet, C. (2007). Digital Approaches to Cartographic Heritage: The Thessaloniki Workshop. *Imago Mundi* 59 (I): 100-104.

Harley, J.B. (1968). The evaluation of early maps: Towards a methodology. *Imago Mundi* 22: 68-70.

Harley, J.B. and D. Woodward (1987). Preface. In *The History of Cartography: Cartography in Prehistoric, Ancient, and Medieval Europe and the Mediterranean,* J.B. Harley and D. Woodward (eds.). Chicago, Illinois: The University of Chicago Press, I, xv-xxi.

Harvey, P.D.A. (1980). *Topographical maps. Symbols, pictures and surveys.* London: Thames and Hudson.

Heere, E. (2006). The use of GIS with property maps. *e-Perimetron* 4 (1): 297-307. Viewed 2 July 2008, < http://www.e-perimetron.org/Vol_1_4/Vol1_4.htm>.

Jenny, B. (2006). Map Analyst – A Digital tool for the analysis of the planimetric accuracy of historical maps. *e-Perimetron* 1 (3): 239-245. Viewed 2 July 2008, <http://www.e-perimetron.org/Vol_1_3/Vol1_3.htm>

Jobst, M. (2006). Hybrid considerations on the sustainability of cartographic heritage. *e-Perimetron* 1 (2): 127-137. Viewed 30 January 2009, <http://www.e-perimetron.org/Vol_1_2/Vol1_2.htm>

Kagan, R.L. (1998). *Imágenes urbanas del mundo hispánico, 1493-1780.* Madrid: Ediciones El Viso.

Livieratos, E. (ed.) (2006). *Digital Approaches to Cartographic Heritage.* Thessaloniki National Centre for Maps and Cartographic Heritage.

Livieratos, E. (2008). The challenges of Cartographic Heritage in the Digital World. In *Third International Workshop 'Digital Approaches to Cartographic Heritage.* Barcelona. Viewed 10 July 2008, <http://web.auth.gr/xeee/ICA-Heritage/Commission/3rd_Workshop/Livieratos_Heritage_Barcelona.pdf >

Martín López, J. (2002). *Historia de la Cartografía y de la Topografía.* Madrid: Ministerio de Fomento, CNIG, 280-282.

Orciani, M., V. Frazzica, L. Colosi and F. Galletti (2007). Gregoriano cadastre: transformation of old maps into Geographical Information System and their contribution in terms of acquisition, processing and communication of historical data. *e-Perimetron* 2 (2): 92-104. Viewed 2 July 2008, < http://www.e-perimetron.org/Vol_2_2/Vol2_2.htm>.

Skelton, R.A. (1965). *Looking at an early map.* Lawrence, Kansas: University of Kansas Library.

Vázquez Maure, F. and J. Martín López (1989). *Lectura de mapas* Madrid: Instituto Geográfico Nacional.

Zentai, L. (2006). Preservation of modern cartographic products. *e-Perimetron* 4 (1): 308-313. Viewed 2 July 2008, < http://www.e-perimetron.org/Vol_1_4/Vol1_4.htm>.