*e*Content*plus*

DIGMAP

Discovering our Past World with Digitised Historical Maps

Description of Work

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1 Rationale

DIGMAP stands for “Discovering our Past World with Digitised Historical Maps”, but It could stand also for, “digging on maps”!

Europe is a continent with a very old and heterogeneous political history. Its large diversity of cultures has been a reason for the definition of multiple borders, but the closed space has been promoting also the inevitable exchanges between people. Our political and social dynamics have raised the need, since a long time, for a clear perception of the territory. Also, when the European people went to outside their borders, they led the mankind in the exchanges and common discovery of the overall World. As a result, the European legacy in historical maps is enormous, very rich and diversified! This cultural and scientific genre of artefacts represents therefore a special perspective of our history.

This European legacy of historical maps is mainly in the hands of many European national libraries, archives, and related public institutions. Those maps are usually described in catalogues, and important collections have been digitised and made available in the Internet. To be able to explore this kind of material in high resolution is a pleasure the scholars have been used to, but which has been made possible usually only on local networks and after special requests. However, at least medium/low resolution copies have been made available in the Internet, for the general public.

Assuming that historical maps have important details that make them very difficult (and therefore expensive) to describe, classify and index in “hand-made” descriptive metadata structures, them we must conclude that the actual related discovering services might be not giving us the best of the worlds.

With these assumptions in mind, we propose to develop a modular software solution to make it possible the development of flexible services for indexing, searching and browsing in collections of digitised historical maps. Maps have a special characteristic: they represent always a limited physical space on Earth. In that sense, we propose to index the maps by their geographic boundaries, and develop technology for services to make it easy (and cheap) to classify, index, search and browse them with the support of multilingual geographic thesauri. This will make it possible, for example, to find all the maps in a collection were Paris is represented, even if they were not described or indexed by “Paris”. Using geographic thesauri with the geographic coordinates of Paris, it is possible to match that with the geographic areas covered by each map in the collection. A system like that could try to take advantage of any available descriptive metadata to improve the search and browse, but even if such exists and "Paris" is not referred there, it'll be not easy to provide positive matches (which can be always assured by the objective geographic information).

These will be the basic functionalities of the system. But we are also proposing more advanced features for the automatic indexing of historical maps, in order to make it possible to add to the collections and process new maps at zero human cost. This can be reached by comparing, at the image level, the new maps with the rest of the collection. Maps can be very rich in decorative and stylistic details, making them very different from, for example, photos. Therefore, this will require much more then simple image comparing, and so new image processing techniques will be tested for this purpose. The system will offer also a browsing environment for humans, in some sense similar to Google Maps [25], but with special features such as timelines (relevant for those maps where it is possible and easy to assess the date).

The software solutions produced in DIGMAP will be released as open-source. They will able to be used as a local digital library of maps, as a standalone system, or as a component integrated with a wider local system (such as for example by a portal management system). Therefore, it will be based on open data models and will be made interoperable with remote systems.

Finally, the project will produce itself three other results in the form of services that will be maintained after the end of the project’s phase, in sustainability scenarios related with the partner’s wider scope (such as for example TEL [54]):

- The “International Catalogue of Digitized Ancient Maps”, integrating
- The “International Authority Database of Maps Engravers, Editors and Printers”
- The “European Multilingual Geographic Thesaurus”

1.1 Scenario: registering a map

Let us imagine a scenario for the registering in the system of the map shown in the Figure 1, available at[1]:

http://www.cia.gov/cia/publications/factbook/maps/sp-map.gif

In this scenario a DIGMAP professional user would start by providing the map URL to the cataloguing system, which would results in the retrieval of the image and the local calculation of its size, in pixels. In a second step the professional would choose at least two points and register them. For each of those points it has to be provided the pair of the physical coordinates in the image (the horizontal and vertical pixels), and their respective geographic coordinates (observing and extracting them from the map). Instead of the coordinates, a name can be given. If that name exists in one of the available thesauri, such as the Getty Thesaurus of Geographic Names [20], the translation to the geographic coordinates can be done automatically. In this example we can choose for example the names "Andorra" and "Huelva", providing for each of them their physical coordinates in the image. In DIGMAP the user will be able to provide these horizontal and vertical pixels automatically trough a point and click flexible user interface.

Finally, and having already the geographic coordinates of the points, the system can complete the record automatically by simply calculating the map full geographic area (in our example the coordinates are shown in decimal degrees, for our actual convenience, but DIGMAP will be able to process the same information in degrees). This simple process creates a valuable map record. If other metadata exists for the map, it could be also added to the system, either by value or reference.

Map Record - data provided by a user	
Size_pixel:	[240, 256]
Point: Andorra	[185, 065]
Point: Huelva	[036, 184]
Corner_LU:	___
Corner_RD:	___

Geographic Thesaurus	
…	
Andorra	[42.50, 01.50]
…	
Huelva	[37.50, -07.00]

Map Description

Map Record – data completed by the system	
Size_pixel:	[240, 256]
Point: Andorra	[185, 065]
Point: Huelva	[036, 184]
Corner_LD:	[34.45, -08.91]
Corner_RU:	[45.25, 04.67]

Figure 1: A map with two chosen reference points

1.2 Scenario: automatic indexing of a map

In another scenario, DIGMAP proposes also to develop advanced features for automatic indexing of maps. The purpose is to allow the addition of new maps to collections without (or with little) human intervention, by using information associated to maps already catalogued in the collection. This will be very valuable for retrieval purpose (and not forcibly for description). To this end, we suggest an approach in two steps:

- First, we apply image processing techniques to extract the more relevant information and discard useless data from the maps (such as decorative elements). This will be not a simple task, because two maps of the same place can have very different representations, as illustrated in the case in the Figure 2 (representing the island of Santa Catarina, in the Brazil, and available online in two Portuguese site, respectively at the National Digital Library[2] and at the Geographic Institute of the Army[3]). For this, we

[1] It is VERY IMPORTANT to stress that this is not an historical map! We are using it only to illustrate this example, since its small size and clear style makes it easy to perceive! In DIGMAP we'll consider only historical maps!!!

[2] http://purl.pt/886/2/

will develop methods to identify and represent only the most relevant features present in the maps, so we will be able to perform selective partial matching. By this way, we believe we can deal with the ambiguities and differences present in maps representing the same geographic areas. Although the challenge is not trivial to solve, we will address it in a structured way making it possible to learn where we can have success and in which cases new approaches will have to be found.

- Second, we compare the models created for the new map (contours detections; vectorial, fractal descriptions, etc.) with the same models of all the maps already registered. During insertion of a new map in the system, its geometric and geographic characteristics will be compared with the same genre of information of the already indexed maps. After finding a similar map, new relevant attributes and information will be automatically created for the new map (copying information directly from the indexed map, or by extrapolating it).

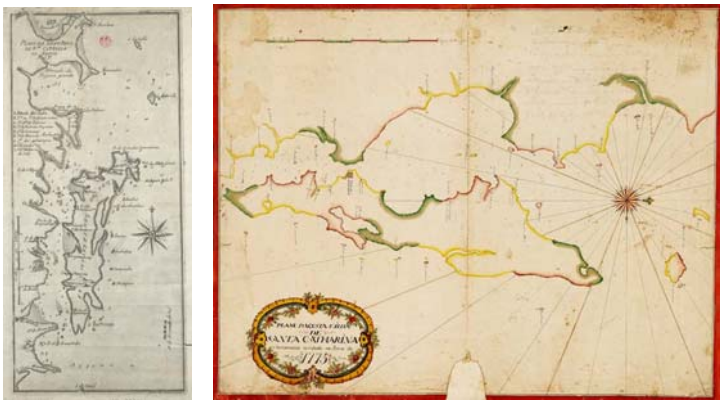


Figure 2: Two matching maps representing the same geographic region.

1.3 Scenario: searching for a map

Let us now imagine that we want to search for maps where Gibraltar is represented. In a traditional system, as those used usually in libraries and archives, a retrieval process for that would be supported mainly by the descriptive metadata (usually a UNIMARC or MARC21 like record). In a more advanced scenario where a search engine could index the web site of the map, if "Gibraltar" is not referred in the descriptive metadata but if it is mentioned in the site, we could still retrieve it. This would be for example the case represented in Figure 3, an atlas existing in Portugal, in the National Digital Library, at http://purl.pt/784, with a UNIMARC record shown in the right and represented in an ISBD visualisation in the figure. This record has not any reference to "Gibraltar", but we have it in text in the index of the HTML site were it was published.

Figure 3: An atlas, with a UNIMARC descriptive record.

LDR: 00748cem 2200229 450
001: 279610
005: 20020306132900.0
095: $a PTBN00290793
100: $a 19951228d1786 m y0pora0103 ba
101: 0 $a spa
102: $a ES
200: 1 $a Atlas marítimo de España $b Material cartográfico $f A. Valdés e V. T. de S. Miguel
210: $a [S.l. $c s.n.], $d 1786
215: $a 1 atlas, 18 cartas $d 61 cm
675: $a 527(460)(084.4) $v BN $z por
675: $a 914.60(084.4) $v BN $z por
675: $a 912"17"(084.4) $v BN $z por
700: 1 $a Valdés, $b Antonio, $f fl. 1786
701: 1 $a Torfino de San Miguel, $b Vincente, $f ca 1732-1795 $4 070
712: 02 $a Ordem de Cister. $b Mosteiro de Santa Maria $c (Alcobaça) $4 390
801: 0 $a PT $b BN $g RPC
856: 4 $u http://purl.pt/784
966: $l BN $m CART $s C.A. 10 R.

[3] http://www.igeoe.pt/diversos/sidcarta/220/4279-1A-10A-53.jpg

In the case of a searching for our reference map, it would be very unlikely that such record would have any reference to Gibraltar on it, so this map would never be retrieved. However, using DIGMAP we would do it! Still using our geographic thesaurus, we could retrieve the geographic coordinates of "Gibraltar" and then query the maps records not by their descriptive content, but by their geographic area. In this case we would learn that our map of Figure 1 comprises the geographic point of Gibraltar. And we could even calculate its physical location (horizontal and vertical pixels), creating a pointer to it, as represented in Figure 4.

Geographic Thesaurus

…
Andorra [42.50, 01.50]
…
Gibraltar [36.15, -05.35]
…
Huelva [37.50, -07.00]
…

Record of the map

Size_pixel:	[240, 256]
Point: Andorra	[185, 065]
Point: Huelva	[036, 184]
Corner_LD:	[34.45, -08.91]
Corner_RU:	[45.25, 04.67]

Gibraltar in the map

Point: Gibraltar [062, 209]

Figure 4: A map signalling a searched point

1.4 Scenario: showing more of a map

Using the same strategy of matching geographic points (with information in the thesauri) with physical points in the image, we could for example find the same point in the specific map from the atlas of the Figure 3. But we could provide even more! BN has this atlas digitised at high resolution (600dpi, 24bit colour, TIFF format), which is available only in the library's local network. In this case, a local installation of DIGMAP, running inside the intranet, could have permission to access this master copy of the map, and make more advanced processing.

Using image processing (based as for example in the detection of shapes, contours and other characteristics), DIGMAP could learn that the point representing Gibraltar in this map would be inside a well detected area, possibly defined as rich in information (due to a high variation of colours/patterns, for example) surrounded by areas defined as of little information (with uniform colours/patterns, for example). This would be valuable to infer that might it would be useful to the user to stress those characteristics. That can be done extracting the focus area and presenting it in a larger detail, as illustrated in the Figure 5.

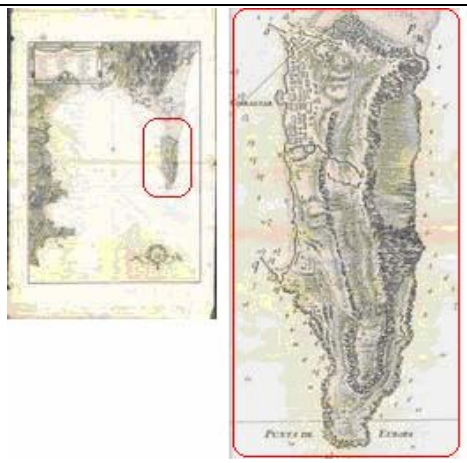


Figure 5: Visualisation of a retrieved area with higher detail.

1.5 Scenario: browsing for maps

The system will offer also a browsing environment for human users. The interface will be, in some sense similar to Google Maps [25] or Virtual Earth [41], but with special features specific to explore the actual contents, such as timelines (for those maps where it is possible and easy to assess the date) and other indexing features. DIGMAP will give special attention to the development of visual clues, functions for browsing by collections, date periods, geographic areas, and other characteristic that can be extracted not only from the metadata but also directly from the digitised image of the maps and that can be used to create indexes for powerful but easy and pragmatic retrieving (and not forcibly for formal descriptions, which would require a higher level of quality control, possible involving human intervention, and therefore the costs that we are trying to avoid).

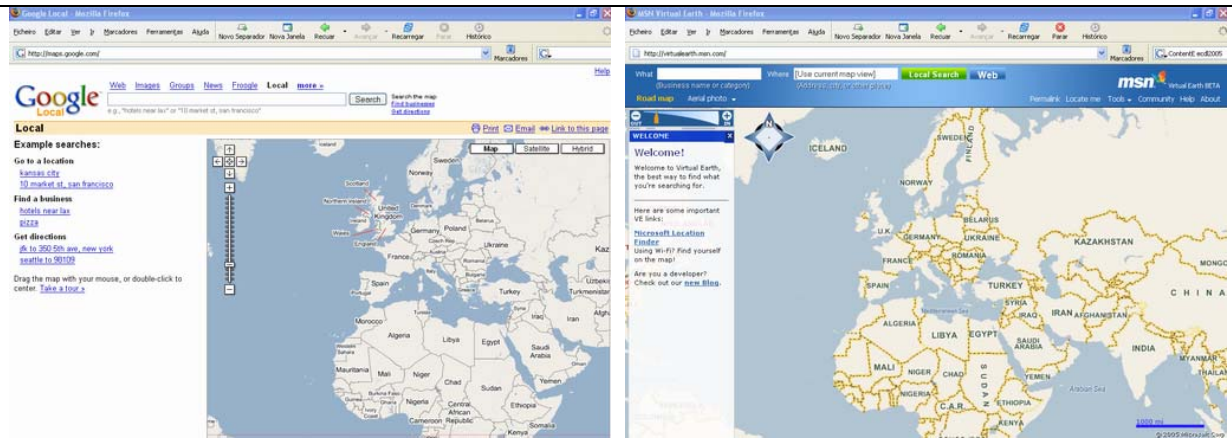


Figure 6: Google Maps and Virtual Earth interfaces will be used as reference for the DIGMAP user interface.

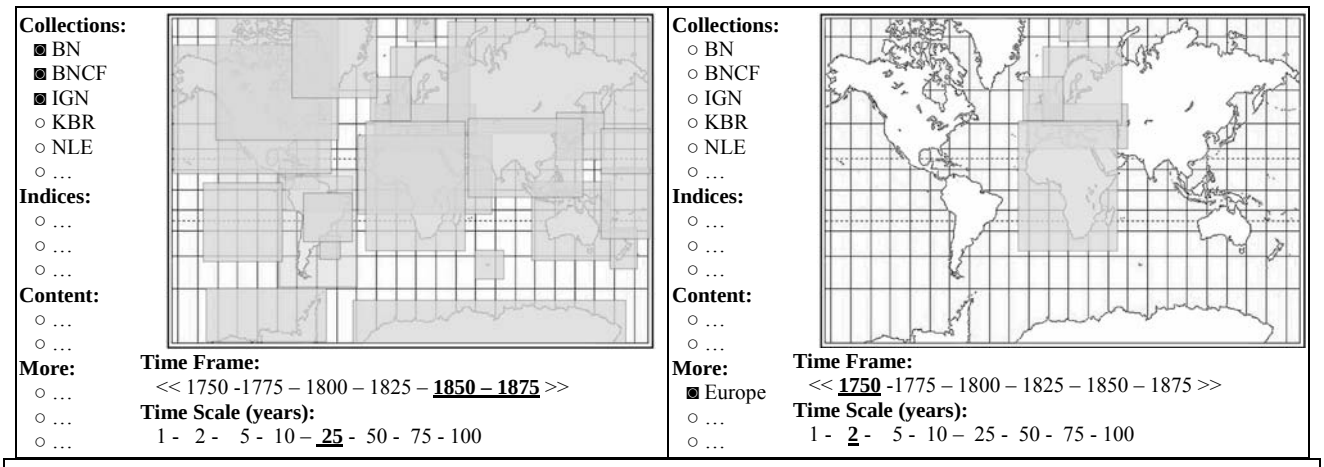


Figure 7: DIGMAP will give special attention to the development of visual clues for the user interface.

1.6 Scenario: external interoperability

Nowadays we live in a networked world. The information society that we are building will be not owned by a single entity neither will be the result of a unique technology. Instead, it'll be the global result of a wide and open cooperation of multiples entities and of encapsulated technological solutions, according with visions such as expressed by the Semantic Web [52].

DIGMAP will give a special attention to this world, promoting all the kinds of relevant solutions for external interoperability with other systems and services (portals, services like Google Maps API [26], etc.). For this, the applications and services to be developed will share features with others in the sense of simplify the linking through keywords to places. To the best of our knowledge this will be the first attempt to promote a wide and systematic linking of historical terms and locations among different services, allowing cross searching with terms or places of mostly historical interest within present day maps, a service to be enabled by this project. Conversely, given a present spatial coordinates it will be also possible to query DIGMAP to check for any geographic place or historical event which took place there.

2 Proposed Solution and Expected Results

2.1 The DIGMAP Services

The software solutions produced in DIGMAP will be released as open-source. They will able to be used as a local digital library of maps, as a standalone system, or as a component integrated with a wider local system (managed for example by a portal management system). Therefore, it will be based on open data models and will be made interoperable with remote systems.

DIGMAP will produce three services that will be maintained after the end of project:

- The "International Catalogue of Digitized Ancient Maps": This service will register or import references to maps (with a URN/URI for each map), as also structured description of the geographic information of the maps belonging to the partners or found in the Web (geographic boundaries, scales, details such as possible detailed maps inside a wider generic map, etc.).
- The "European Multilingual Geographic Thesaurus": DIGMAP will develop a framework to manage multiple thesauri in the same system, with possibilities of cross-references between them! The instantiation of that in the main service "International Catalogue of Digitized Ancient Maps" will be a service in itself.
- The "International Authority Database of Maps Engravers, Editors and Printers": This will be another service accessible trough the "International Catalogue of Digitized Ancient Maps". This service will be integrated in the main DIGMAP service, but it will be promoted with its own identity.

2.2 The DIGMAP Framework

The software solutions produced in DIGMAP will be released as open-source. They will able to be used as a local digital library of maps, as a standalone system, or as a component integrated with a wider local system (managed for example by a portal management system). Therefore, it will be based on open data models and will be made interoperable with remote systems.

An important component to be produced in the project will be the Indexer. The main purpose is to identify relevant areas in the images of the maps, compare those areas of different maps looking for overlaps, produce indexes with these results, and support geographic queries using these indexes. This toolset will be a component of the DIGMAP Information System, but it'll be able to be used independently as a standalone component in itself. Therefore its interfaces will be carefully designed for that purpose.

The DIGMAP Information System will have the architecture shown in Figure 8. This infrastructure will be used in a DIGMAP Central Service, maintained by the co-ordinator partner, and will be installed locally in all the other partners that will express the will for that. This infrastructure can be used for local digital libraries of maps, both as a standalone system or as a component integrated in another system (like for example a portal management system).

The DIGMAP Information System will be released in the end of the project as open-source. It'll be all based on open data models and will be interoperable with remote systems through WMS - Web Map Service, CSW - Catalogue Web Service, and others conformal with OGC - Open GeoSpatial Consortium [43]. However, we will explore also a wider range of technical solutions for interoperability with other communities, like Z39.50 [64], SWW/SRU [53], OAI-PMH [60], Google Maps API [26], etc.

We assume clearly that the value of these results will be not in the software in itself, but in the added value of its wide re-use in services by other European libraries, archives and other institutions with digitized historical maps and willing to disseminate its information and promote its access!

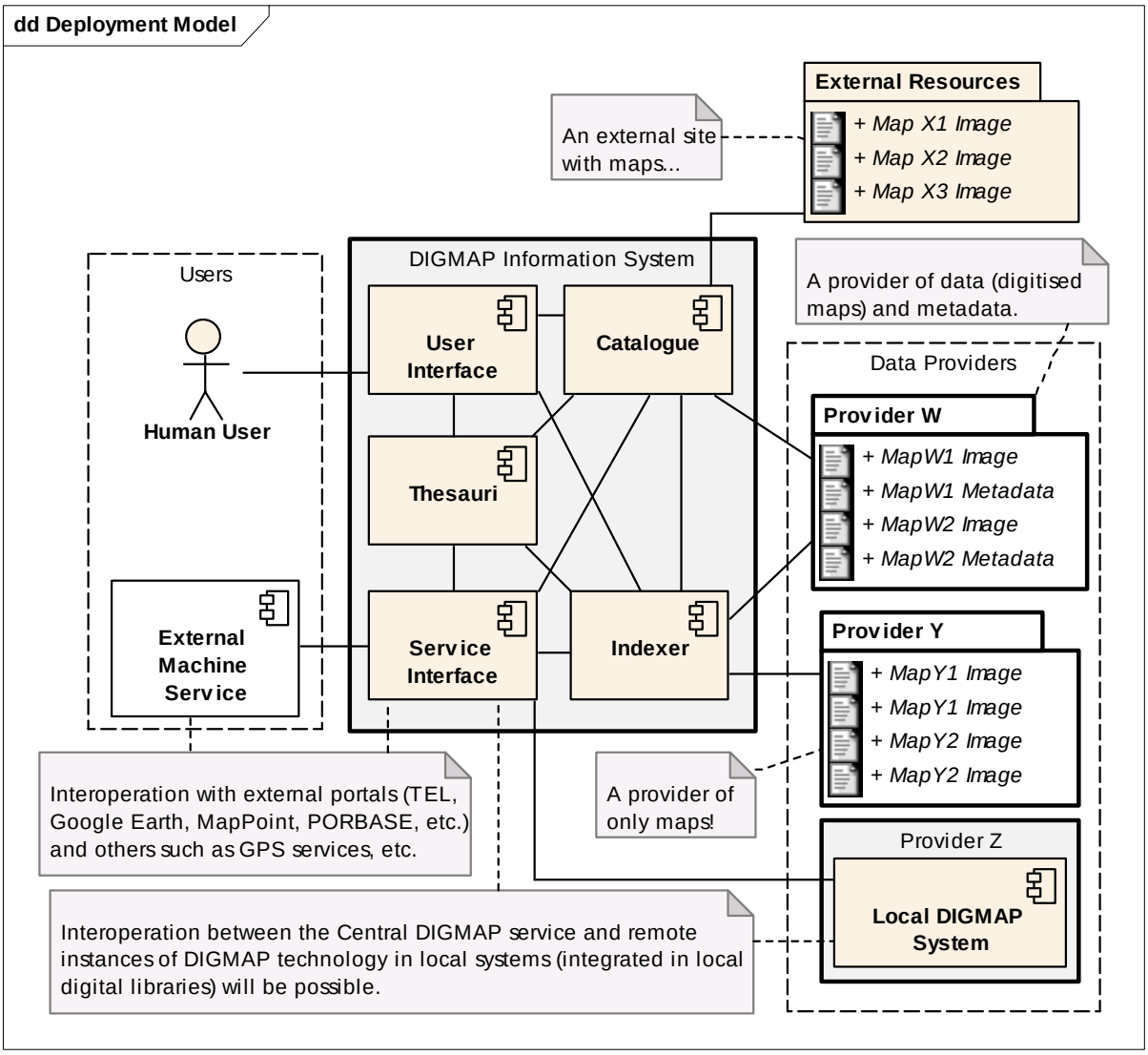


Figure 8: The DIGMAP Information System.

3 List of Participants

Role[4]	No.	Participant name	Short name	Country
CO	1	Instituto Superior Técnico	IST	Portugal
BE	2	Universidad Politécnica de Madrid	UPM	Spain
BE	3	National Library of Portugal	BN	Portugal
BE	4	Royal Library of Belgium	KBR	Belgium
BE	5	Biblioteca Nazionale Centrale di Firenze	BncF	Italy
BE	6	National Library of Estonia	NLE	Estonia
BE	7	Institute of Mathematics and Informatics of the Bulgarian Academy of Sciences	IMI	Bulgaria

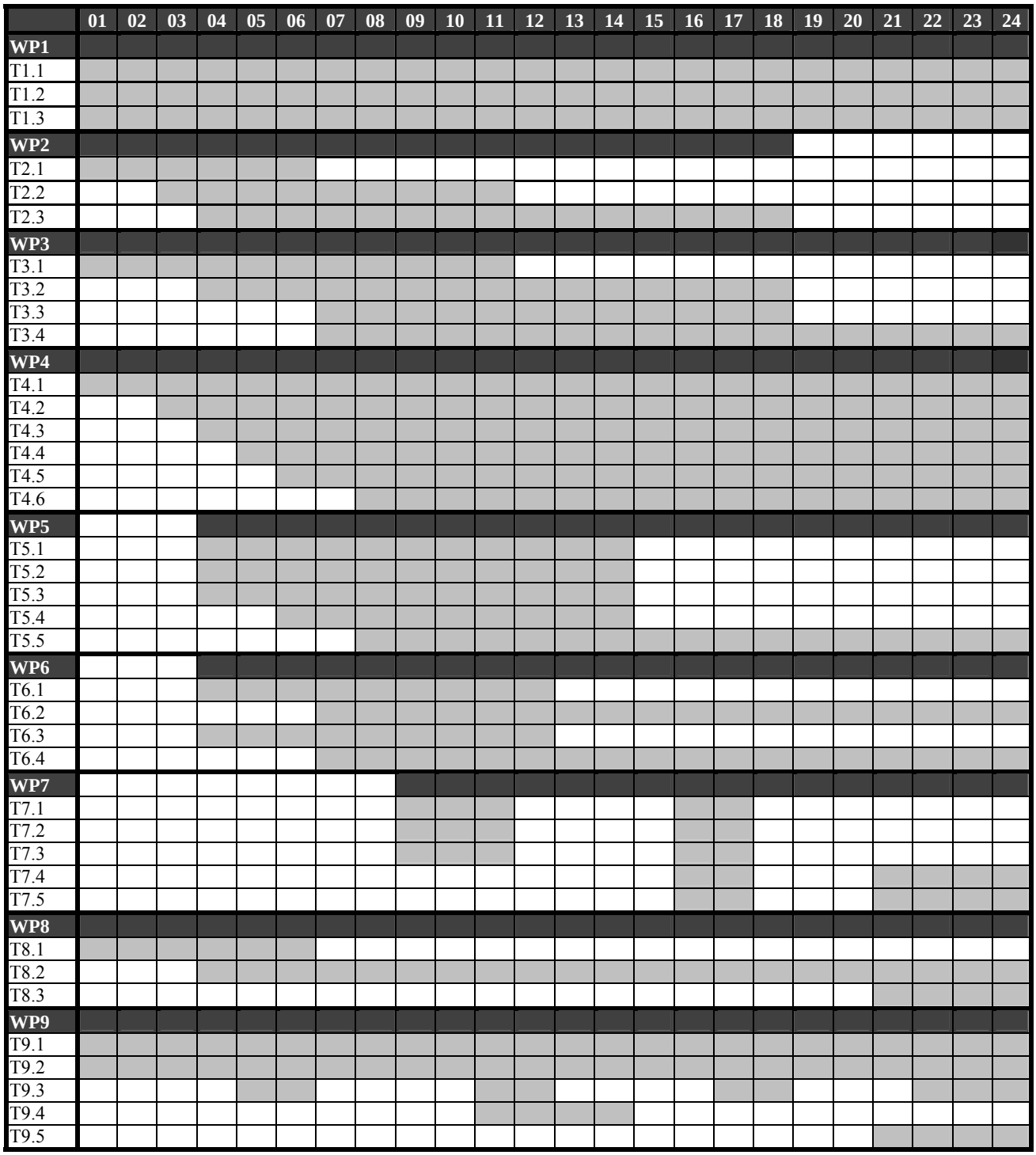
[4] Either CO- Coordinator or BE - Beneficiary

4 Detailed Implementation plan

4.1 General description of the work plan

The project will be developed in 9 work packages, detailed in the next sections. The work package 1 will assure the project management, and will be co-ordinated by the IST. The technical work will be developed in the work packages 2 to 6, co-ordinated by IST, UPM and KBR. The work package 7 will assure the assessment and evaluation of the results, and will be co-ordinated by the NLE. The work package 8 will promote an external advising group. This work will be coordinated by the BNCF. Finally the work package 9 assures the actions for dissemination, co-ordinated by BN.

4.2 Project plan



4.3 Graphical presentation

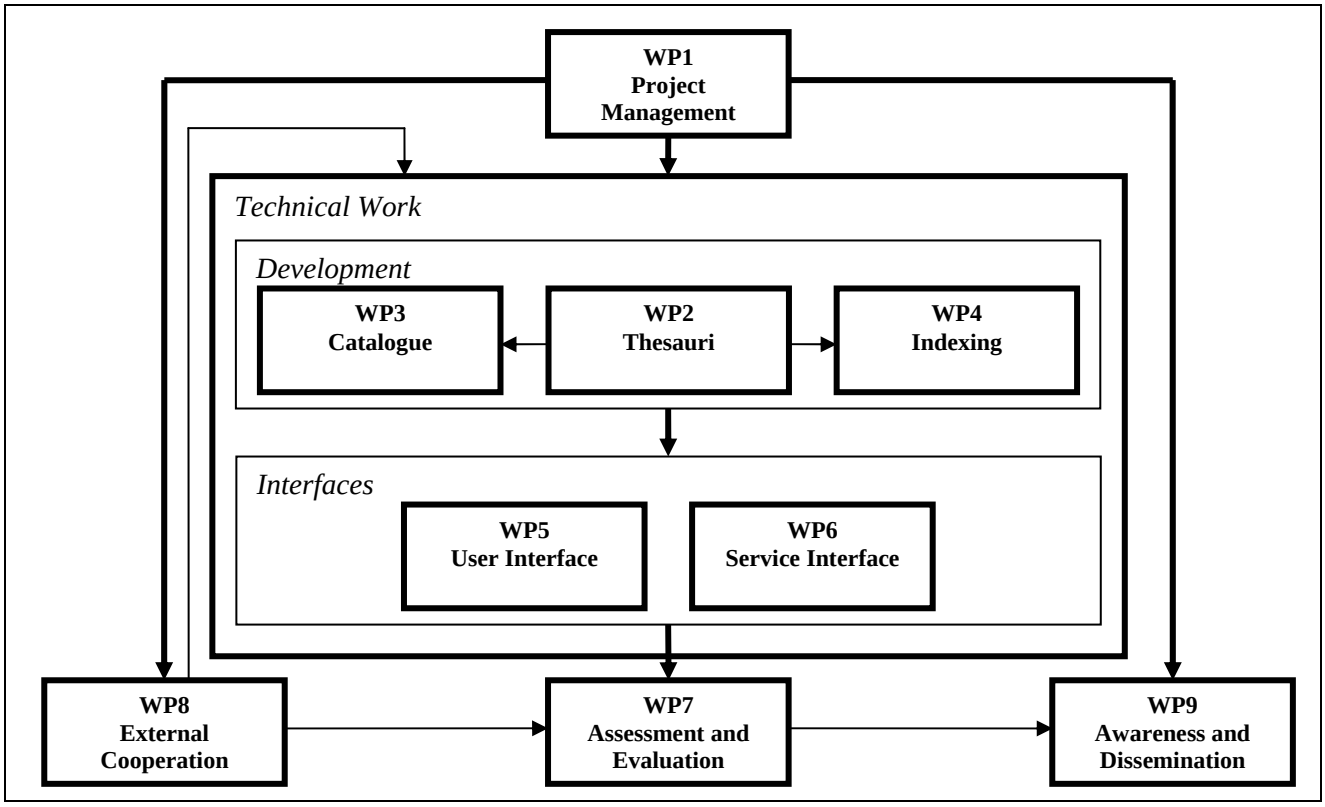


Figure 9: Work packages dependencies

4.4 Work package overview

Work packageNo	Work package title	Lead Contractor No	Start month	End month
WP1	Project Management	P1	M01	M24
WP2	Thesauri	P2	M01	M18
WP3	Catalogue	P4	M01	M24
WP4	Indexing	P2	M01	M24
WP5	User Interface	P4	M04	M24
WP6	Service Interface	P1	M04	M24
WP7	Assessment and Evaluation	P6	M09	M24
WP8	External Cooperation	P5	M01	M24
WP9	Awareness and Dissemination	P3	M01	M24
	TOTAL			

4.5 Work package description

Work package number :	WP1	Start date:	M01	End date:	M24
Work package title:	**Project Management**				
Objectives					

The main objectives of this work package are (done in close co-operation with the local project managers):

- To manage the administrative and functional coordination between the partners;
- To manage the financial responsibilities of the consortium;
- To manage the technical tasks of the project.

Work package number :	WP2	Start date:	M01	End date:	M18
Work package title:	**Thesauri**				
Objectives					

The objectives of this task will be the development of a system to manage multilingual geographic thesauri. This will be developed as a semantic information system, to manage and provide access to information relating to geographic coordinates, name of places, names of areas, and historical events related with the geographic points, places or areas (with dates or time intervals).

We will not target in one specific thesaurus. Instead, we will develop a framework to manage multiple thesauri in the same system, with possibilities of cross-references between them! The framework will be able to interoperate also with external thesauri, if their interfaces are available.

Work package number :	WP3	Start date:	M01	End date:	M24
Work package title:	**Catalogue**				
Objectives					

The objective of this work package is to produce the DIGMAP Catalogue. A specific module, the Catalogue, will make it possible to register or import references to maps (with a URN/URI for each map), as also structured description of the geographic information of the maps (geographic boundaries, scales, details such as possible detailed maps inside a wider generic map, etc.). This catalogue will be able to maintain the descriptions of authorities and of the maps in multiple metadata formats, when available, especially in ISO 19115 [32], MARC21 and UNIMARC [30], Dublin Core [58], etc.

Work package number :	WP4	Start date:	M01	End date:	M24
Work package title:	**Indexing**				
Objectives					

The main objective of this task is to produce a toolset for content-based image retrieval tuned for the special case of the historical maps. This is a very complex problem, not new for the community (see for example [38], [7], [11], [12], [1],[16], [14] , [62], [46], etc.), but as far as we could confirm it, its application focused in this area is innovative ([27] is one of the very few references that we could find).

This task will be made possible by the synergies of the strong engineering competencies of IST and deep knowledge of the original data resources and its contexts by UPM and the other data providers.

Work package number :	WP5	Start date:	M04	End date:	M24
Work package title:	**User Interface**				
Objectives					

This work package will produce the DIGMAP Human Service Interface. This will be a multilingual service for users to search and browse in collections registered in the DIGMAP Information System, through its main services:

- "International Catalogue of Digitized Ancient Maps", including
- "International Authority Database of Maps Engravers, Editors and Printers"
- "European Multilingual Geographic Thesaurus"

In this task we will promote a careful analysis of experiences of relevant related services or projects, such as [25], [3], [55], etc.

Work package number :	WP6	Start date:	M04	End date:	M24
Work package title:	**Service Interface**				
Objectives					

The objective of this task is to develop two functional modules for interoperability with external systems and services, using traditional web-service technology or others relevant.

One interface, the "External Service Interface" will provide on-line searching services for and with external services (such as portals).

Other interface, the "Internal Service Interface" will be internal to the architecture of the framework, in order to make it possible to different DIGMAP Information Systems to interoperate in a uniform network.

Work package number :	WP7	Start date:	M09	End date:	M24
Work package title:	**Assessment and Evaluation**				
Objectives					

The objectives of this work package will be to control the outputs of the project by developing a testing and validation plan and assure its application.

The tests will be performed by all the project's partners, with a special effort from the data providers (representing the potential users of the final technology). We will invite also other external entities to test the solutions, such as the TEL Central Office [54], members of AGILE and OGC [43], of the Advising Committee, etc.

Work package number :	WP8	Start date:	M01	End date:	M24
Work package title:	**External Cooperation**				
Objectives					

The objective of this task is to set up an external Advising Committee composed of individuals or representatives of relevant bodies or organisations. These members will have privileged access to all the relevant information from the project, and will be asked to express their opinions about it. The participation will be invitational, and the modus operandi will be based on email and meetings when possible.

Work package number :	WP9	Start date:	M01	End date:	M24
Work package title:	Awareness and Dissemination				
Objectives					
The main objectives are to disseminate the results of the project to target groups as well as to a broad audience. Interested professionals shall have the opportunity to get informed about the project, its perspective and results. A public web site, a newsletter and a final workshop shall guarantee the specific dissemination of information.					

5 References

[1] A. A. Goodrum. Image information retrieval: An overview of current research. Informing Science, 3(2):63-66, February 2000

[2] A. Zhang, B. Cheng, and R. Acharya. A Fractal-Based Clustering Approach in Large Visual Database Systems. The International Journal on Multimedia Tools and Applications, 3(3):225--244, November 1996

[3] Alexandria Digital Library Gazetteer Server Client - http://middleware.alexandria.ucsb.edu/client/gaz/adl/

[4] Antique maps of Iceland. http://kort.bok.hi.is/

[5] Billington, James H. Proposal for a World Digital Library - http://www.loc.gov/about/welcome/speeches/wdl/wdl_6-6-05.html

[6] Borbinha J., Pedrosa G., and Penas J. ContentE: Flexible Publication of Digitised Works with METS. Research and Advanced Technology for Digital Libraries: 9th European Conference, ECDL 2005, Vienna, Austria, September 18-23, 2005. Springer-Verlag, Lecture Notes in Computer Science. ISSN: 0302-9743 / DOI: 10.1007/11551362

[7] Charles Jacobs, Adam Finkelstein, David Salesin, "Fast Multiresolution Image Querying", Computer Graphics, Annual Conference Series (Siggraph'95 Proceedings), pp. 277-286

[8] CIRES: Content Based Image REtrieval System - Department of Electrical and Computer Engineering, The University of Texas at Austin, http://amazon.ece.utexas.edu/~qasim/research.htm

[9] COMPASS – Computer Aided Search System - http://compass.itc.it/ (Image Retrieval links: http://compass.itc.it/links.html)

[10] Computer Vision Meets Digital Libraries - Digital Library Project, University of California, Berkeley - http://elib.cs.berkeley.edu/vision.html

[11] Deselaers, T., Keysers, D., Ney, H.: FIRE - flexible image retrieval engine: ImageCLEF 2004 evaluation. CLEF Workshop (2004)

[12] E. Remias, G. Sheikholeslami, A. Zhang, and T. F. Syeda-Mahmood. Supporting Content-Based Retrieval in Large Image Database Systems. The International Journal on Multimedia Tools and Applications, 4(2):153--170, March 1997

[13] eContentplus Work Programme 2005 - http://europa.eu.int/information_society/activities/econtentplus/docs/call_2005/ecp_work_programme_2005.pdf

[14] Farzin Mokhtarian, Sadegh Abbasi, and Josef Kittler. Efficient and robust retrieval by shape content through curvature scale space. In Proc. International Workshop on Image Databases and MultiMedia Search, pages 35-42, Amsterdam, The Netherlands, 1996

[15] FIRE: Flexible Image Retrieval Engine - Computer Science Department, RWTH Aachen University, http://www-i6.informatik.rwth-aachen.de/~deselaers/fire.html

[16] Fonseca, M. J. and Jorge, J. A. Using Fuzzy Logic to Recognize Geometric Shapes Interactively. In Proc. of the FUZZIEEE 2000, San Antonio USA, May 2000

[17] French, Josephine. Tooley's Dictionary of Mapmakers. Revised Edition A - D. Tring: Map Collector Publications, 1999.

[18] French, Josephine. Tooley's Dictionary of Mapmakers. Revised Edition E-J. Riverside: Early World Press, 2001.

[19] GeoTransform - http://www.ai.sri.com/geotransform/

[20] Getty Thesaurus of Geographic Names <http://www.getty.edu/research/conducting_research/vocabularies/tgn/>

[21] GML - the Geography Markup Language - http://www.opengis.net/gml/

[22] Google Book Search - http://books.google.com/googlebooks/about.html

[23] Google Directory (Reference > Maps > Historical) - <http://directory.google.com/Top/Reference/Maps/Historical/>

[24] Google Library Project – An enhanced card catalog of the world's books - http://print.google.com/googleprint/library.html

[25] Google Maps (Google's world map resource featuring web-based search and satellite photos) - <http://maps.google.com/>

[26] Google Maps API - http://www.google.com/apis/maps/

[27] H. Samet and A. Soffer. MARCO: MAp Retrieval by COntent. IEEE Transactions on Pattern Analysis and Machine Intelligence, 18(8):783--798, 1996

[28] HDF-EOS Project - http://hdf.ncsa.uiuc.edu/hdfeos.html

[29] HTTrack Website Copier - http://www.httrack.com/

[30] IFLA-CDNL Alliance for Bibliographic Standards (ICABS). http://www.ifla.org/VI/7/icabs.htm

[31] IIPC – International Internet Preservation Consortium - http://www.netpreserve.org/

[32] ISO 19115:2003, Geographic information – Metadata. http://www.iso.ch/iso/en/CatalogueDetailPage.CatalogueDetail?CSNUMBER=26020&ICS1=35

[33] ISO 5964 - Guidelines for the establishment and development of multilingual thesauri.

[34] ISO TC 211 (ISO Geographic information/Geomatics technical committee aiming to establish standards for digital geographic data representation and exchange) - <http://www.iso.org/iso/en/stdsdevelopment/tc/tclist/TechnicalCommitteeDetailPage.TechnicalCommitteeDetail?COMMID=4637>

[35] J. Z. Wang, G. Wiederhold, O. Firschein, and S. X. Wei, "Content-based image indexing and searching using daubechies' wavelets," International Journal of Digital Libraries 1(4), pp. 311--28, 1998
[36] Map History / History of Cartography: THE Gateway to the Subject - http://www.maphistory.info/imageworld.html
[37] METS – Metadata Encoding and Transmission Standard. http://www.loc.gov/standards/mets
[38] Michael J. Swain, "Interactive Indexing into Image Databases", IS&T/SPIE International Symposium on Electronic Imaging: Storage and Retrieval for Image and Video Databases, February 1993.
[39] Microsoft MapPoint Developer Center - http://msdn.microsoft.com/mappoint/
[40] MINERVA – Ministerial Network for Valorising Activities in Digitisation - http://www.minervaeurope.org/
[41] MSN Virtual Earth (MSN web-based world map resource with road maps and aerial photography facilities) - http://virtualearth.msn.com/
[42] NCSA/NARA Technical Report: Scientific formats for geospatial data preservation - http://www.ncsa.uiuc.edu/NARA/Sci_fmts_and_geodata_HDF.pdf
[43] Open Geospatial Consortium - http://www.opengeospatial.org/
[44] Perry-Castañeda Library - Map Collection - Historical Maps - <http://www.lib.utexas.edu/maps/historical/>
[45] PORBASE – Base Nacional de Dados Bibliográficos – http://www.porbase.org (OPAC: http://opac.porbase.org)
[46] R.C. Veltkamp. Shape Matching: Similarity Measures and Algorithms. Technical Report UU-CS-2001-03
[47] Resource Description Framework (RDF). http://www.w3.org/RDF/
[48] Scalable Vector Graphics (SVG). http://www.w3.org/Graphics/SVG/
[49] Scott, Valerie. Tooley's Dictionary of Mapmakers. Revised Edition K-P. Riverside: Early World Press, 2003.
[50] Scott, Valerie. Tooley's Dictionary of Mapmakers. Revised Edition Q-Z Riverside: Early World Press, 2004
[51] SEEDI - South-Eastern European Digitization Initiative - http://www.ncd.matf.bg.ac.yu/seedi/
[52] Semantic Web. http://www.w3.org/2001/sw/
[53] SRW – Search/Retrieve Web Service - http://www.loc.gov/z3950/agency/zing/srw/
[54] TEL service (The European Library) - http://www.europeanlibrary.org/
[55] TerraVision - https://sourceforge.net/projects/terravision (also at http://www.tvgeo.com/)
[56] The Alexandria Digital Library (ADL) - http://www.alexandria.ucsb.edu/
[57] The Alexandria Digital Library Gazetteer - http://www.alexandria.ucsb.edu/gazetteer/
[58] The Dublin Core Metadata Initiative. http://dublincore.org/
[59] The Library of Congress - Map Collection: 1500-2004 - http://memory.loc.gov/ammem/gmdhtml/gmdhome.html
[60] The Open Archives Initiative Protocol for Metadata Harvesting - http://www.openarchives.org/
[61] The Ultimate GIS Search Engine - http://search.geocomm.com/
[62] Thomas B. Sebastian, Philip N. Klein, and Benjamin B. Kimia, "Alignment-based recognition of shape outlines," IWVF, pp. 606-618, 2001
[63] Viviane Reding (member of the European Commission responsible for Information Society and Media). i2010 : A new start for Lisbon and for European Information Society and Media policies, The i2010 Conference - London, 6 September 2005. <http://www.i2010.org.uk/keynote_speeches_Viviane_Reding.html>
[64] Z39.50 Maintenance Agency - http://www.loc.gov/z3950/agency/