Integrated Topographic, GNSS, Remote Sensing and GIS/WebGIS Techniques Applied to the Study of Aquileia River Port Structures

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Abstract. Integrated use of multidisciplinary researches have been applied in the last years for the study of Aquileia archeological sites and, in particular the River Port structures. Since 1992 GPS (Global Positioning System) techniques have been adopted with the aim of linking together various independent topographic networks and georeferencing single relevant points. In 2001 a scientific cooperation between different Institutions and national and international Research Centres has been established and renewed in 2006, in the framework of PICS 3064 CNRS Project. Different 3D topographic, geodetic, remote sensing, laser scanner and geophysical surveys have been performed and analyzed with the principal aim of reconstructing the ancient Aquileia landscape and, in particular, the integrated water system. GIS (Geographical Information System) and WebGIS applications have been implemented by researchers of GeoSNAV Laboratory, University of Trieste, joining all the data on a common cartographic basis, in order to enhance their sharing inside the scientific community.

Keywords: Aquileia; Port River Structures; Archeological survey; GNSS; Remote Sensing; Laser Scanner; Geodatabase; GIS; WebGIS.

1 Introduction

Aquileia is one of the most important archaeological sites in Italy. It was a rich Roman town and a commercial centre connecting Central Europe with the Mediterranean area during the imperial period with a maximum population of more than 200.000 inhabitants. Attila razed it to the ground by the 5th century.

The Aquileia River Port is considered as one of the best-preserved examples of the Roman world [1].

In the last years the integrated use of multidisciplinary researches has been applied for the study of this archaeological complex, with the principal aim of reconstructing the Aquileia ancient landscape and, in particular, the integrated water system.

1.1   The Topographic and GNSS (Global Navigation Satellite System) surveys

Since 1992 GPS (Global Positioning System) techniques have been adopted with the aim of linking together various independent topographic networks and georeferencing single relevant points [2].

This need arose in the framework of the cooperation existing between Geometer Giovanni Meng[†,1] and the group of Topography and Geodesy, directed at that time by prof. Giorgio Manzoni, Department of Civil Engineering (actually Department of Civil Engineering and Architecture), university of Trieste.

A GNSS network was then established and surveyed choosing the vertexes in such a way as to optimize the link between the topographic networks surveyed by G. Meng. Moreover, thanks to the presence of a 100 meters height crane, it was possible to include the first order geodetic vertex of the Basilica of Aquileia into the GNSS network. This allowed the georeferencing of the GNSS survey into WGS84 ellipsoidal Global Geodetic Reference System and the subsequent coordinate transformations to the Italian ITA40 and Gauss-Boaga Systems.

2   The Aquileia river port and the GIS-implemented application

Already in the past some hypotheses relative to the Aquileia Port permitted to locate, on the topographic map of Pietro Kandler (1869), two big zones at the West and East of *cardo maximus*, respectively called the port of *navicelle* and the port of ships [2]. Kandler based his studies on the observations done by the Zuccolo brothers in 1806. He put into evidence the artificial origin of the Anfora canal and the ramifications of the Isonzo river, supposing at least a partial circumnavigability of Aquileia [3]. All the current archaeological researches are based on the Giovanni Brusin experiences. Starting from the Kandler's discovers, he tried to put in relation the ruins with the ancient sources. In the 30's he disclosed and excavated the river port. Using the materials extracted from the excavations, he built the archaeological path located on the river bed, thus highly increasing the value of the impressing artifact.

Almost all the existing archaeological data come from the excavations done in the first half of the twentieth century that unearthed some structures aligned along a front long some hundreds of meters [1].

This huge excavation work transformed Aquileia into one of the best known sites with regard to the port structures. Nevertheless, the techniques used at that time prevent the exact dating and surveying of the modifications of this complex.

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[1] Geometer Giovanni Meng[†], born in Trieste on 21 April 1932 and dead in Trieste on 12 May 2006, dedicated a big part of his professional work and life to the topographic survey of the Aquileia archeological ruins, in cooperation with Soprintendenza per i Beni Archeologici del Friuli-Venezia Giulia. This paper is dedicated to his great professionalism and passion.

Thus, in the 90's, under the impulse of the Ministry of Cultural Activities, a scientific cooperation between different researchers belonging to the Department of Geosciences and the Department of Civil Engineering and Architecture (DICAR), University of Trieste, Italy, has been established. The principal aim of this cooperation was to define the evolution of the Aquileia recent landscapes and, in particular, the hydrographic net.

Subsequently, also the archaeologists and historians[2] working since 1991 to an archaeological excavation planned on the site of the river port, the geographers belonging to Université Paris-7[3] and Physics Department[4], University of Trieste, joined the Project. This Consortium was formalized in 2001 with the signature of a scientific Agreement of studies and researches, renewed in 2006.

Since 2005 to 2007 a funding given by CNRS (Centre National de la Recherche Scientifique) has been dedicated to this cooperation agreement, in the framework of a "Programme International de Coopération Scientifique" (PICS) entitled "Recherches paléoenvironnementales sur le territoire d'Aquilée (Italie Nord-orientale) dans l'Antiquité" ("Paleo-environmental Researches on Aquileia territory in the ancient times") coordinated by M.B.Carre, CCJ - Centre Camille Jullian - CNRS, Aix-en-Provence, Marseille, France and N. Pugliese, Department of Geosciences, University of Trieste. The organ gram of the PICS Project is shown in Fig.1. An intense and long cooperation has been established between prof. M.B.Carre and a number of students, PhD students and researchers scientifically working inside the GeoSNAV (Geodesy and Satellite Navigation) Laboratory, directed by prof. R.Cefalo, university of Trieste.

The great amount of existing archaeological, geodetic and geophysical data, coming from different sources and characterized by not homogeneous formats and accuracies, induced the idea of implementing a GIS application able to join all the data onto a common cartographic platform and take advantage from all the potentialities of the GIS solutions.

The data used to implement the GIS application are shown in Fig. 2. They include all the data surveyed in the framework of the PICS Project and other archaeological data from previous surveys: the archaeological ones (Department of History and Cultures from Antiquity to Contemporaneous World, university of Trieste); the SARA (Subacquea Archeologia Romana Aquileia – Roman Aquileia Underwater Archaeology) data, surveys directed by F. Maselli Scotti, at that time Director of the Archeological Museum of Aquileia); the cadastral cartographic data by scanning the old cadastral maps; the georadar profiles (Department of Geosciences, University of Trieste); the laser-scanner data (prof. G. Giannini, INFN, University of Trieste); and

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[2] Excavation directed by prof. C.Zaccaria, Department of History and Cultures from Antiquity to Contemporaneous World, university of Trieste, Italy) and prof. M.B.Carre (CCJ - Centre Camille Jullian - CNRS, Aix-en-Provence, Marseille Université, France) and given in concession to the École Française de Rome (EFR) with the participation of dr. P.Maggi, dr. F.Oriolo, Department of History and Cultures from Antiquity to Contemporaneous World, university of Trieste, Italy, R.C.Rousse, CCJ, M.Sternberg and C.Machebeuf.

[3] Prof. Arnaud Fassetta, équipe "Dynamique des Milieux et Risques", PRODIG, CNRS, université Paris-7, France, and dr. I.Siché.

[4] Prof. Gianrossano Giannini, INFN – National Institute of Nuclear Physics - university of Trieste, Italy.

those relative to the drilling sites (prof. R.Marocco, Department of Geosciences, University of Trieste) [4].

ESRI® ArcGIS 9.3 was initially chosen as the software platform, being the most diffused within the scientific community.
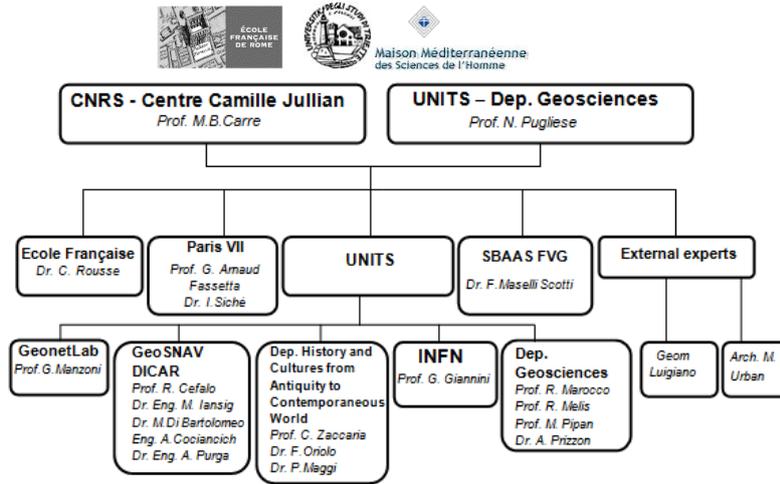

Fig. 1. Organ gram of the PICS CNRS 3064 Project, showing all the national and international Institutions and Research Centres involved.
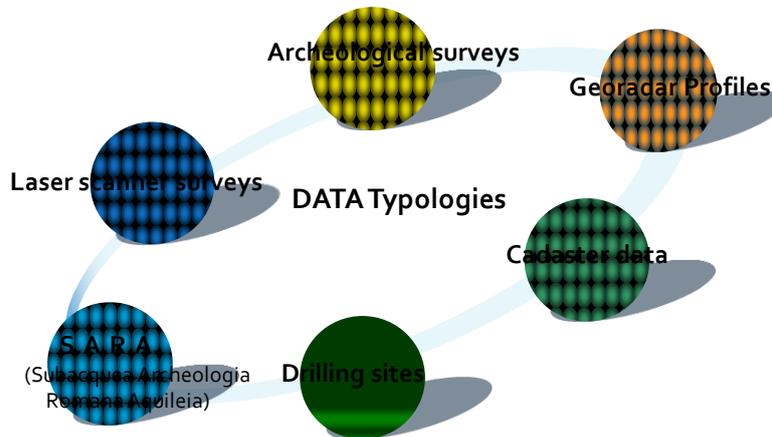

Fig. 2. The different typologies of data surveyed by the researches involved inside the PICS CNRS 3064 Project and implemented inside the GIS application relative to the Aquileia River Port

In the meantime different GNSS surveys had been carried out by GeoSNAV Laboratory, in order to study possible alignments between the river port archaeological structures and to precisely localize the drilling sites.

In Table 1 the coordinates of a part of the points obtained from a geodetic GNSS survey performed some years ago inside the River Port, have been reported as an example. The planimetric coordinates are expressed into the Gauss - Boaga Italian Cartographic System and have been obtained through a 7 parameters transformation using the official IGM (Italian Geographic Military Institute) parameters relative to IGM95 Aquileia – Chiusa vertex. The heights are referred to the WGS84 ellipsoid.

Table 1. Gauss-Boaga coordinates and WGS84 ellipsoidal heights of the surveyed points. The 7-parameter transformation has been performed using the official IGM parameters relative to the IGM95 Aquileia – Chiusa vertex.

Point N.	Northing (m)	Easting (m)	Height (m)
P001	5070407.410	2393207.344	45.600
P002	5070360.524	2393200.109	46.108
P003	5070275.399	2393221.143	45.630
P004	5070225.101	2393225.335	46.275
P006	5069912.709	2393352.590	46.994

A complex relational geo-database, able to put together the huge amount of archaeological, cartographic, geodetic and geophysical data, was projected and created by A. Cociancich [5], using Access 2003. This database, shared between the members of the involved scientific community, allows an easy and friendly data input by the users and can be used also by not expert users. The choice of Access 2003 was driven considering the large data volume, the relative small number of users and the easiness of use. Furthermore, it allows to easily create the input masks using also the support of VBA (Visual Basic for Application) programming.
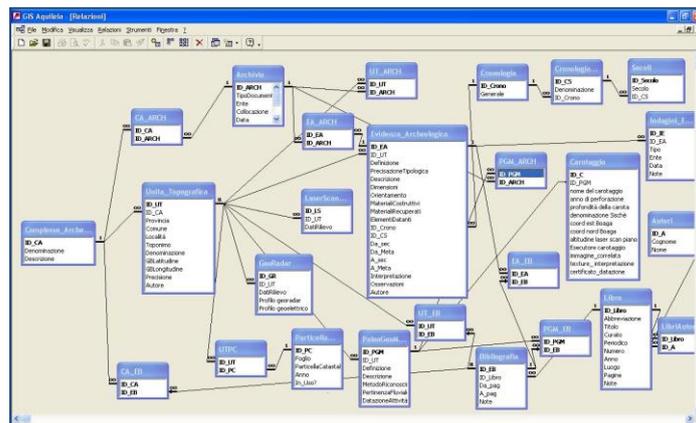A scheme of the database realized has been reported in Fig. 3.

Fig. 3. The relational geo-database structure [5].

A further database implementation specifically projected to manage the drilling sites data, the laser-scanner data and the cadastre cartographic data has subsequently been implemented by F. Ferro [6] in 2009. A mixed typology strategy for the identification of the entities and the main relationships has been applied. The database has been realized in Access 2007 and linked to the ArcGIS software platform.

3   WebGIS application and the use of remotely-sensed images

A WebGIS *open source* application for the management of archaeological, paleo-geo morphological and historical-cartographic data relative to the Aquileia ancient hydrographic network has been realized by M. Di Bartolomeo [7] using a MapServer platform. This platform allows for a dynamic connection to the georeferenced data by the user on the basis of his/her own choices. The user interacts with *HTML* pages, structured in a proper way, through a *web browser* (Fig. 4).

In order to simplify the implementation of a WebMapping interface, the front-end user friendly "p.mapper" application has been used, developed on PHP/Mapscript e JavaScript. PHP/Mapscript is an extension of the PHP language allowing to dynamically check the syntax and logic of object PHP scripting programming language.
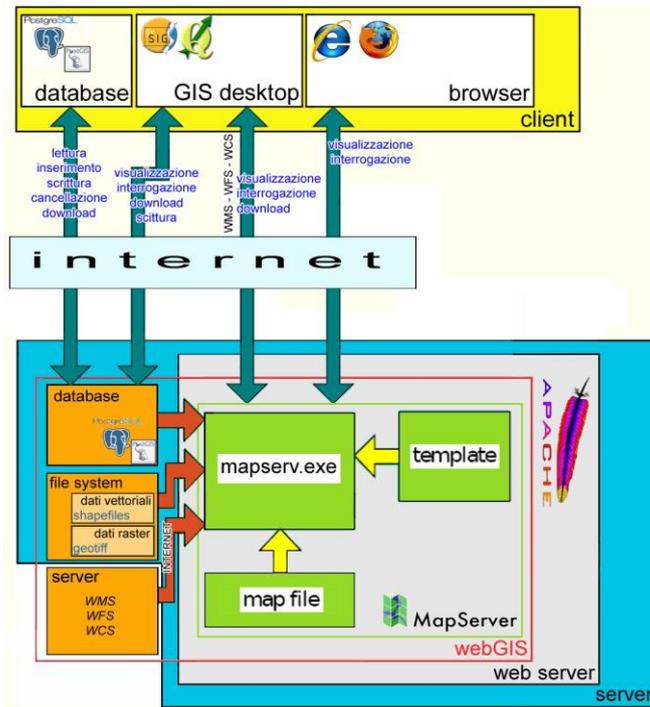

Fig. 4. The Client/Server structure of the MapServer Web/GIS application [7]

Furthermore, in 2010 an integrated study using aerial photos and MIVIS images for the individuation of archaeological anomalies has been carried out by G. Montagner [8]. Different data analysis techniques were applied in order to enhance the image quality and radiometric characteristics, and allow for the visualization of anomalies that could be due to archaeological underground structures. A result is shown in Fig.5, where the comparison between a hyperspectral MIVIS[5] (Multispectral Infrared and Visible Imaging Spectrometer) RGB image of a portion of terrain and the same image processed using PCA (Principal Component Analysis) (P.C.5) is presented.

Fig. 5. A comparison between a MIVIS RGB image of a portion of terrain (on the left) and the same image processed using PCA (Principal Component Analysis) (P.C.5) (on the right) [8].

4   Conclusions and future developments

Since 1992 the Group of Topography and Geodesy of the Department of Civil Engineering and Architecture, university of Trieste has been involved in multidisciplinary researches on the territory of Aquileia.

Thanks to a scientific agreement of studies and researches formalized in 2001 in Aquileia and renewed in 2006, an important cooperation between different researchers belonging to national and international Institutions and Research Centers was realized. The funding provided by the by CNRS - Centre National de la Recherche Scientifique - in the framework of the PICS Project, gave the possibility to carry out different multidisciplinary studies and surveys, and made available a huge amount of data to the scientific community.

The GIS and WebGIS *open source* applications implemented by the Authors and relative to the Aquileia river port structures allowed to join all the available data on a common cartographic base (CTRN 1:5000 and CRN 1:25.000 digital maps) and take advantage from all the potentialities of the GIS solutions. The added information coming from the performed surveys permitted to better study and spatially correlate

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[5] The MIVIS images used for this study have been kindly put at disposal by the Cartographic Direction of the Friuli-Venezia Giulia Region.

the data relative to the Aquileia river port structures with the aim of creating a map of the ancient and recent hydrology.

The WebGIS application will also allow the multiuse and update of the geo database by the researchers. Furthermore, remote sensing analyses have been studied and applied taking advantage from the most recent technologies, with the aim of enhancing the actual knowledge on the Aquileia territory.

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