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A WEBGIS FOR THE KNOWLEDGE AND CONSERVATION OF THE HISTORICAL BUILDINGS IN SARDINIA (ITALY)

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ABSTRACT:

The presented work is part of the research project, titled "Tecniche murarie tradizionali: conoscenza per la conservazione ed il miglioramento prestazionale" (Traditional building techniques: from knowledge to conservation and performance improvement). This research project has the purpose of studying the building techniques of the 13th - 18th centuries in the Sardinia Region (Italy) for their knowledge, conservation, and promotion. The end purpose of the entire study is to improve the performance of the examined structures. In particular, the task of the authors within the research project was to build a WebGIS to manage the data collected during the examination and study phases. This infrastructure was entirely built using Open Source software.
The work consisted of designing a database built in PostgreSQL and its spatial extension PostGIS, which allows storing and managing feature geometries and spatial data. The data input is performed via a form built in HTML and PHP. The HTML part is based on Bootstrap, an open tools library for websites and web applications. The implementation of this template used both PHP and Javascript code. The PHP code manages the reading and writing of data to the database, using embedded SQL queries. The database is published on the Internet as a WebGIS built using the Leaflet Javascript open libraries, which allows creating map sites with background maps and navigation, input and query tools. This too uses an interaction of HTML, Javascript, PHP and SQL code. The Database can be accessed in QGIS via a PostgreSQL connection.
As of today, we surveyed and archived more than 300 buildings, belonging to three main macro categories: fortification architectures, religious architectures, residential architectures.

1. INTRODUCTION

In the recent years, the archiving and diffusion of data about Historical-Architectural Heritage, through the new digital information technologies, has represented a very important moment for a new and better management of this heritage. (D'Urso, 2017)
This is due, in particular, to the fact that, at present, the amount of data affecting buildings and structures of cultural heritage has increased massively. This is thanks to the new multidisciplinary approach to the study of the architectural heritage aimed not only on its knowledge but above all on its restoration and conservation. Architects, restorers, structural engineers, energy engineers and geomatics experts are involved, each by their specificities, to contribute to the historical, metrical-dimensional, structural, material and energy performance knowledge of the buildings.
Conservation of the architectural heritage is held as a fundamental issue in the life of modern societies. In addition to their historical interest, cultural heritage buildings are valuable because they contribute appreciably to the economy by providing key attractions in a context where tourism and free time are major industries in the 3rd millennium. The study of historical buildings must use an approach based on modern digital technologies. The final goal must be to choose and satisfactorily manage the possible technical means needed to obtain the required understanding of the morphology and the structural behaviour of the construction and to characterize the needs of repair.
In this context of study, the geomatic can offer an important contribution both from the point of view of the survey and for the management and storage of the data, as well as their sharing on the Internet for greater diffusion among the users involved.
During these last years, indeed, new survey technologies became influential, allowing an accurate and a detailed knowledge of historical buildings. UAV/drones or Terrestrial Laser Scanner technologies allow us to get exhaustive point clouds that restitution a high-resolution 3D model of the building. (Scianna, 2017). These instruments are characterized by being compact, fast in acquisition and, at the same time, producing high accuracy data of buildings in shorter working time, also for more complex buildings. (Fabbri, 2016).
Besides, the implementation of Geographical Information System (GIS) technologies applied to historical-archeological heritage has reached a fundamental importance for the valorization of these buildings and it could be an important step for planning their restoration (Pelcer-Vujacic and Kovacevic, 2016). Indeed, the Geographic Information Systems have been developed to create relationships between data, to analyze spatial information recorded in a database and for the heritage management. Many types of data can be managed in a GIS, not only geographical or geolocalized data, but also historical, architectural, material and other data (Meyer, 2007) and it is very important to share this data on the Web.
The relatively recent emergence of WebGIS functionality has modified the traditional way of using GIS as a database-mapping and spatial analytical tool (Huang, 2009; Pessina and Meroni, 2009). WebGIS provides an efficient and powerful way

for delivering, managing and analyzing multi-source data on the Internet.

In this paper, we present a WebGIS infrastructure for the management and storage of a large amount of data concerning to the structural, morphological, material, dimensional and energy characteristics of the historical buildings present in Sardinia and built between the 13th and the 18th century.

The presented work is part of the "L.R. n. 7/2007 Promozione della ricerca Scientifica e dell'innovazione tecnologica in Sardegna" (Regional Law 7/2007 – Promotion of scientific research and technological innovation in Sardinia) research project, titled "Tecniche murarie tradizionali: conoscenza per la conservazione ed il miglioramento prestazionale" (Traditional building techniques: from knowledge to conservation and performance improvement), with the purpose of studying the building techniques of the 13^{th} - 18^{th} centuries for their knowledge, conservation, and promotion. The end purpose of the entire research project is to improve the performance of the examined structures on both the structural and the energetic use sides. The study, indeed, is founded on a multi-disciplinary approach involving several specialists integrating their expertise and providing their input to the knowledge of the dimensional, technical-constructive, mensio-chronological, material, physical-mechanical and energy-performance features in order to define the peculiarities and behavior of the examined structures, their performance levels, and then direct the interventions toward innovative, mindful and ethically correct solutions. All data acquired in the distinct steps of the research have been organized in a GeoDatabase and a WebGIS, built according to the standards and specifications of the Regione Sardegna (local autonomous government of Sardinia) and CISIS (Italian inter-regional center for GIS and statistical services) which in turn are based in the INSPIRE directive specifications. The geodatabase can be integrated in the SITR (Regional Geographic Information System) and in the Regione Sardegna Web geo-portal. This infrastructure was entirely built using Open Source software.

The work consisted of designing a database built in PostgreSQL and its spatial extension PostGIS, which allows storing and managing of feature geometries and spatial data. The data input is performed via a form built in HTML and PHP. The HTML part is based on Bootstrap, an open tools library for websites and web applications. The implementation of this template used both PHP and Javascript code. The PHP code manages the reading and writing of data to the database, using embedded SQL queries.

The database is designed to store and manage data building in order to turn them into comparable information and to make them available in single or aggregate form. The database structure is based on two levels of detail: the first one consists in a territorial census of buidings to the architectural scale; the second one, however, is oriented to investigate technological specificity relative to the structural elements, with indications on the energy performance related thereto, to masonry construction techniques and to the window fixtures. The structure of the DB is organized in schemes. Each scheme represents a specific architectural typology of the building and contains several tables pertain to the different input categories for each data type. Until now, we surveyed and archived more than 300 buildings, belonging to three main macro categories: fortification architectures, religious architectures, residential architectures. The masonry samples investigated in relation to the construction techniques are more than 150.

The Database is accessed in QGIS via a PostgreSQL connection, with the ability to import, export and modify the DB tables. A number of queries for interrogating the DB have also been built in QGIS.

The database is published on the Internet as a WebGIS built using the Leaflet Javascript open libraries, which allows to create map sites with background maps and navigation, input and query tools. This too uses an interaction of HTML, Javascript, PHP and SQL code. Figure 1 shows the architecture of the WebGIS infrastructure as implemented.

The GIS files were predisposed for their eventual publishing on the official GIS of the Autonomous Region of Sardinia (SITR).

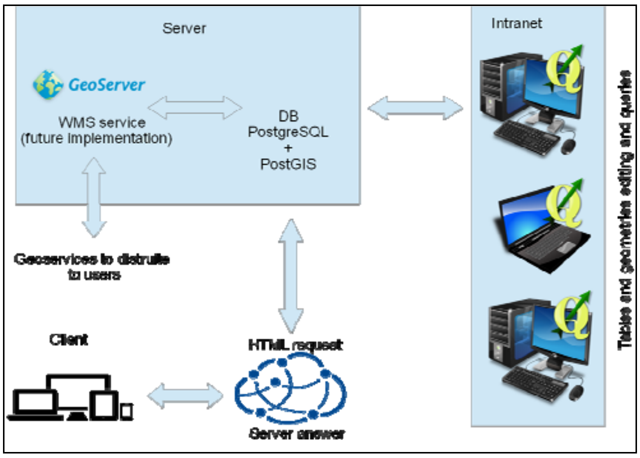

Figure 1: WebGIS Infrastructure

2. DATABASE STRUCTURE AND DATA TYPES

This section presents the typology of the data and the database project in which they are implemented. As mentioned previously, the project presents a strong multidisciplinarity. This has led to a remarkable amount and diversity of data from the various disciplines involved, which required a database designed to meet the different needs of all users.

2.1 Data types

Building an effective tool for cataloguing, systematizing and managing information collected through the direct and indirect data acquisition phases has been critical considering the amount and heterogeneity of the data to be taken into consideration in this research project.

The multifaceted nature of Sardinian architectural heritage, whose complexity is also a consequence of stratification and transformation over time, forms a mosaic of knowledge greatly articulated in qualitative and quantitative terms. For this reason, the database is designed so that it can collect the data produced, transform them into comparable information and finally make them available in a simple or aggregate form. The design of such a system of storage and management has highlighted, since the beginning, the need to have an immediate geographical overview that can be visualized through effective cartographic representations.

The structure of such apparatus is based on two levels of depth: the first being a survey of the constructions on the territory at the architectural scale; the second, directed toward inspecting the technological peculiarities of the structural elements, giving indications about the energetic performance due to them, the construction techniques, and at the window fixtures.

The first step in building the database consisted in the definition of a hierarchy of data types, subsequently parameterized

through the definition of coded values, in order to make the acquired information easily comparable. A particular care was given to the ability to make the tool interoperate with the already existing national and regional databases. Still, the information layers were defined taking into consideration the homogeneity of the data acquired for the examined items; this is necessary in order to have an organic interpretation of the whole system, through the interrelation of information coming from different cultural scopes, emphasizing once again the interdisciplinary aspect of this research.
The tool was also designed to be simple and modular, to be easily implemented and deployed, even in a partial state, as the information from the different disciplines progressively come in.
For some data types, we built predefined dictionaries, with the possibility of integrating them with new items as the research progresses. Defining closed dictionaries is necessary in order to extrapolate meaningful thematic maps from the GIS.
In further detail, the data were divided in 4 macro-categories (fig. 2):
- “Unità architettonica” (Architectural Unit)
- “Struttura” (Structure)
- “Infisso” (Window Fixture)
- “Campione murario” (Masonry Sample)

The Architectural Unit macro-category contains the data pertaining to the name, location (with georeferencing), function, cultural and chronological dating, legal status and restrictions, stratigraphy and conservation, including all the previous restorations.
The Structures macro-category contains the data pertaining to the distinct structures that form the architectural unit, in particular the typology of the structure (covers, walls, slabs), the static type (load-bearing or not), the constriction technique and the energetic efficiency.
The Window Fixtures macro-category contains the data pertaining to the architectural unit’s window fixtures, their dimensions and materials, and their overall energy transmittance.
The Masonry Sample macro-category contains the data pertaining to the construction elements of the architectural unit and in particular their position, chronology, survey, restitution, wall structure, materials used (stone, cement, brick), and examinations performed.

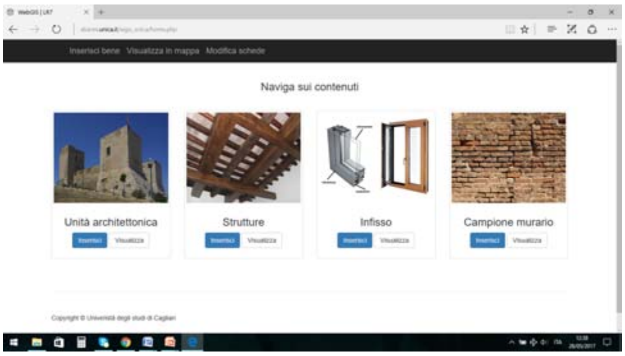

Figure 2: The database and its 4 macro-categories

2.2 Database design and implementation

The database was designed and implemented using PostgreSQL (https://www.postgresql.org), a relational DBMS distributed under a BSD license. The spatial functions of the database were provided by the PostGIS extension (http://www.postgis.org), distributed under GPL license. This extension turns the DBMS into a geodatabase by adding functions and data types that can manage geometries and reference systems.
Data queries are performed using SQL (Structured Query Language), the standard language for data extraction in relational databases. SQL is used to create and edit database schemas, input and edit data, in addition to querying.
The management of the database was done using the pgAdmin graphical interface (https://www.pgadmin.org).
The database is structured in schemas and tables. Each schema contains multiple tables, in order to organize the tables into cohesive themes. (fig. 3)
The schemas created in the DB are “*decodifica*”, “*campione_murario*”, “*infisso*”, “*struttura*” and “*unità_architettonica*”. Each schema contains the tables pertaining to a single input form. (fig. 4, 5, 6, 7)
The “decodifica” scheme contains the tables of the domains used in the input forms, such as the municipalities and provinces of Sardinia. Some fields of the input forms have closed dictionaries in order to prevent misspellings and variant spellings, which would make queries impossible.
The users can input and edit data through the forms created for the applications. These forms, implemented in PHP (PHP: Hypertext Processor, a server-side scripting language), retrieve data from the database tables with built-in queries. The PHP web client creates variables that are instanced from the values input in the form:

```
<select type="text" class="form-control" name="livello_ricerca" id="livello_ricerca">
```

This line exemplifies how the PHP variables are linked to the HTML form. The value of the variable “livello_ricerca” (in bold) will be used.

```
<option value="">Seleziona un valore</option>
<?php
$query ="SELECT * FROM decodifica.livello_ricerca ORDER BY valore ASC";
$result = pg_query($query);
//apro il tag select per il menu a tendina
 while($myrow= pg_fetch_assoc($result))
{
echo'<option value="'.$myrow['valore'].'">'.$myrow['valore'].'</option>';
}
?>
</select>
```

In this case the value to be input in the form is chosen from the dictionary implemented in the table “livello_ricerca” in the schema “decodifica”.
In order to pass the value input into the form to the DB insertion query we have defined a variable:

```
$livello_ricerca = $_POST['livello_ricerca'];
```

The insertion query is as follows:

```
Example:    INSERT INTO table_name (column1, column2, ...) VALUES (value1, value2, …);
```

The input form was implemented in HTML5 using a free template from Bootstrap (https://getbootstrap.com), a repository of free tools for creating web sites and applications. The

graphical appearance is defined in CSS, and Javascript was used to implement navigation and some controls.
In addition to the input forms, there is the possibility of querying the surveyed assets. For now, the query consists in selecting a specific asset and obtaining the related tables. Every architectural unit is related to a structure form, a window fixture form and a masonry sample form through the "ID Bene" attribute. This allows to select all records related to a specific architectural unit.

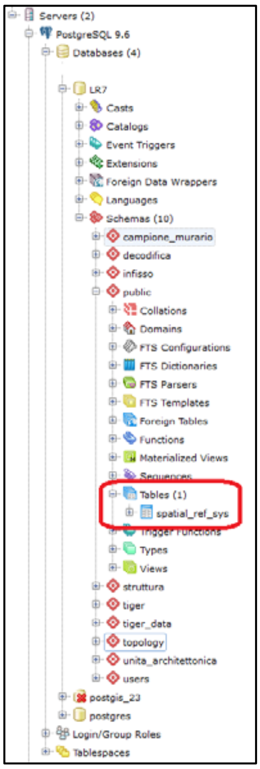

Figure 3. Database structure

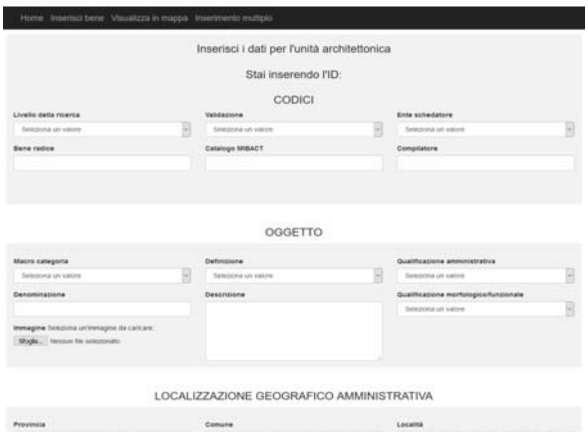

Figure 4. Architectural unit: input form

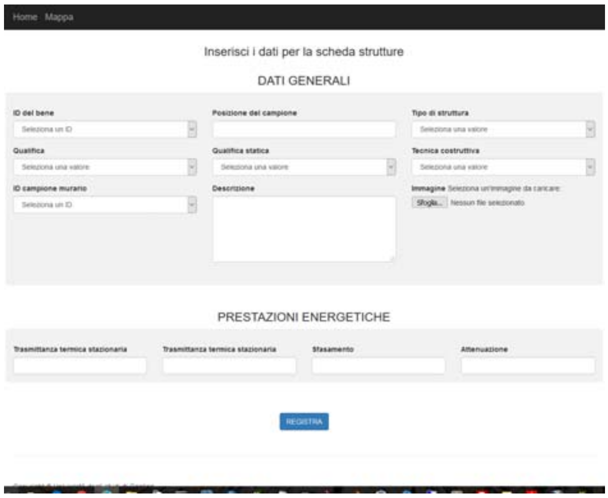

Figure 5. Structure: input form

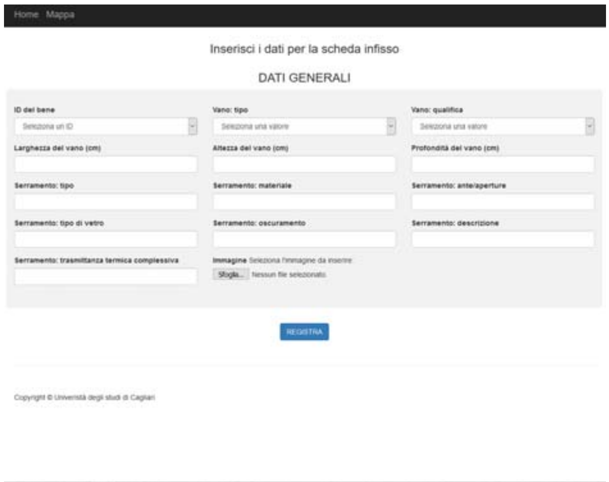

Figure 6. Window fixture: input form

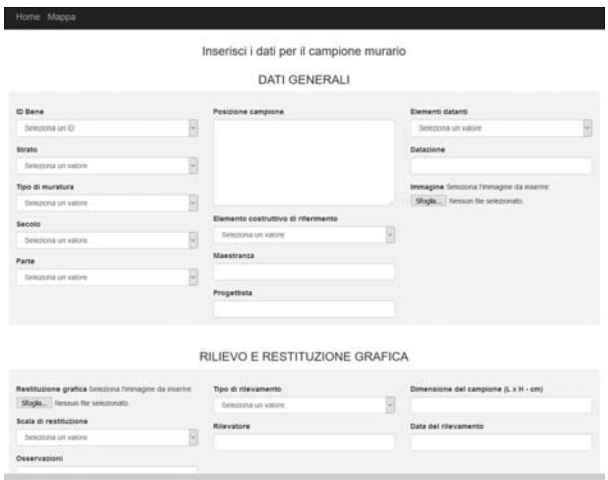

Figure 7. Masonry sample: input form

At the present time, the database contains the data of over 300 architectural units belonging to three main categories: military, religious and civil-residential. The masonry samples examined on the architectural units, regarding the construction techniques, are over 150. The survey, as mentioned, used a multi-disciplinary approach involving different areas of expertise such as history and architecture, materials, restoration, construction techniques, physics and mechanics, and so on, and was performed by multiple researchers who contributed to populate the database with their data.

2.3 QGIS implementation

Quantum GIS (QGIS) is a popular choice for desktop GIS. In 2002, a group of volunteers started Quantum GIS as an alternative to GRASS, mainly aiming for a better graphical user interface and fast spatial data viewing for Linux based systems. It was programmed in C++ while its extensions can be written in C++ and Python (Steiniger and Bocher, 2009). It provides plug-ins that can be used to extend its functionalities. It supports a large range of vector and raster formats like PostGIS, PNG, JPG, GRASS, Shapefile, DXF, WFS, WMS, GeoTiff etc. The software can also manage tables of non-spatial data. The data can reside on the local file system, or be retrieved and updated through a database connection or a Web service.
In this work, the database was built in PostGIS, as mentioned, and accessed from QGIS through a database connection. The database can be both browsed and edited in the QGIS client. (Figure 8)

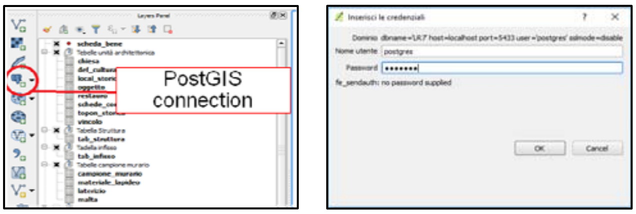

Figure 8**:** QGIS connection and client

Not all tables of the database contain spatial information; those that do not are linked to the spatial ones through a relationship. This relationship must be defined in QGIS by selecting the common key fields (Figure 9). In order to select the features by querying the non-spatial data, the software was extended with an "action" (a Python script) developed by A. Borruso and S. Larosa (https://pigrecoinfinito.wordpress.com/2017/04/16/qgis-selezionare-feature-partendo-dalle-relazioni-1m/).
Finally, the base layer for the WebGIS was provided by the Regione Sardegna WMS service (http://webgis.regione.sardegna.it/geoserverraster/ows?service=WMS&request=GetCapabilities) (Figure 10).

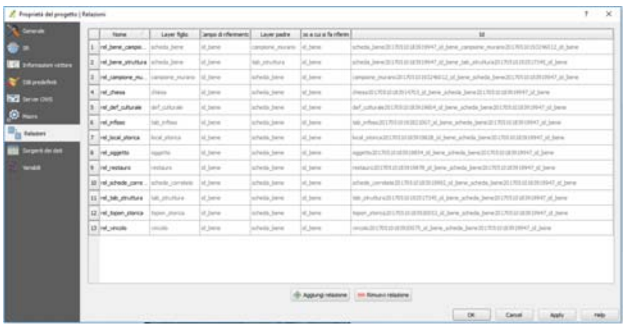

Figure 9: QGIS relationship

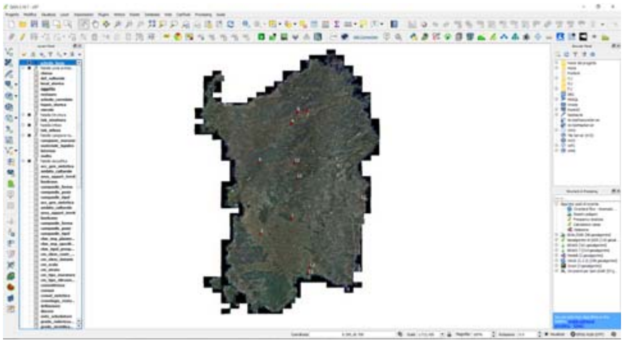

Figure 10: QGIS project

3. WEBGIS DESIGN AND IMPLEMENTATION

The requisite to make the GIS accessible to a high number of users, most of which are unfamiliar with GIS software, brought us to design and implement a Web-based interface to the database. The resulting web map portal also contains forms for data input and editing.
The WebGIS was built using the Leaflet Javascript open libraries, which allow creating map sites with background maps and navigation, input and query tools. This too uses an interaction of HTML, Javascript, PHP and SQL code. More specifically, the Leaflet libraries were used to publish the map, publish the GeoJSON file containing the attributes of the heritage feature, control the visibility of the layers and manage the mouse pointer.
The following example shows some of the map creation and management functionalities, by selecting the position of the map center and the zoom level:

```
var map = L.map('map').setView([40, 9.11], 8.5);
```

The next code snippet is the one that creates the popup showing the ID, name and photo of the heritage feature, populating its fields with data from a GeoJSON record:

```
var bene = new
L.GeoJSON.AJAX(["bene.geojson"],{onEachFeature:function
(feature, layer) {
layer.bindPopup('
<p>ID del bene:'+feature.properties.id_bene+
'</p>Denominazione: '+feature.properties.denominazione+
'</p><img src="../img/UpLoad/un_architettonica/'
+feature.properties.immagine_path+
'" class="img-thumbnail" alt="Immagine"
width="200" height="200">');
 }
 }).addTo(map);
```

The Javascript library files are referenced in the HTML file through the <script tag>, as in the following example (releteive to the library that manages the mouse pointer):

```
<script src="dist/L.Control.MousePosition.js"></script>
```

The interaction between the WebGIS and the PostgreSQL database is implemented via SQL queries embedded in PHP templates. The base maps of the WebGIS (Figure 11) are the orthophoto mosaic of 2017 from the Regione Sardegna, and the Open Street Map base map (Figure 12). The two maps are

alternately visible with the layer control. Other layers can be activated using the same control.
The WebGIS was designed to leave the most possible screen space to the map itself, limiting the navigation tools to the strict minimum. It also includes a list of visible layers and a search tool for querying the WMS services.

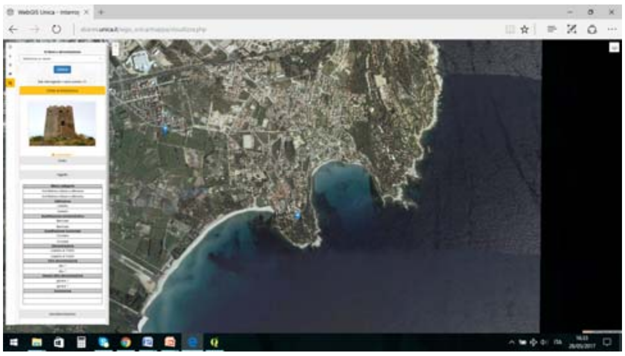

Figure 11. The WebGIS with mosaic orthophotos

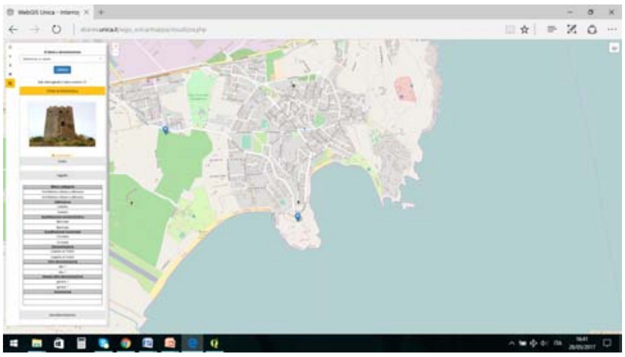

Figure 12. The WebGIS with Open Street Map

The WebGIS was designed to georeference the architectural unit contained in the geodatabase, as mentioned before. The input form requires the coordinates of the asset in the ETRF2000 datum.
Every GIS database table is characterized by a geometry field. The geometry is created by a GIS software when a new record is added, or when the coordinates of a point or vertex (of a polyline or polygon) are modified. In the WebGIS designed in this research, the coordinates of the point are required in the input form (fig. 13) but the input query does not populate the geometry field. Instead, a trigger updates the geometry field of the architectural unit table (fig. 14).

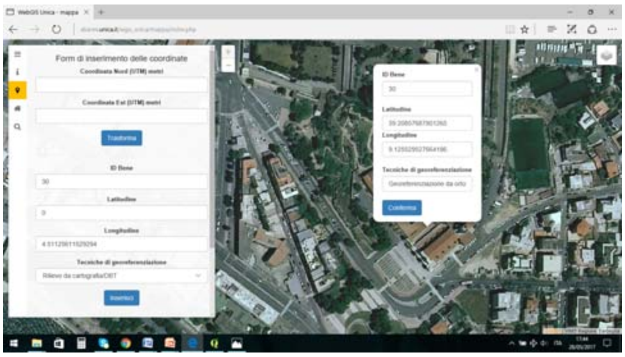

Figure 13. Coordinates input form

A trigger is a construct that signals the database to execute a particular function every time a certain operation is performed. In this case, the trigger is activated when a new record is input using the asset form, and compiles the geometry field using the coordinates submitted in the form.

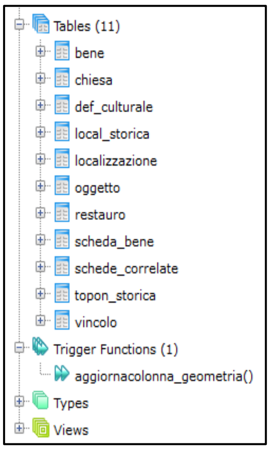

Figure 14. Trigger schema

After the input of the coordinates, the input forms will be filled in with all the data related to architectural unit and its components (structures, window fixtures, masonry samples) (Figure 15). At the end of the input, the data will be inserted into the database through a GeoJSON file. (GeoJSON is an open format for spatial data based on JSON, the JavaScript Object Notation).

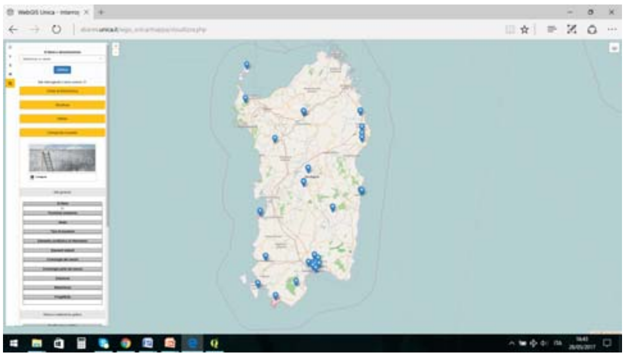

Figure 15. The WebGIS with the Architectural Unit filled in

4. FUTURE DEVELOPMENT

The project, beyond the design and implementation of the geodatabase and WebGIS presented in the previous pages, is going to involve the design and implementation of a WebGIS following the specifications of the Open Geospatial Consortium (OGC). OGC is an international organization that defines standards and technical specifications for localization and geospatial services. The OGC is formed by over 280 members (governments, companies, universities) with the purpose of developing and implementing open and extensible standards for the geographical data and their interchange and distribution. The specifications defined by the OGC are public (PAS) and freely available.
The OGC maintains more than 30 standards, including:

- WMS - Web Map Service

- WFS - Web Feature Service
- WCS - Web Coverage Service
- GML - Geography Markup Language

The research project requires in fact the interoperability of the data collected in the research and the ability for the involved agencies and companies to retrieve the data and publish them on their own portals. In particular, the project involves the development of WMS and WFS services to be made available for the Regione Sardegna and the Ministero dei Beni Culturali (Ministry for Cultural Heritage).
The geoservices will be developed using Geoserver, a J2EE implementation of an Open GIS Web server (Huang andXu, 2011). It is an open source platform that supports the OGC standards like Web Map Service (WMS), Web Coverage Service (WCS), Web Feature Service (WFS) and Web Feature Service Transactional protocols. It can work with a large range of data formats, including PostGIS which is the base of this project's architecture.

5. CONCLUSIONS

The work presented here is a important part of the multidisciplinary research project for the study of buildings made in Sardinia between the 13th and 18th century. The purposes for the design and implementation of the database and the WebGIS were to have an infrastructure for collecting the large amount of data retrieved in the various phases of the research, and to allow users to perform queries both on the data and on the geospatial component. The data collection process involved specialists in several disciplines, such as historians, conservators, surveyors, structural engineers, petrographists, and experts of the thermal and hygrometric properties of wall structures; each of them surveying and studying for their part the characteristics of the historical buildings of Sardinia in order to populate the database. Indeed, this multi-disciplinary approach is the main strength of this infrastructure, which may become a very useful tool to reach a complete knowledge of the historical structures and contribute to define methods and techniques supporting the maintenance, conservation, consolidation, promotion and static an energetic improvement of the structures, based on the precise knowledge of the chemical, physical and mechanical behavior of the studied elements, and also respectful of the authenticity of the historical matter, and thus informed to principles of reversibility, distinguish ability, authenticity, least intervention, and compatibility.
The development of the WMS and WFS geoservices will bring a further contribution to the dissemination of these data, especially to the agencies involved in the conservation and promotion of the massive historical-cultural heritage of the 13th-18th century in Sardinia.

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We thank the whole research group of the project "L.R. n. 7/2007 Promozione della ricerca Scientifica e dell'innovazione tecnologica in Sardegna" (Regional Law 7/2007 – Promotion of scientific research and technological innovation in Sardinia) research project, titled "Tecniche murarie tradizionali: conoscenza per la conservazione ed il miglioramento prestazionale" (Traditional building techniques: from knowledge to conservation and performance improvement) for their scientific contribution throughout the surveying of the architectural units, structures, window fixtures and masonry samples.

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