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Integrated System for the Study and the Management of the Historical Buildings

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Abstract
Procedures for recording the material structure of the historical buildings strongly evolved, in recent years, according to the exponential increase of the computer and digital technologies. In particular, current technologies for digital photography allow to capture high-detailed information, so that large part of the job that had to be previously carried out on the field, can be now managed in the laboratory. Several skills are required for the recording of the building features, and they deal with archaeology, engineering, conservation and restoration. Therefore, it is necessary to establish a consistent "Integrated System" that allows scholars and users to deal with all different building features. In this contribution, an integrated system is proposed for the cataloguing and the management of historical buildings, in line with the Italian rules in force about seismic risk.

Keywords: Integrated System, GIS, Building Archaeology.

1. Introduction

The data capture for the study of historical buildings compel to face specific problems:

- a relevant amount of buildings to be surveyed (thousands of historical buildings need to be recorded);

- the integration of data of different type;

- the survey of the external walls of the buildings;

- the management of information concerning vertical surfaces.

This contribution proposes an Integrated System for the localization of the historical buildings linked to an on-line database finalized to the first description of a complex or of a simple building-unit. The aim is to develop a system to be applied in order to carry out simple and affordable instrumental surveys in situations of natural disasters (e.g. after an earthquake), providing 3D models with photographic layouts, ortophotos and a GIS for the monitoring and the management of the first conservation and for the following steps of the work.

The Integrated System foresees the use and the integration of softwares that represent standards for the Italian regulations concerning Cultural Heritage. The System is also integrated with applications already in use by the Italian supervision boards for Cultural Heritages, i.e. the *Soprintendenze* for the management of the seismic emergency and the monitoring of the historical buildings. The proposed System exploits an open source GIS predisposed on general aerophotos for the location of the sites and the buildings, implementing the available images through Google Earth or other satellite- or aerial-images. Such a basis can be georeferenced and put on-line, at a very high definition, into the GIS system and arranged for the interconnection with the system of management of the damage survey cards (ArtIn XML) and the 2D GIS system for the recording of vertical surfaces, in order to better plan future interventions of restoration (SICaR w/b). The 3D models are realized with new, fast and reliable methodologies, are georeferenced on the available cartographic basis and can be displayed by means of a viewer.

2. Towards an Integrated System

After the 1976 earthquake in Friuli (Italy), many photographic surveys were carried out between May and September of that year, in order to develop new procedures and protocols for cataloguing historical

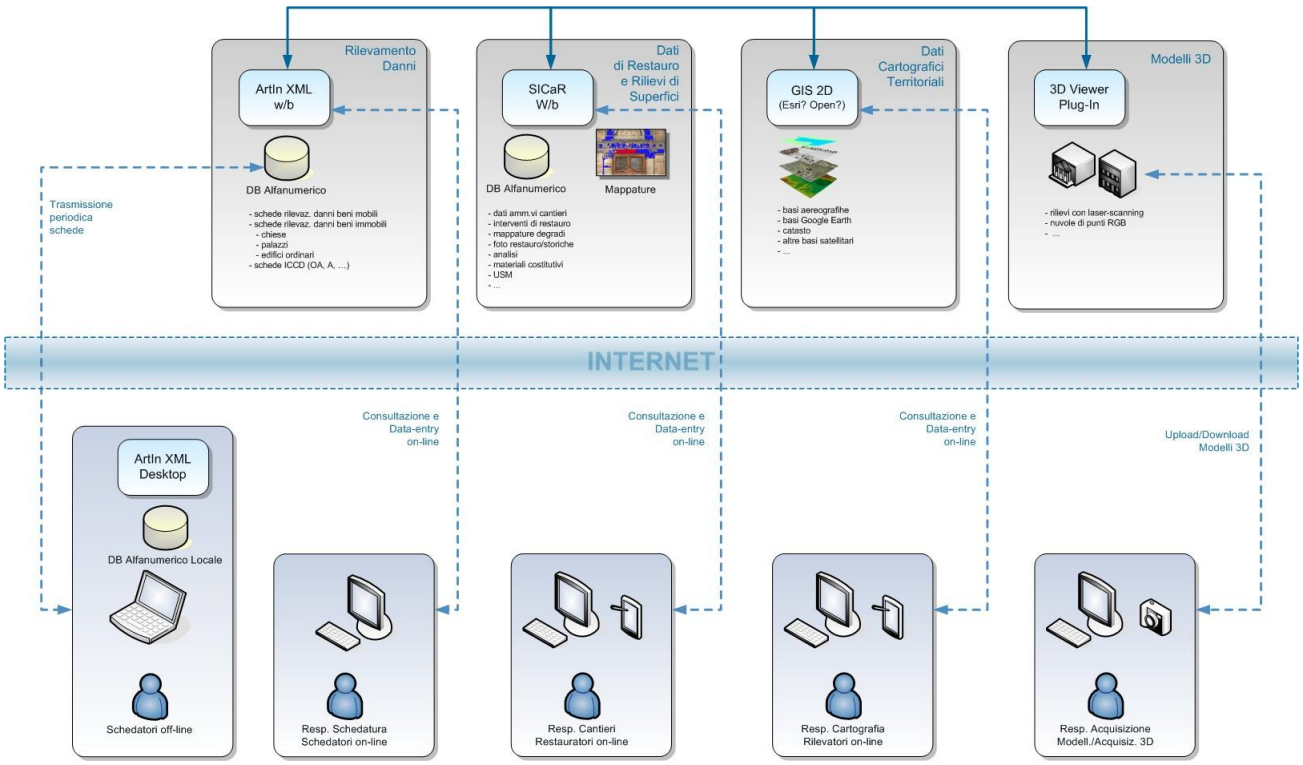

Figure 1: *The conceptual scheme of the Integrated System*

buildings; furthermore, useful proposals were put forward for the analysis of the damages (DOGLIONI et al. 1994).

After the 1997 earthquake in Umbria and Marche and the 2002 earthquake in Molise, a sort of "Iterative Damage Mechanisms" were defined, according to the "macroelements" of the building (façade, lateral walls, apse and transept, covering, etc.). In 2008, the Italian Ministry of Cultural Heritage published the document "Linee Guida per la valutazione e riduzione del rischio sismico del patrimonio culturale", MiBAC 2007 (Guidelines for the evaluation of the seismic risk - MiBAC, 2007), now approved as an official Directive.

The "Guidelines" clearly indicate that the stratigraphic analysis of a building is necessary for its complete evaluation. According to this new scenario, the goal of this paper is to illustrate a project for the cataloguing an historic building after an earthquake, and to propose an integrated system that can manage all the building features.

We figure out essential to point out the importance of the following issues of such a project:

- an integrated system for the catalogue of the damaged buildings, that allows to precisely locate them on space;

- a data set with the results of the instrumental surveys of the standing buildings;

- the development of an on-line GIS, based on these data.

In 2009 a major Earthquake rocked the Italian Region of Abruzzo.

The earthquake of the 6 April 2009 interested the historical centre of the main town L'Aquila and other 49 municipalities. An impressive amount of historical buildings and monuments were destroyed or strongly damaged.

In such a situation, i.e. with a very large amount of buildings to be recorded, with the necessity to do the job as fast and safe as possible, it is necessary to develop an operating procedure that guarantees the accuracy of the data capture and the safety of technicians in charge of the survey; in particular, it is important that:

- data are consistent and easy to share with different archives;
- different users are allowed to access data and to meet the needs of other scholars and technicians;
- the system is the result of a "common" work, carried out in synergy by all investigators (engineers, architects, building archaeologists, art historians).

2.1. Data-capture and structure of the Integrated System

The system aims to deal with the data concerning all the phases of the project, starting from the first census and survey of the damage, up to the analysis of the building techniques, the conservation and the following management and monitoring of the building.

In each phase, a special software is adopted, which is well known in the Italian domain of the management of Cultural Heritage, and a new process for integrating and sharing data is proposed.

Herewith the different steps of the system's management:

1 – Localization of buildings with geographic coordinates on the basis of a zenithal photo survey (mainly by means of satellite photos, but not exclusively), without limits for their definition degree.

2 – Development of a database, on-line or desktop, for the description of all data concerning the first emergency survey.

3 – Development of a 3D survey with vector data, ortophotos, 3D photo high-resolution models of the surfaces.

4 – Development of a GIS for the vertical standing surfaces, in order to enter data concerning building techniques, building materials, analyses, conservation procedures, monitoring, etc.

5 – On-line access to the above mentioned data.

All these data need to be collected with topographical, cartographical and historical data for the following management and monitoring of the building itself.

We propose to adopt a specific open-source GIS for the cartographic data. As for the damage survey cards, we propose to adopt ArtIn XML (www.liberologico.com/artinxml), available both on-line and desktop. As for the instrumental survey, we propose to use the application Z-Scan by Mencisoftware (www.menci.com: see on "photogrammetry and point clouds"). As for the data concerning the conservation, we suggest to use the SICaR system, by Liberologico (www.liberologico.com/sicar: GIS based and open source). The Data sharing will be possible on-line, with three access levels: a first one for the full open access to the data (for Scientific Coordinators and Administrators), a second one with restricted access for the other participants in the "Working Teams" (that allows to access data filled in by other people, but without the possibility to modify them); a further restricted access, for consultation only, devoted to the whole scientific community.

3. ArtIn XML

ArtIn XML is the software for cataloguing (standard ICCD), used in About 30 Italian "Soprintendenze" participating in the ARTPAST programme (www.artpast.org), promoted by the Italian Ministry of Cultural Heritage (MiBAC) with the scientific collaboration of the *Scuola Normale Superiore* di Pisa. It is a multi-standard data entry platform, articulated in three integrated formats:

- ArtIn XML desktop: system for the multi-standard catalogue in desktop version;
- ArtIn XML w/b: system for the multi-standard catalogue in web-based version;
- ArtIn XML WebGIS: GIS web-based version for the georeference of the catalogued heritage.

The software allows to plan both on-line and off-line sessions of data-entry, and warrants the information storage in a single sure and shared repository. The peculiarity of ArtIn XML consists in the independence from the catalographic formats that it is able to manage. ArtIn XML is able to import and manage every card's layout. The system is developed in order to manage every XML file (shaped with the SIGEC standards) and to set up autonomously. The adopted solution allows that personalization or future versions of a layout in ICCD standards and of other formats can be easily managed by the system.

ArtIn XML provides, both in the desktop and in the web-based version, mechanisms of synchronization of the based data on import / export in the standard formats of interchange ICCD (*.trc) and XML, thanks to which it is possible to plan on-line and off-line cataloguing sessions, with memorization and management of data in a shared, sure and centralized file. In the desktop version, the application has been used with success within the project ARTPAST (www.artpast.org).

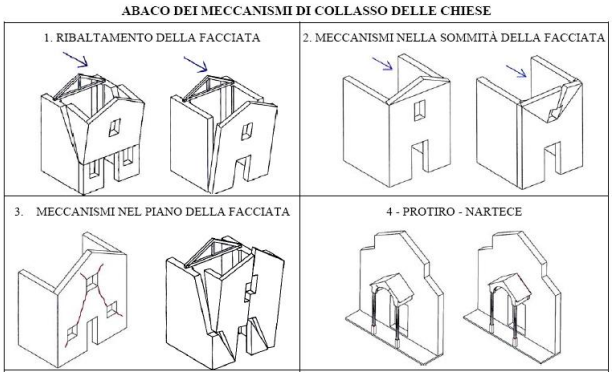

Figure 2: *Abacus of the church collapse mechanism, 4 of 28 (Gazzetta Ufficiale 55, march 7, 2006)*

The web version of ArtIn XML, autonomously developed by Liberologico, is already in use in several public and private institutions (es. National institute for the Graphics, Cini Foundation, etc.).

For each 3D model of the building, a recording card for the technical data can be realized, in order to allow the indication of the 28 collapse mechanisms of the macroelements of the churches and the 23 of the buildings (*Gazzetta Ufficiale* 55, March 7, 2006) that can be integrated in the ArtIn XML system.

4. The Geometric Survey

One of the first steps in the knowledge of an historical building consists of its Geometric Survey. The knowledge of a building may help to draw up its constructive history, and to understand the differences between construction techniques of various historical periods.

Furhermnore, in strongly seismic areas, it helps:

1. to identify damages and repairs due to ancient earthquakes;

2. to draw up the kinematic mechanism of damages;

3. to improve the vulnerability of the building.

The geometric surveys constitute a necessary basis for many "Working Teams". The adoption of new economical and easy-to-use tools has modified the recording strategy of the material structure.

We are currently testing a 3D scanning instrument for point cloud acquisition through digital camera. The software is very friendly and easy-to-use; 3D RGB Model acquisition and computation are done using digital images only. From this instrument we can obtain:

- 3D models of the building with photography resolution of the surfaces;

- surveys characterized by geometric and chromatic accuracy;

- stereometric surveys.

ZScan (www.menci.com/zscan) is the instrument that we use for the survey of the historical buildings (GHEZZI et al. 2009). It is a 3D scanning instrument for point cloud acquisition through digital camera, slide bar and software. It's characterized by geometric and chromatic accuracy and solid components.

As for the generation of 3D point cloud from pictures, we work with a different specific software: ZMap Laser (www.menci.com/zmap). This is a software specifically projected for CAD drawing and orthophoto production on point clouds**.** Vectorized 3D wall surfaces are generated, on which all necessary analyses can be successively carried out (reading of the stratigraphy, characterization of dimensions, presence of modern and ancient repairs, results of archaeometrical analyses, etc.). Data will be available on-line after their have been processed. Moreover, Z-Map Laser allows several advanced specific functions, such as to editing surfaces, building orthophoto-mosaics, handling and merging 3d models, orienting and drawing on images. On 3D models, we can work and register the whole material structure of a building. We could obtain specifically 3D CAD model with the building phases of the structure.

It's also possible to register all essential features of the material structure and, for example, to characterize the constructive techniques of the building, and even the very small lesions (up to ca. 5 mm) caused by an earthquake.

Figure 3: *3D high-resolution photo model of San Pietro Church, Coppito, L'Aquila, Italy*

Figure 4: *Particular of the dislocation of ashlars of the main apse of San Pietro church, Coppito, L'Aquila, Italy*.

All the above mentioned information are fundamental for the monitoring of the building and for the following restoration project.

We have tested this instrument in some churches in L'Aquila, which were partially or totally destroyed by the 2009 earthquake. We achieved the following results: a 3D model with high photorealistic definition of the surface, in which it was possible to record the first dimensional features, macroelements, lesions, stratigraphical sequence, finishes and workmanship, characterization of the main building techniques. In a second phase of post-processing work, we could quickly obtain: Digital Elevation Model of the surfaces, Specific section of the building, Specific geometric and structural Analyses. This process allowed to provide all useful elaborated data for the various investigators of the Working Team (engineers, architects, archaeologists, art historians), in order to carry on a complete analysis of the building. In fact, the software allows the generation of ortophotos on which a first reading of the stratigraphy is possible, in order to distinguish the different building-phases; on the contrary, the 3D model allows to recognize materials and constructive elements for the individualization of the behaviour of the macroelements. With the generation of the DEM (Digital Elevation Model), we can calculate all the geometric deformations of the surfaces.

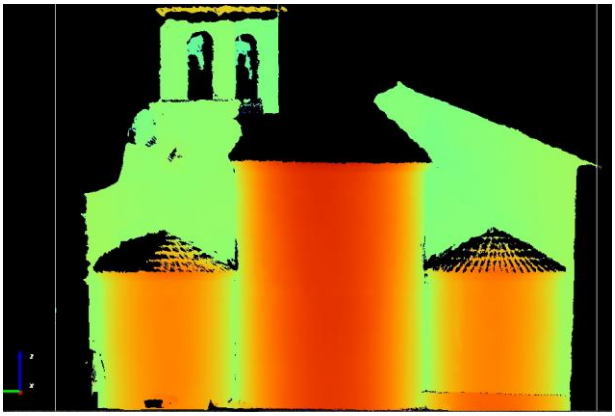

Figure 5: *DEM of the apse of San Pietro church*

It is also possible to draw vertical and horizontal sections of the building on the DEM surface. From these sections misalignments, deformations and dislocation of ashlars are immediately pointed out. All these data are required by the Italian rules, according to the above mentioned "Guidelines", and are fundamental on the first quickly recording of the building (MiBAC, 2007).

5. SICaR w/b

SICaR w/b is the acronym for *Sistema Informatico per la Catalogazione dei cantieri Restauro*. It is a web-based GIS for the management of data concerning one or more conservation projects. Data managed in SICaR w/b can be alphanumeric and geometric.

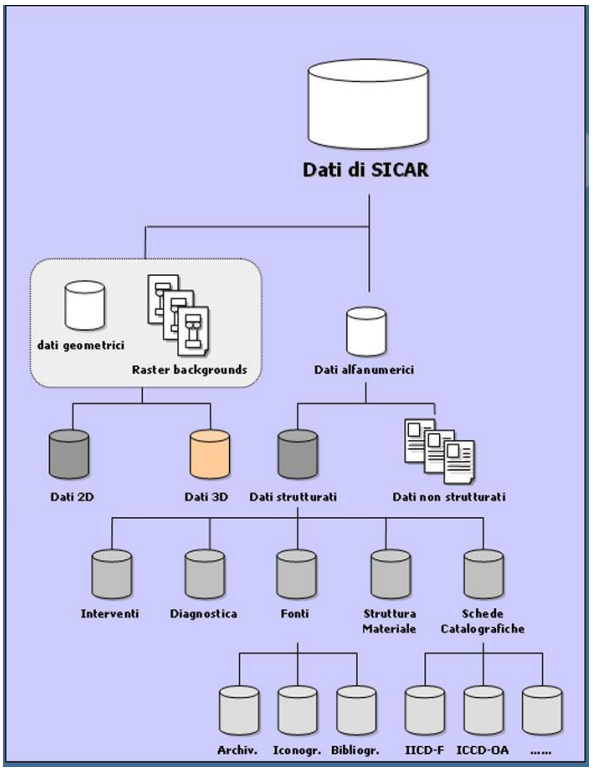

Figure 6: *The SICaR Data structure*

Alphanumeric data are stored in four main repositories:

1. general data;
2. historic and artistic data;
3. conservation and diagnostic;
4. material structure.

Geometric data are vector drawings and high-definition raster images, as well as maps that can be drawn by the user on the surface of the analyzed object. Also a photo-realistic representation of the building can be displayed. These graphic data could be derived from building survey with ZScan, Zmap.

The testing of this system has been the occasion to reconsider the protocol for stratigraphic analysis of the architectural heritage, with the aim to develop a new GIS, open to multi-discipline researches.

5.1.The SICaR w/b technologies. Server Side

SICaR w/b uses the Apache HTTP Server. It is the more spread web basis that can operate on UNIX-Linux and Microsoft. Apache is a software that realizes the functions of carrying information, internetwork and connection, with the advantage to also offer control functions for the safety as those that the proxy completes.

PHP is a language of scripting interpreted, with license open source, used in SICaR.

SICaR employes MySQL, which is a relational Database Management System (DBMS), composed by client and server sides. Both sides are available for the Unix and Windows systems, even if its use for Unix prevails. From 1996 it supports most of the SQL syntax.

5.2. The SICaR w/b technologies. Client Side

SVG, Scalable Vector Graphics, is a technology that can visualize graphic vector objects and can manage images with different dimensions and solutions. More specifically, it is a language from the XML, developed with the goal to describe 2D static and animated figures. SVG become a recommendation (standard) of the World Wide Web Consortium (W3C) in the September 2001. SICaR uses this technology for the digitalization and mapping of the building surfaces.

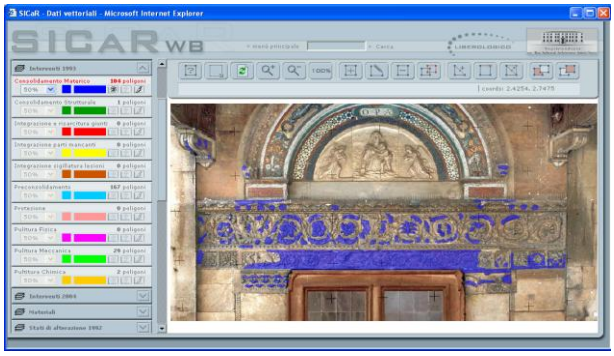

Figure 7: *Mapping surfaces on ortophoto in SICaR w/b.*

Javascript is a scripting language oriented to the objects generally used in the websites. It is also a standard ISO and it is utilized on SICaR w/b.

5.3. The recording of material structures and the building archaeology

The description of the objects in SICar follows a precise hierarchy. The card *edificio* (Building) contains general information (location, type of building, name etc). The building can be subdivided in more *corpi di fabbrica* (Building Items). A futher card can be linked to the *corpo di fabbrica*, for tye description of the preservation state.

Each *corpo di fabbrica* can be splitted also in *settori* (Sectors) or *prospetti* (Façades); also in this case, a further description for the preservation state is possible.

A further level of description concerns the *sistemi di riferimento* (Reference Systems) of each sector: they are the real basis for the graphic work, by means of raster orthophotos on which graphic works and georeference operations are performed. The main advantage of this system consists in the possibility to work at different degrees, from the building complex to the plasters and decorations. The versatility of SICaR allows to overcome the too rigid schematism of the previous paper-cards, and allow to use digital cards consistent with the different typologies of the various buildings.

The effectiveness and the originality of the so organized system consists of the possibility to operate at different levels of elaboration. This recording methodology allows to carry on analyses from the level of the architectural complex to the coverings and colorings, according to a stratigraphical logic, i.e. it allows a high level of description of the material structures.

6. Conclusions

As the plug-ins for 3D drawing in a 3D GIS are still in the testing phase, only currently-available 2D GIS for recording information on vertical surfaces bases can be used at present, such as the SICaR.

The largest part of the information related to:

- constructive history
- damages and repairs caused by ancient earthquakes
- qualitative characteristics of the masonries
- diagnostic analysis and characterization of the materials
- operative activities linked to the intervention of restoration
- management and monitoring of the results of the restoration

are individualized in the best way on the vertical surfaces. For this reason, a GIS like SICaR nowadays represents a good solution, because it allows to manage all required operations on the standing surfaces through the use of georeferenced and vectorized images.

This procedure, based on the use of new IT instruments and methodologies, can provide excellent results for the study and management of the historical buildings, specifically before and after natural disasters like an earthquake. The database is readly accessible and, above all, can updated by expert users even on-line, and can thus be managed by different research groups.

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