THESIS - Vol. 10, No. 2, Autumn 2021

International Research Journal

Kolegji AAB
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ISSN: 1848-4298 (Print) **ISSN: 2623-8381**(Online)

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How to cite this article:
Maino, G. and Biagi Maino, D. (2021). Documenting architecture. From 3D simulations to virtual restoration. *Thesis*, 10(2), 105-130.

Published online: January 15, 2022.

Article received October 14, 2021.
Article accepted December 21, 2021.

Conflict of Interest: Author declares no conflict of interest.

Original Article

Documenting architecture. From 3D simulations to virtual restoration

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Abstract
The *Casa del Mutilato (House of the Mutilated)* in Ancona, Italy, is a significant example of twentieth-century architecture and the current initiatives aimed at its recovery and restoration can represent a useful and interesting test bed for experimenting with the most innovative IT methodologies for documenting the history and state of conservation of the building. This contribution therefore intends to propose some possible strategies for the design and implementation of a new concept of digital information system to preserve all the documentation relating to the *Casa del Mutilato*, make it accessible online also to citizens and the wider public, create a useful service for the management of the building itself, and enhance the asset, making known its history, constructive and artistic characteristics, and the possibilities of use. The results so obtained can then be usefully utilized for the documentation and planning of the recovery of monumental buildings of the twentieth century of historical and artistic interest in Europe.

Introduction

For a few years the *Casa del Mutilato* in Ancona (fig. 1) has been the subject of renewed attention, including media, after a long period of neglect (Munafò & Pigliapoco, 2018; Biagi Maino, Cassani Simonetti & Maltoni, 2019). Therefore, it was possible to recover an important amount of archival, historical, artistic, planning information on the *Casa del Mutilato* and many others will be added also during the desirable restoration; it is essential that this documentary heritage is not lost or dispersed, it can be easily consulted and available above all to interested citizens and not only to scholars and the public administration. An opportunity to experiment a new type of approach to the documentation of the architectural work that must not be wasted, that can become a prototype model for other significant applications to the monumental heritage and serve for a shrewd and sensitive policy of scheduled maintenance of the buildings.

This paper therefore intends to propose some suggestions, possible ways for the design and implementation of an innovative digital information system to preserve the documentation, make it accessible also online, create a useful service for the management of the building, and enhance the asset by exploiting the enormous potential that current computer technologies, hardware, and software, make available to us.

Fig. 1. The *Casa del Mutilato*, Ancona, Italy.

The science of acquiring and processing information in digital format is now an all-encompassing and omnipresent element in our society and pervades, largely determining them, our lifestyles. Digital technologies, hardware, and software are an integral part, for better or for worse, of our lives and no discipline can ignore them. Above all, the extraordinary advances in image processing and pattern recognition techniques and in the development of sophisticated and innovative instrumentation for the acquisition of high and very high-resolution digital images, even in the multispectral diagnostic field, have allowed previously unthinkable applications, for example in the field of documentation and knowledge of cultural heritage (Biagi Maino & Maino, 1999).

Information technology (IT) tools, just think of the use of Computer Aided Design (CAD) software, in architectural design, in the conception of exhibitions and installations, etc., have now replaced traditional drawing techniques with undoubted advantages in the quality of work and in the saving of required time, in the ease of revisions, in the rapid transmission and communication of results via the internet.

On the other hand, digital data, due to their intrinsic characteristic, allows for the homogeneous management of heterogeneous multimedia information, coding texts, images, sounds and videos in bits and storing the related data on a single special device. support - DVD, cloud, etc. - for any type of information. The digital medium consequently allows the integration of all the different sources of information and documentation on the historic building, its context, the city, and the territory to which it belongs.

Furthermore, the reconstructions of three-dimensional virtual reality - now within the reach of common computers, including laptops - lend to numerous innovative applications relating to the study of historic buildings and monuments. First, virtual reality allows one to move freely in the external and internal spaces of the architecture, observing the building from multiple points of view, including the aerial one, in a dynamic way and without apparent continuity. In this way, the future expectations of Bruno Zevi (1950, 1962) are accomplished now, finally having at disposal an instrument capable of "exhausting the representation of a building" and above all of making possible "that process that we could call musical of continuous succession of points of view that the observer experiences in his motion within and around the building " (Zevi, 1962).

As this scholar and historian of architecture noticed, “if the main character of architecture is the interior space and if its value derives from living all its spatial stages successively, it is evident that neither one nor a hundred photographs will be able to exhaust the representation of a building, and this for the same reasons for which neither one nor a hundred drawn perspectives could do. Each photograph embraces the building from a single point of view, statically, […] is a detached sentence from a symphonic poem or a poetic discourse whose essential value is the synthetic value of the whole” (Zevi, 1962, p. 49).

Virtual reality simulations, especially in the extended definition of augmented virtual reality, are not limited to proposing three-dimensional representations that can be travelled at will, but together with virtual restoration techniques allow to view reconstructive hypotheses of archaeological sites, damaged and degraded monuments or even destroyed and no longer existing and, finally, to produce real 4D representations, where the temporal dimension is added to the three spatial ones. The 4D simulations are therefore diachronic representations of the development of a building over time, which can thus be visited in its various evolutionary phases, reuses, renovations and changes that have occurred throughout its history.

IT in the architectural field becomes a precious, indeed unique aid, not only for the design and documentation of a historic building, but to create a permanent multimedia archive that can continuously be updated, indispensable for the necessary knowledge and understanding. Last but not least, IT and the web allow to reach a wider audience to disseminate and enhance a priceless cultural heritage, often difficult to access and little known except to professionals.

But the key word underlying these considerations remains the integration of information in a single (digital) support.

Theory

The historic building is obviously always part of a built context, lived in, modified by human intervention and, in general, integrated into a very large territorial system, whose historical evolution cannot be ignored. Consequently, knowledge and real understanding of a building or monument require the acquisition, storage and management of a large amount of data of all kinds. Databases meet these needs exactly (Maino, 2019).

Furthermore, digital databases can be integrated into general information systems and, for example, be combined with 3D and 4D reconstructions, so as to constitute interactive software that allows querying the database starting from the individual building elements, from the decorations, from the paths, simply by activating the appropriate points with the mouse in such a way as to bring up descriptive cards of the detail in question or by opening scrolling menus from which to choose the possible options for consultation.

In this way, a single computer system can manage all the information relating to the historic building, including surveys, maps, archival documents, restoration reports, historical data, any films, photographs, engravings, as well as allowing the (virtual) visit of the external and internal spaces from multiple points of view and according to paths chosen by the user.

On the scale of the single building, it is essential - in addition to the retrieval and archiving in digital format of the classic documentation - to be able to apply the BIM (*Building Information Modelling*) methodology for the optimization of processes which, introduced in the 1970s, thanks to the subsequent developments of the related IT, is now widely practiced (Del Curto & Grimoldi, 2017). A BIM model is a sort of centralized digital archive (repository) of information relating to the physical and functional aspects of a project, which evolves and enriches with information during the related life cycle of the project itself. BIM uses intelligent parametric multidimensional modelling to record and share information about a building, relating both to design and construction, and to the management and maintenance of the asset. Basically, the virtual model of the constituent works of the building is created, but - unlike a CAD software that represents data starting from geometric elements such as points, lines and surfaces - a software underlying the BIM methodology is of the object type based on a representative scheme modelled around the different entities of the project, such as walls, pillars, windows, etc., and their mutual relationships. In fact, geometry constitutes only one of the various properties of these objects (Del Curto & Grimoldi, 2017).

Therefore, BIM becomes a fundamental digitization tool to support the sharing and management of information, also in view of scheduled maintenance. In fact, it is precisely the knowledge of the inventory and inspection data of the works that lays the foundations for an effective scheduled maintenance system and the ICT technology available to BIM allows its practical implementation: The integration between webGIS systems (territorial, context urban) and BIM (premises, individual buildings) would finally allow to have all the necessary tools for a valuable and effective policy of planned maintenance of cultural heritage (Logothetis & Stylianidis, 2016; Logothetis, Karachaliou, Valari & Stylianidis, 2018).

Finally, it should be remembered that the BIM methodology is a process originally introduced for new constructions, where the industrial production of building components plays an important role in the integration of the parts. But the advantages of the information management offered by BIM have suggested its application even in the context of the already built, however, implying approaches and tools with different characteristics than those commonly used for the design of the new buildings. Recently, to define this precise scope of intervention on historic buildings, the acronym *HBIM* has begun to spread: *Historic Building Information Modelling* (HBIM) is a novel prototype library of parametric objects, based on historic architectural data, in addition to a mapping system for plotting the library objects onto laser-scanned survey data. The HBIM term was proposed in 2009 by Maurice Murphy, of Dublin Polytechnic, and then picked up in his PhD work (Murphy, 2012).

The HBIM model therefore introduces a technical procedure of geometric modelling first, and then of information storage: The existing historical buildings, regardless of their function, are detected by 3D laser scanners and the resulting measurements, consisting of point clouds, are compared with models (objects) contained in special digital libraries and superimposed on the cloud until the similarity is satisfactory (Böhler, 2005). The results are simplified models, 'light' from an

IT point of view to which data can be associated for documentation or numerical simulations. The HBIM methodology therefore does not mean applying BIM to buildings already built but obtaining simplified models starting from a survey.

Then, the HBIM methodology provides us with the necessary ingredients to be able to develop 3D and 4D virtual reality models. The problem to deal with therefore becomes that of the necessary integration between the three main information moments in the life of the historic building, represented by GIS, (H)BIM and virtual reality methodologies.

Methodology and results

The term open source indicates a software whose source code is made accessible to anyone and of which the holders of the relative rights allow and favour the free study and the introduction of modifications by other independent programmers. Among the best known and appreciated open-source software, at least the Unix-like FreeBSD, GNU (recursive acronym for "GNU's Not Unix") and the Linux kernel should be mentioned.

Open source is a powerful IT resource as it does not involve purchase and use costs, it is also continuously tested, verified, updated and enriched by the contributions of users and programmers around the world. This tool is therefore very useful for designing and developing low-cost but high-tech applications, such as the one we propose for the integrated documentation of the history and restoration of the *Casa del Mutilato* in Ancona. As an example, GIMP, *GNU Image Manipulation Program* (https://www.gimp.org/), is a powerful digital image processing software, capable of managing, modifying, producing visual information both raster or bitmap, and vector one, for the creation of a multimedia database and a GIS system.

The processes of planning and territorial development now show more and more clearly how any action or intervention that has as its objective the conservation, enhancement and promotion of a site of historical and artistic interest cannot fail to consider the geographical identification at the base of the knowledge of the asset itself. Therefore, the availability of tools such as GIS makes it possible to disseminate contextualized information on cultural heritage and plays a fundamental role. The understanding of individual historic buildings and monuments cannot take place without a simultaneous consideration of the building-urban fabric and of the landscape and environmental context that produced them and with which they have been or are related.

Territories, landscapes, cities, roads, rivers, monuments, buildings, sites, every spatially identifiable and codable element can be inserted and represented in a GIS. The canonical image of the GIS is in fact a multi-level representation of superimposed themed maps in the same spatial system (see fig. 2). A sort of collection of transparent glossy sheets arranged in overlapping layers (information layers) that contain any type of spatial information: Aerial photos, geophysical and satellite data, databases, and any type of information that can be represented in spatial coordinates. These layers can be modified and updated in real time following the historical evolution of a territory and dynamically providing its representation.

There are two types of data that can be stored and consulted in a GIS system:

1. raster data, consisting of cell arrays that generate an image whose content is linked to specific quantities but cannot be interrogated in an alphanumeric way. This system is mainly used for image management;

2. vector data that represent the fields through points, lines, surfaces that define geographic objects, to which alphanumeric attributes are associated.

However, the most important functions of a GIS reside in its ability to visualize, interrogate, and cross-reference data, creating new relational contexts and original information. In the case of GIS, the query includes the possibility of querying the system by associating the relational databases (alphanumeric archives) to the various cartographic bases, themes, aerial photos, etc. base of the fields (fields) present in the databases.

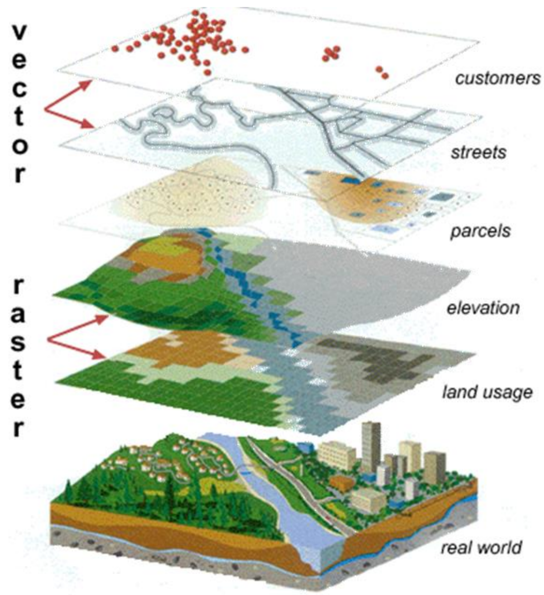

Fig. 2. Some of the possible layers of a GIS containing images and floor plans

In fig. 3, relating to the GIS system we have prepared for the territory of the municipality of Finale Emilia, for example, the different levels of damage suffered by the historic buildings of the town following the two earthquakes in 2012 are shown in different colours.

The results of the GIS search appear both in the cartographic window, as in fig. 3, and in the database tables according to the adopted criteria. It is worth considering a GIS not as the landscape, but - in accordance with Bruno Zevi's considerations on architectural representation - as a tool for interpreting space, describing it with a new language and at the same time returning to perceive it in different dimensions and through appropriate simulations.

The reference open-source GIS software is certainly GRASS (*Geographic Resources Analysis Support System*, https://grass.osgeo.org/); another open-source software recommended for reasons such as ease of interpretation and use of the interface and compatibility with different platforms is *Quantum GIS* (https://qgis.org/en/site/). Finally, the *OpenGeo* suite should be mentioned, which unfortunately is no longer updated (the website http://opengeo.org/ is no longer active) as the new versions (Boundless Server) are not freely available according to the open-source logic. The *Ushahidi* application (http://ushahidi.com/) is an open-source software for collaborative mapping, useful for collecting and displaying the information provided by users and relating them through feedback mechanisms and approval workflows, to create a real work in progress.

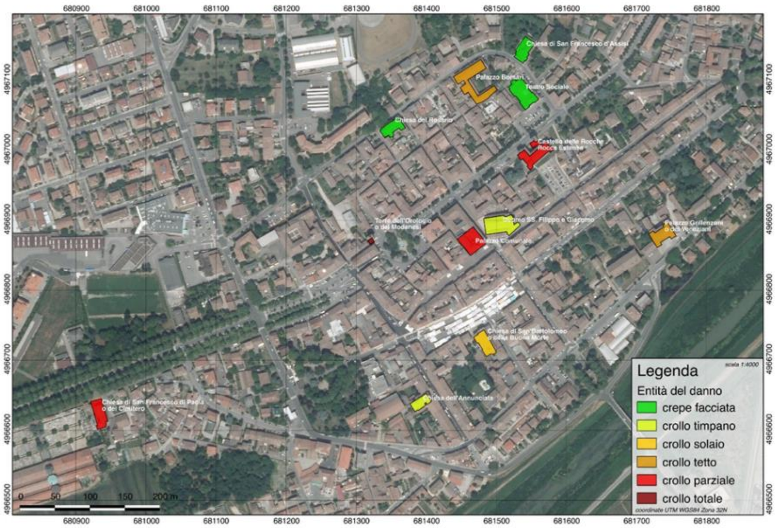

Fig. 3. GIS image relating to the mapping of the historic buildings of Finale Emilia (Italy) which suffered damage following the Emilia-Romagna earthquakes of May - June 2012.

Usually, the official cartography is in DXF (Drawing Exchange Format), which is an ASME/ANSI standard for CAD/CAM platforms, used for the communication of vector data and 2D and 3D graphic images. To be inserted into a GIS system, this information must be converted into the GIS acquisition format (ESRI shapefile), an operation that can be carried out with an appropriate open-source software with GNU GPL license such as *DXF to Shapefile Converter*.

Also as regards the (H) BIM methodology, open-source software of excellent quality and constantly updated is available. Recently, exhaustive critical reviews of existing products have been published and available on the net and therefore reference should be made to these bibliographical references (Logothetis & Stylianidis, 2016; Logothetis, Karachaliou, Valari, & Stylianidis, 2018) for all information relating to computer programs to create BIM models for cultural heritage; of particular interest is the innovative use of cloud-computing technologies.

In the specific field of the documentation of restoration interventions, we have created a descriptive sheet of all the aspects related to restoration (diagnostic investigations and surveys of decay and of the state of conservation, techniques, materials, managerial and economic, legal and administrative aspects, etc.) and implemented an IT system - TECHNÈ - for image processing, diagnostic imaging and virtual restoration, which includes a prototype for the constitution of hypertextual and multimedia computer archives where to store and trace information relating to restoration, diagnostics, dating interventions on finds and artefacts of historical and artistic interest. Multimedia information systems were thus developed and validated for the efficient and easy-to-use classification and conservation of all the documentation on important restoration interventions carried out by private companies for local public bodies and for the State (Biagi Maino & Maino, 1999; Maino, 2003).

Two types of databases have been created: one more purely scientific, for use by art historians, conservators, restorers, the other more strictly technical and economic, which allows you to enter all the technical and executive information on the interventions of restoration, of specific interest to businesses.

The last piece of the prototype information system that is proposed in this paper concerns 3D and 4D modelling with virtual reality simulations, including augmented ones.

It should be emphasized that, until a few decades ago, the technique mainly used for the survey of cultural heritage was photogrammetry (De Luca, 2011), combined with the topographic support survey for the acquisition of control points. Then, with the advent in the last decades of the last century of the first scanning lasers actually usable in this field (Maino, 2007), the enormous amount of data acquired using this methodology, which has since undergone substantial progress in terms of precision, reliability of measurements and portability of the equipment (essential the combination between laser scanner instrumentation and GPS technology), together with the acquisition speed, initially suggested a possible replacement of the two previous techniques (Böhler, 2005). In fact, today it is recognized that the optimal solution for an accurate survey from a metric point of view and with the wealth of details necessary to fully describe an object involves the integrated use of the two techniques, photogrammetry and laser scanning.

Therefore, starting from the information acquired in this way, with appropriate software - possibly, as pointed out, open source - it is possible to develop 3D models of the building and possibly also of its urban context, up to designing virtual simulations that represent both interventions possible restoration and/or reconstruction, and the temporal evolution of the building itself, showing its construction history, the modifications, the reconstructions, the reuses that have taken place over the years (Bennardi & Furferi, 2007; Biagi Maino & Maino, 2017).

There are numerous open-source programs for drawing, designing, creating 3D animations, from CAD software to those specifically designed for creating 3D animations; of particular interest are the virtual reality tools for/on the web (*WebVR* tools) which operate simply through a browser and are therefore independent of the specific hardware or device to be used.

In conclusion, there is a wide possible choice of very valid and efficient programs, free, open source and continuously updated and above all kept in operation with all the necessary technical and documentary support, to achieve the objective, proposed here, of an integrated information system for applications to historical architecture and to be applied to the *Casa del Mutilato* in Ancona.

The 4D animation of virtual reality, in this digital documentary system project, constitutes a sort of access route - an interactive door - to all the other software modules and databases integrated into the information system itself; A kind of meta-software that allows the user to move in the urban context and inside the building and, at the same time, to activate query windows and data search on historical, material, conservation, managerial and administrative aspects, etc., relating to structures, decorative details, systems, etc.

An important aspect of virtual reality representations that deserves to be highlighted is the use, or rather representation, of light sources. Light is a substantial architectural tool. Photographic and even cinematographic reproductions of a building strongly depend on the particular lighting sources used for filming. If we then think of the nocturnal version of the historic centre of Ancona, like that of any other city, it is clear that it is no longer legible as the sum of its architectural components illuminated by the sun or by lighting systems in use in the past when the historic building we are considering was designed and built; this fact is even more true if we think of indoor lighting. The 3D simulation programs can provide visual routes, visits to the building and its urban context, not only from different perspective points but also with different lighting conditions: Arrangement and characteristics such as spectral composition and intensity of the light sources can be chosen according to personal liking and according to the needs of the research.

A working methodology was proposed by researchers of the Department of Industrial Engineering of the Federico II University of Naples (Bellia, Agresta, & Pedace, 2013), based on the study of the chromatic variations of some buildings in the Neapolitan city affected by light sources with different SPD (where SPD is the acronym for '*spectral power distribution*', i.e. distribution of spectral power that serves to define the power of a lighting source per unit of area and unit of wavelength) and on the concept of '*perceptual salience*', that is the quality that makes an object recognizable and capable of instantly capturing the attention of our eyes and mind. This methodology would allow the construction of a lighting system capable of enhancing the characteristics of a historic city centre and of a building while respecting its materials and different colour gradients.

Unlike traditional restoration which operates directly on the original asset to consolidate and improve its present status and prevent subsequent alterations, the virtual one is a non-real action conducted, as the name itself implies, only in the field of virtuality. of fiction. Therefore, it does not perform an intervention on the constitutive matter of the work of art, but with the use of dedicated software - such as GIMP- it intervenes exclusively on its digital reproduction, ensuring an exclusively visual improvement or proposing a hypothetical reconstruction. Consequently, we can say that virtual restoration fully falls within the area of safeguarding cultural heritage, meaning the latter as a "*conservation measure that does not imply any direct intervention on the work*".

3D simulations and related virtual restoration operations, like any technology, have advantages and disadvantages, namely dangers of misunderstanding and interpretation. Virtual restoration is not to be considered only as an alternative to actual restoration, but also as a functional and integrative intervention, precisely an analysis and study support for the activity of the designer, conservator, and restorer. It allows one to create restoration hypotheses and to evaluate in advance which of the many is the most suitable. Fig. 4 briefly shows the possible virtual restoration operations and the relationships existing between them (Bennardi & Furferi, 2007; Chirici, 2009; Biagi Maino & Maino, 2017).

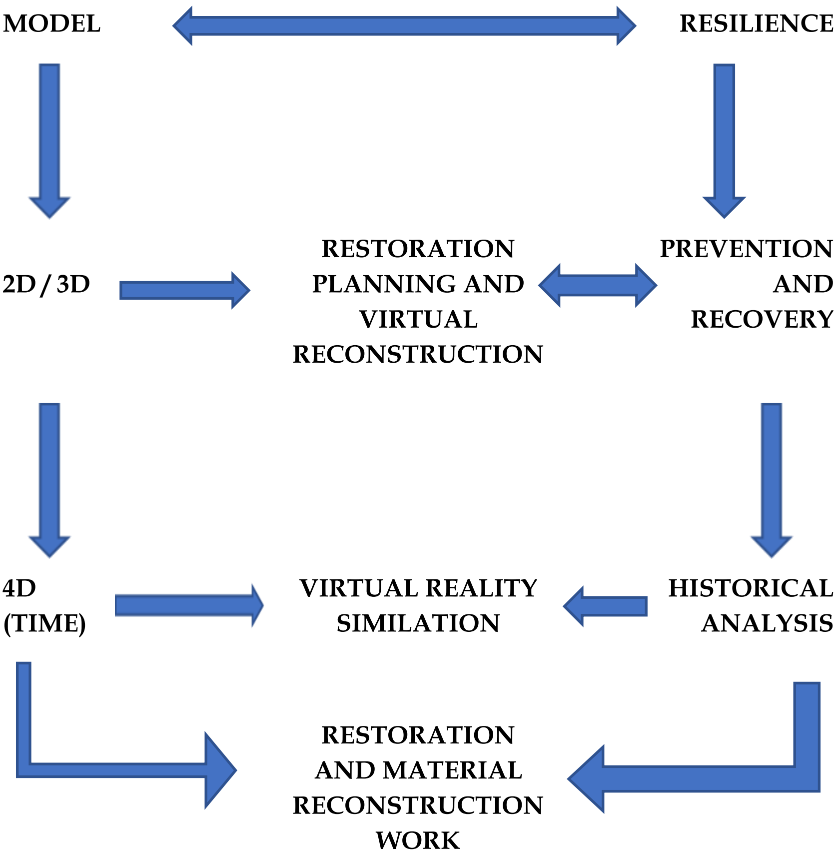

Fig. 4. Logical diagram of the possible virtual restoration operations

Furthermore, virtual restoration methodologies are very useful as an aid for the reconstruction of severely damaged or even completely destroyed historic buildings. This is the case of the *Frauenkirche* in Dresden, the eighteenth-century church burned down and collapsed entirely during the terrible Allied air raids on the German city, carried out between February13 and 14, 1945. Part of the original construction materials were recovered and filed with the typical methods of the archaeological survey and excavation, to allow - starting from the nineties of the twentieth century - to design, thanks to the techniques of computer anastylosis and virtual restoration, and consequently to proceed with the computer and therefore physical reconstruction (Friedrich, Schöner, & Nitschke, 2005). In 2005 it was possible to inaugurate the 'new' *Frauenkirche*, very similar to the original.

A similar computer work was experimented by Valeria Caggiula and myself following the repeated earthquakes that caused serious damage to the historical and artistic heritage of Emilia-Romagna in May and early June 2012. In fact, after two violent earthquakes at the end of May, a new strong earthquake of magnitude 5.1 ML which occurred at 21:20 on 3 June 2012 with its epicenter in Novi di Modena was felt throughout northern Italy and again hit the entire area of the provinces of Modena and the lower Mantuan Oltrepò. The historic *Clock Tower* in Novi di Modena - already damaged by the previous shakes - collapsed completely during this latest earthquake. Unfortunately, all the documentation relating to the *Tower* was also lost due to the damage caused by the earthquake to the Municipal Archives.

According to the documents, the *Tower* was built in the year 1712. In 1928, the tower and the bell were subject to restoration and renovation, as the former showed structural deterioration, while the latter had been cracked by lightning and rendered almost silent. Designed by the Novese architect Pietro Pivi, the tower assumed the crenelated structure, raised by three meters in the protruding form, which was possible to admire before the earthquake that caused its collapse (thus reaching almost 22 meters d height, see fig. 5) and equipped with a new four-quadrant.

Today - after the collapse of the building - the only available documentation of the tower consists of some photographs that have been possible to find from private collectors. Based on these, an attempt was made to virtual reconstruction of the tower, both in its original form (project A) and after the transformation of 1928 (project B), including metric information, etc., to provide suitable information for a future intervention of material reconstruction.

Photomodeling refers exclusively to the use of photographs to conduct the three-dimensional reconstruction of real objects (De Luca, 2011), effectively defining a work environment that allows the 3D rendering of buildings based on the global and coherent integration of the survey, modelling and representation phases. In our work (some results are shown in figs. 6 and 7), *SketchUp* software was used. After the 3D modelling phase, the photographic texture was directly projected onto the model, following the articulated trend of the surfaces in three dimensions, as shown in fig. 6.

Finally, through a geo-positioning operation, with the insertion of georeferencing data (in this case: piazza 1 Maggio, Novi di Modena), the search engine, present in the 3D model sharing bank, correctly positions the building recreated three-dimensionally. This operation also involves the generation of a Google Earth file (.kmz) which is subjected to evaluation before being inserted into the Google Earth browser and made available to any user on the network.

Fig.5. The *Clock Tower* in Novi di Modena (Italy) before the 2011 earthquake.

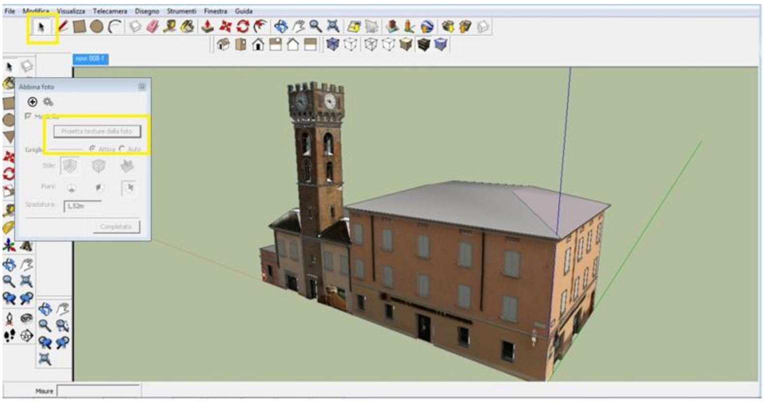

Fig.6. Texture projection from the photo in fig. 5

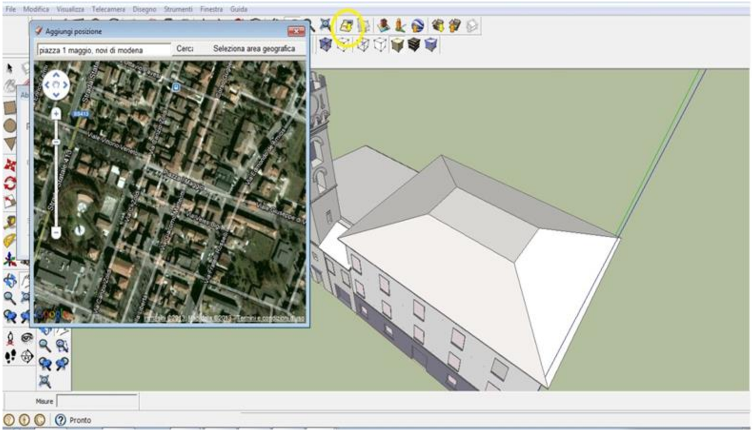

Fig.7. Entering the GPS position in the 3D reconstruction of the tower

Conclusions

In this work it was proposed a design scheme relating to the creation of a multimedia and integrated computer system that guarantees the acquisition, conservation, management, and research of all historical and archival documentation for the *Casa del Mutilato* in Ancona, and, at the next time, allows one to enter the information that will gradually be produced before and during the restoration interventions. To this platform, which partly uses GIS and HBIM methods and technologies, it will be possible to add 3D representations and the historical evolution of the building (4D simulations) using virtual reality techniques and the creation of films to create tour itineraries. and knowledge that can be defined by the user at will and according to his/her own interests. The system will be available on the internet and, of course, there will be different access and consultation methods based on the confidentiality of the data.

From the historical archive to the management data for a scheduled maintenance of the building, up to the 4D reconstruction, a general-purpose information system will be created in continuous development and becoming, divided into modules, also fundamental for the dissemination and enhancement of the asset and for the involvement of citizens in carrying out the restoration works of the building thanks to the website kept constantly updated and in the subsequent use of the architectural structure if, as hoped, it will be partly dedicated to hosting cultural institutions with their activities (historical library , newspaper library, rooms for seminars and conferences, etc.).

Concluding how it was started, with a citation from Zevi (Zevi, 1962, pp. 53-54), it is necessary to observe and reiterate that "within the limits for which it is legitimate to schematize a historical-critical process, in the face of an era or an artistic personality one should first illustrate the following data:

a) the social conditions. Each building is the result of a building program. This is based on the economic situation of the country and of the individuals who promote construction, and on the way of life, on class relations and on the custom that derives from it;
b) the intellectual presuppositions, which differ from the former to include not only what the community and the individual are, but also what they want to be, the world of their dreams, their social myths, aspirations and religious beliefs;
c) the technical conditions, that is, the progress of the sciences and their artisan and industrial applications, regarding the construction industry technique and the organization of the construction workforce;
d) the figurative and aesthetic world, the set of conceptions and interpretations of art and the

figurative vocabulary that in every age form the language from which poets draw words and phrases to express their creations in individual language".

Even the criticism of monuments can be schematically articulated in the following approximate classification:

e) urban analysis, i.e. history of the external spaces in which the monument stands and which it helps to create;
f) architectural analysis, properly called, that is history of the spatial conception, of the way of feeling and living the interior spaces;
g) volumetric analysis, i.e. the study of the wall box that encloses the space;
h) analysis of the decorative elements, that is of plastics and painting applied to architecture and in particular to its volumes;
i) analysis of the scale, i.e. the dimensional relationships of the building with respect to the human parameter.

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