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Bim: an integrated model for planned and preventive maintenance of architectural heritage

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Abstract—Modern digital technologies give us great possibilities to organize knowledge about constructions, regarding multidisciplinary fields like preservation, conservation and valorization of our architectural heritage, in order to suggest restoration projects and related work, or to suppose a planned preventive maintenance. New procedures to archive, analyze and manage architectural information find a natural support in 3D model, thanks to the development of capacities of new modeling software. Moreover, if the model contains or interfaces with a heterogeneous archive of information, as it is for BIM, this model can be considered as the bases of critical studies, projects of restoration, heritage maintenance, integrated management, protection, and valorization, and evaluation of economic aspects, management and planning, that can flow into a planned preventive maintenance [1]. The aspect that limit the use of BIM technology is the set up parametric object library inside programs: the standardized level of these objects deals difficulty with survey and restoration issues, where each single element has its own historical and architectural characterization [2]. From this foreword, the goal of this research is more evident: the possibilities of using BIM modeling to the existing constructions and cultural heritage, as a support for the construction and management of a Plan for planned preventive maintenance.

Index Terms—3D Model, BIM, Planned and Preventive Maintenance

I. PLANNED AND PREVENTIVE MAINTENANCE OF CULTURAL HERITAGE

From earlier “Carta del Restauro”[3], it’s continuously stated the importance of preventive actions to monitor the state of health and of degradation. This cultural position brings to formalize the Maintenance Plans, defined also planned preventive maintenance, in order to maximize the lifetime and the permanence of heritage buildings.

The main goal of this type of research project is a change in perspective: the suggestion is to limit single and isolated actions and to support the idea of maintenance as a process. Regione Lombardia set up a Regional Centre of Risk Map for cultural heritage and drew up the guidelines for planned and preventive maintenance, from which we have taken the format for our experimentation, as it can be seen forward [4, 5].

Actually, planned preventive maintenance has a low diffusion; it is quite unknown or considered with skepticism. The first motivation of that is the lack of resources. Normally

in fact, the priority is given to resolve emergency maintenance and, in this way, conservation becomes secondary. Another motivation is the complexity and the time consuming procedures to survey heritages. Operators commonly denounce that instruments are too complex and few accurate to define the priority and the kind of works to activate; they state also these instruments are too complex, too slow and too expensive, so it’s necessary to find qualified experts that labor market can’t guarantee. In addition, there is a poor knowledge of the planned preventive maintenance and its operating methods.

Although the culture incites to processes of planned preventive maintenance, at this moment for the majority of the promoters of restoration the Maintenance Plan is considered only as a simple and boring bureaucratic work, and for designers as an obligation not enough rewarded. In Italy, the planned preventive maintenance is still at its first applications, but foreign experiences has shown good results [6].

II. BIM IN EXISTING HERITAGE

In the field of architecture, engineer and constructions, BIM is the most promising information technology and innovative reference system for the creative process of building [7]. A BIM system [8] is a valid, and nowadays indispensable, tool in every field of constructions. It can be used in many areas -productive, economical, financial and energetic- and in each level of process (from feasibility study, to design, construction and the later management of the building).

Only recent researches tried to explore the value of BIM in existing heritage. Even if the major part of architects continue to use traditional CAD, the transition to BIM technology would improve restoration processes.

The BIM systems offer a technology that answers to the increasing need of a multidisciplinary knowledge and in the world of Cultural Heritage there is awareness that the BIM and WEBBIM processes can effectively contribute to the management of historical and architectural heritage data (any kind of them) as evident in different researches [9-11].

In Cultural Heritage, the representation of the object (building or other) cannot be disjoint from the information that describes the history, the materials, the state of conservations, the decays, the systems, etc. The information stored in BIM models concern all parts of the building and are valuable in creating the database needed for ongoing preventive

maintenance.

As next evolution of BIM, recently the new idea of Building Lifecycle Management (BLM) has been introduced. It enlarges the limits of BIM project to management and control of constructions [12, 13]. With BLM system, it is possible to integrate inside BIM design, 3D model and information form the “Fascicolo del Fabbricato”(building report) in order to define the best way to maintain, restore and plan investments, controlling at the same time all costs of the operations and management.

The same aim moves our interest toward the investigation of the potentiality of a BIM model as base and support for planned preventive maintenance addressed to cultural heritage.

III. STUDY CASE: GALVAGNINA CHURCH

Galvagnina church (figure 1), built in the XVI century, is located in a little town of Pegognaga (Mantua). After the earthquake of 20 and 29 May 2012 the survey of the church was necessary to document the damage of the seism and to project the restoration. After the intervention, according to current Italian regulations (D.P.R. 207/2010) and the guidelines supported by Regione Lombardia, it was necessary to make the Planned Preventive Maintenance Program (PPMP). It is composed of three documents: maintenance manual, maintenance program and user manual.

The plan includes the verifications to be carried out about the performance and preservation of the technological elements and all the information for the correct maintenance of the renewed structure.



Fig. 1. Galvagnina church

IV. 3D MODELING

A. TLS survey

The restoration project cannot be considered the final step of the lifecycle of a Cultural Heritage. After the intervention, the Planned Preventive Maintenance Program contains all the information for the correct management of the building during the time. The assumption of the Plan is a deep knowledge of the asset, its structure and facilities.

In the case of Galvagnina Church an accurate survey was the first stage to guarantee a complete knowledge of the building. Terrestrial Laser Scanning was used to have a precise and quick 3D reality based model of the building.

A Leica HDS7000 (a phase-shift instrument) was used with a scan resolution of about 6.3 mm at 10 m distance. Overall, 24 scans were realized: 10 outside church and 14 inside, for 865.5 million of points. GCP coordinates were collected using Total Station Leica TS30 in order to georeference all the scan in the same reference system. RMS of the registration process was about 3mm, compatible with the precision of used instruments. At the end of the registration process, (realized with the Cyclone, by Leica Geosystems AG) TLS data were imported in CAD software in order to extract horizontal and vertical profiles, obtained using Leica Cloudwork, to made classical 2D representations for the restoration design, as the followings in figure 2.

The 3D model, basis for BIM, was realized in CAD environment by using all the information from laser scanner data. This choice was made to foster the use of the most diffuse program in restoration field and supposing a good interoperability with one of the most widespread BIM software (REVIT).

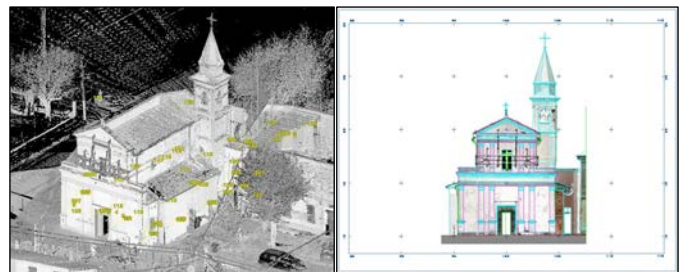


Fig. 2. Integration of drawings and raster images from laser data for the main facade

B. CAD modelling

Before modeling, it was necessary to think about a subdivision of elements, which is functional to the Plan (PPMP) to identify each single architectural element, about which there will be inspections and operations.

Presuming this subdivision, the modeling step was quite simple and quick, but it depended on the software and the knowledge and capabilities of the designer. Indeed, in this case, only few operations were enough to model the monument, such as extrusion, revolution, loft, sweep and Boolean operations using real data.

The model realized in AutoCAD is made of simplified solid elements, characterized only by geometrical information. The solids can be used to verify and solve geometrical problems, but unfortunately, they cannot have other kind of extra information. Therefore, we tried to import the model in REVIT Architecture, suitable to create and manage BIM.

We tried many methods for importing the CAD model in REVIT. However it was not possible to convert the geometric solid model into a parametric object, suitable for a BIM for planned preventive maintenance.

We tried an alternative and more laborious operation (new Conceptual Masses) but also this approach was not correct as some elements could contain only geometrical information.

These problems caused a change in the supposed workflow for the construction of the 3D model.

C. REVIT modelling

To obtain a correct BIM of Galvagnina Church, it was necessary to re-create the solid model directly in REVIT. Each single element was modelled using *System family* or *Model in-Place*. These REVIT tools allow to model historical and complex elements in a parametric way as to permit the connection with a database.

For example, walls were modelled using the *family system* "Wall". Among negative features of this family, walls can have only a vertical development and we cannot personalize any inclination, often present in ancient buildings. Moreover, the program does not always connect exactly next walls, especially when they are not perpendicular or when they are made of different materials. However, unlike AutoCAD model, walls created in REVIT can be characterized by different materials, thickness and disposition, with parametric tools. Differently, this seems to be a limitation to the possibility to analyze separately the architectural elements (i.e. plaster stratigraphy on an old surface), as it is in the Maintenance Plan.

V. FROM BIM MODEL TO MAINTENANCE PLAN

To use the model as the base for the Maintenance Plan, it is necessary to identify univocally all the elements that will be linked to the documents of the Plan.

All the solids of the model are characterized by a series of parameters that can be modified in the properties panel. In this study case, we created and added *new shared parameters* to each solid. This choice allows to use the same parameters in other projects or with other stakeholders. Therefore, shared parameters are particularly valuable if we have to create an abacus of quantity of different families (for example the abacus of all different kind of walls).

Shared parameters are created and saved in a text file outside REVIT environment so that everyone can apply these parameters.

In our case, the first idea was to create as many parameters as the number of information that is managed in the Maintenance Plan (problems, state of conservation, controls...), but information would be redundant, repetitive and useless. Furthermore, in the abacus it is not possible to filter the elements based on information included in parameters. Finally, parameters admit only a one-to-one relationship while the reports created on Regione Lombardia guidelines have parameters linked to multiple information. So we decided to create only few parameters of URL type for each object that could identify univocally the technological elements and could link to related reports, elaborated with external software (in our case with Excel: ID element, ID clining-external, ID lining-intenal, Element Report, Clining Report, Lining Report).

To foster the completing of documents, we decided to realize an abacus of elements (figure 3): the ID element allows to highlight the parameters to be filled and the links to external directories. Obviously, when parameters are not completed, their columns appear empty. The advantage of giving

information to the parameters using the abacus, instead of the property panel, is that the abacus shows together all the elements and, by completing tidy their empty spaces, we could avoid to forget codes and directories to someone.

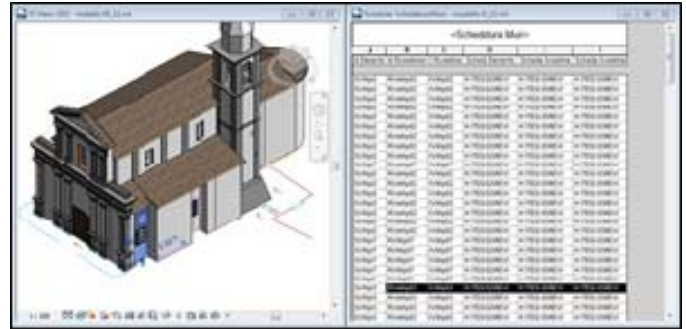


Fig. 3. Abacus of shared parameters completed with codes and external link

VI. BIM FOR CULTURAL HERITAGE: BIM3DSG

Commercial BIM software have some limitation in creating a useful model for PMP of existing and ancient buildings. Therefore, our research moved to another software to combine both model (from any modelling software) and information in a unique database: this software is BIM3DSG. This software is thought divided in:

- i) a first part, mainly used from professional and 3D specialist. It is required to add or modify (export process) 3D models into the system; every kind of previously modelled surface are supported;
- ii) the second part, for all other users and, therefore, it is specially designed to be easy to use and usable in mobility on different devices. This part requires only a web browser;
- iii) at last, the system needs a central database that collects both 3D models and all information and additional files related to each object. The use of a central database allows users to share and synchronize all changes in real-time [14].

Thanks to the great interoperability of this software, we could use already 3D modelled assets. This program, in fact, allows importing 3D AutoCAD, REVIT and Rhino models. After the import, the software requires to create a hierarchic structure of four levels and to characterize each single element with a layer of the fourth level of hierarchy and a name that is the code attributed to the element in the Maintenance Plan. Furthermore, as each element of the Plan does not correspond to a single solid, it is required to join all solid related to the same architectural element.

After that, the model is ready for the export, that allows to transfer and archive all the information related to the model in an external database, named "Galvagnina".

The database is managed with the software *pgAdminIII*. Opening the hierarchic structure of the DB, among the entries of Tables menu, we can find the two entries we have worked on to create all the tables useful for the Maintenance Plan: *Pezzi_ListaSchede* and *Pezzo_ListaInformazioni*. The first entry allows to create a list of all records we can visualize in or each element and the second one allows to list and to define

features of all cells of the tables.

Considering that the plug-in is already in a developing phase, now it is impossible to format tables composed by multiple information, so we could not use the tables prepared in Excel. The tables have to be formatted again to have only a one-to-one relationship between a record and its information, as required by Regione Lombardia. For example, to an architectural element corresponds many problems, each one with relative anomalies, risk zones, controls etc.

After creating the tables and having defined all records and their characteristics, the compilation was done by using plug-in BIM3DGS.

The first form of an element shows a box to complete with its material and technical information, then it shows a list of problems to mark with a “V”, that appears on a check box near the problem name when you click twice. Moreover, near the check box, there is a button named “View” that links to the report scheme about the problem: it is possible to click on the button and visualize the forms of all problems, but, obviously, only the marked and completed forms tables of marked problem, if completed, would show all the information.

VII. CONCLUSIONS

From this experience, it appears that commercial BIM software are not yet ready to be used for existing buildings. In particular, the main problems regard the modelling stage and the necessity to identify each single element with a code and to connect the same element with documents of the Maintenance Plan as an external link. In particular, in a restoration context, REVIT is a great database that allows to collect all information, planning or not, related to a 3D object, but it does not allow to add extra information. REVIT can be used to visualize the object development, but it is much more difficult to use it as support for successive decisions. Nevertheless, compared to traditional pipeline, it surely gives big advantages in the management of documents of planning. Furthermore, when information are integrated or externally linked to the BIM model, they earn a surplus value because they are all located in the same reference database and they can be shown in the third dimension, given back their immediate comprehension.

The positive result deriving by the application of the experimental program BIM3DSG is surely that it offers the possibility to include both model and data in a unique database outside the software. Moreover, the shared database allows each professional figure involved in the project (planning, construction and building management) to take part in the decision stage and to follow the development of the architecture, for a total integration of the workflow.

This method of management of the building could be interesting and useful also for Public Authority designed for heritage management or everyone with specific responsibilities in planning or restoration field. Furthermore, it is easier to create and to manage information inside the database developed with BIM3DSG. In fact, we need very few notions in order to understand how it can be possible to personalize tables of information based on specific necessity of a Public

Authority and to connect them to the model. No doubt, the transition to both these methods requires professional figures with enough deep familiarity in modelling field, but certainly, the experimented process requires a little waste in education of specialized staff for phases after the creation of the model.

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