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Laura Inzerillo
Associate Professor at the University of Palermo, Dept. of Architecture. She is responsible for Metalab laboratory, University of Palermo. She is Director of the Department of "interactive graphics Communication AR" the I.E.ME.S.T. Her research topics are: architectural surveying and representation, 3D modeling and descriptive geometry.

Massimiliano Lo Turco
Associate Professor at Politecnico di Torino (DAD- Dept. of Architecture and Design) since 2015. Engineer, Architect, PhD. He leads research activities in the field of survey and digital modeling. He has been working for years to analyze the BIM capabilites applied to the design process, with particular regard to intervention on Cultural Heritage.

Sandro Parrinello
Associate Professor at the Dept. of Civil Engineering and Architecture at University of Pavia. European PhD; scientific coordinator of the Joint Laboratory Landscape Survey & Design, and Director of DAda Laboratory, he is part of the editorial board of several International Journals and honorary professor in University of Odessa.

Cettina Santagati
Building engineer, fixed-term researcher at the Dept. of Civil Engineering and Architecture, University of Catania. The research focuses on IT for the surveying and representation of architectural, archaeological and environmental heritage. She is part of the editorial board of several International Journals and reviewer of European projects.

Graziano Mario Valenti
Associate Professor at the University of Rome "La Sapienza". His research activities is focused on the application of new digital technologies to the disciplines of the survey, representation and visual communication. Speaker and reviewer for international conferences He is the author of several papers and books about survey and 3d modelling.

BIM and architectural heritage: towards an operational methodology for the knowledge and the management of Cultural Heritage

BIM e beni architettonici: verso una metodologia operativa per la conoscenza e la gestione del patrimonio culturale

The study aims to answer the growing need for virtuously organize informational apparatuses related to Cultural Heritage. We propose a methodology that integrates multidisciplinary processes of interaction with information aimed at survey, documentation, management, knowledge and enhancement of historic artifacts.
It is needed to review and update the procedure of instrumental data acquisition, standardization and structuring of the acquired data in a three-dimensional semantic model as well as the subsequent representability and accessibility of the model and the related database. If the use of Building Information Modeling has in recent years seen a consolidation in the procedures and the identification of standard methods in design process, nevertheless in the field of architectural heritage, the challenge to identify operational methodologies for the conservation, management and process enhancement is still open.

Lo studio intende rispondere alla crescente necessità di organizzare in maniera virtuosa gli apparati informativi relativi al Patrimonio Culturale, attraverso una metodologia che integri processi multidisciplinari di interazione con l'informazione, finalizzati al rilievo, documentazione, gestione, conoscenza e valorizzazione del Bene.
È necessario ripercorrere, attualizzandolo, il processo di acquisizione strumentale dell'informazione, di normalizzazione e di strutturazione dei dati acquisti in un modello semantico tridimensionale e la successiva rappresentabilità e la fruibilità del modello e della banca dati associata. Se nel campo della progettazione l'utilizzo del Building Information Modeling ha visto negli ultimi anni un consolidamento nelle procedure e l'individuazione di metodologie standard, nell'ambito dei Beni Culturali, la sfida volta all'individuazione di metodologie operative è ancora aperta.

keywords: Cultural Heritage, Virtual Heritage, Big Data, HBIM, 3D Modeling
parole chiave*: Patrimonio culturale, Patrimonio virtuale, Big Data, HBIM, Modellazione 3D*

INTRODUCTION

Understanding and managing cultural heritage constitute a real objective of knowledge and science.
The potential offered by today's digital technologies, which are useful to this purpose, has opened an international challenge on the ability to identify appropriate operational methods to the different needs of Cultural Heritage domain.
The acquisition of instrumental activities must be understood as improvement of data integration processes. That is, to allow the repeatability of processes both on the real object and on the virtual model: this way, the virtual model becomes the scientific basis for the study, the comparison and the integration with the following in-depth analysis.
The realization of an information-cognitive integrated model needs a process of data normalization and organization. This process has to be based on a multidisciplinary approach that takes into account the specificities and needs of the potential users of the system.
The implementation of parametric models, interconnected through constraints and rules that guarantee formal, constructive and relational coherence within a single virtual system, is indispensable.
It is necessary to fully explore the potential of the various technologies available, both in BIM and in data processing field, which permit us to store, elaborate and represent the heterogeneous data that characterize the architectural organism.
For this reason some researchers, from different Italian universities, have created a network that aims to organize virtuously information systems related to cultural heritage, and to share the different experiences of theoretical and applied research, which they conducted in recent years. The network also aims to develop a methodology that integrates multidisciplinary processes of interaction with information aimed at survey, documentation, management, knowledge, and therefore, at the enhancement of heritage. In this scenery it is important to highlight two methodological requirements for action:
- Critical and logical summary of data
Being able to access a large amount of data does not necessarily mean to achieve a high level of knowledge. In the management of the architectural heritage, to increase the available data does not always correspond to a level of knowledge and awareness that enables the development of appropriate policy and managerial strategies.
Therefore, it is necessary to develop a model that takes into account a critical and logical summary of data; a model that can be a support to the choices and decisions that are useful to safeguard heritage in time.
Knowledge can be experienced and made explicit through a drawing, selective and symbolic, whose new digital frame is the basin of information appropriately selected and interconnected.
This reduces the danger of running into a disorganized world of redundant information.
- Osmosis of cross-multidisciplinary knowledge
Even though the cataloging methodologies for the conservation and reuse are well-established and proven, the geometrical, documentary, and iconographic components rarely are related effectively between them.
We perceive, therefore, the lack of an osmosis between the environments related to the design and execution of the works, and the sectors that operate in the administration, in the protection, and management of Cultural Heritage.
The challenge is ambitious because the interventions on the existing buildings present different problems of standardization with respect to what happens in designing new buildings.
For example, in the initial phase of acquisition and representation of the status quo, it is necessary to normalize a large amount of data that have a highly mixed nature.

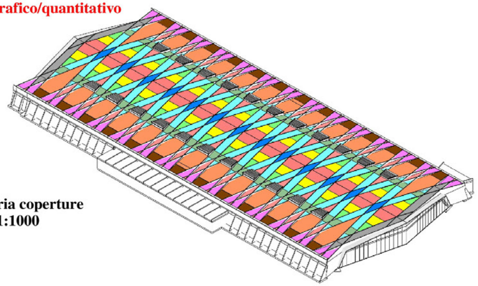
SOME OPEN ISSUES

The idea of bringing together in a unique virtual place all the elements which define the knowledge, "as designed / as-built / as is", of the cultural heritage (archival documents, documents related to the different measurement campaigns, status and the various types of degradation, the different phases and layers that over time have interested the fabric, etc ..) involves a reflection on various issues:
- The distinction between instrument and method
Historically, the term "instrument", besides the physicality of the medium through which we can operate, represents the scientific and intellectual condition that is determined by the performance of a procedure [Koyré, 1967].
- Interaction / integration with ICCD records.
The need for interaction / integration between digital reproduction techniques and the current methods of cataloging and management of the cultural heritage, provided by the "Istituto Centrale per il Catalogo e la Documentazione" is always increasing.
The cataloging system, currently in force at national level, provides the use of records that contain technical, documentary or geographical information. These information are linked, in a hierarchical and dynamic structure, to other more specific type of records and digital contents.
An update of the records relative to the architectural heritage and their integration into a parametric virtual model is an essential milestone for the knowledge and the management of architectural heritage itself.
Accessibility and data communication can be also classified according to different profiles, from a purely divulgative purposes to the most specialized, such as those of operational / procedural nature. [Parrinello, 2012]
- Methodological accuracy of the parametric virtual model.
In line with the principles of transparency, communicability and repeatability of the methods and results, the three-dimensional representation of the building must comply with the principles of the Charter of the Architectural Survey [AA. VV., 1999] and the London Charter for digital visualization of cultural heritage [Bernard, 2009].

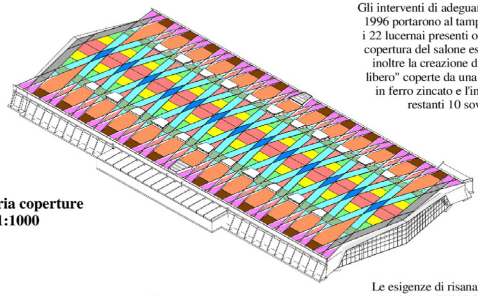
METHODOLOGY

When you investigate cultural heritage, the phenomenon breaks down into many parts, just like a drop of ink in contact with the water: a key element of the research is the analysis, the aggregation of these parts through the definition of languages representative of reality and the experimentation of technological systems that support these languages, where each sign takes a specific meaning.
Our challenge is to propose a methodology aimed at the realization of a system which is:
- Informative / 3D cognitive, multi-disciplinary, implementable and scalable;
- preparatory to the setting of the design and maintenance activities of Architectural Cultural Heritage;
- able to guarantee each kind of data permanence, consultation and implementation;

Il confronto grafico/quantitativo



Assonometria coperture 1959 scala 1:1000



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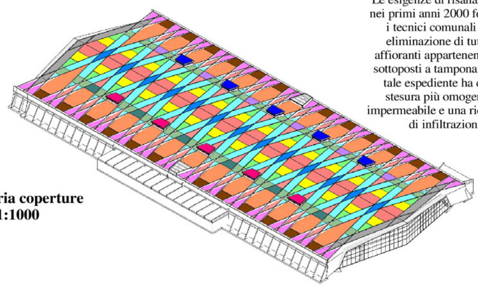


Assonometria coperture 2006 scala 1:1000

Legenda

- solaio "a" h: 35 cm
- solaio "b" h: 35 cm
- solaio "c" h: 25 cm
- solaio "d" h: 25 cm
- solaio "e" h: 8 cm
- solaio "f" h: 25 cm
- solaio "g" h: 45 cm
- solaio "h" h: 35 cm
- solaio "i" h: 25 cm
- solaio "n" h: 25 cm
- solaio di testata
- lucernai '59/'96/2006
- lucernai bassi lato est '06
- lucernai bassi lato ovest '06
- lucernai alti lato est '06
- lucernai alti lato ovest '06

Gli interventi di adeguamento funzionale del 1996 portarono al tamponamento di 12 fra i 22 lucernai presenti originariamente sulla copertura del salone espositivo. Si ravvisa inoltre la creazione di due "aree a cielo libero" coperte da una griglia calpestabile in ferro zincato e l'innalzamento delle restanti 10 sovrastrutture

Le esigenze di risanamento palesatesi nei primi anni 2000 fecero propendere i tecnici comunali alla completa eliminazione di tutte le strutture affioranti appartenenti ai 12 lucernai sottoposti a tamponamento nel 1996: tale espediente ha consentito una stesura più omogenea del manto impermeabile e una riduzione dei rischi di infiltrazioni piovane

Si mostrano le analisi grafiche e quantitative estratte dal modello parametrico del padiglione V di Torino Esposizioni realizzato con il *software* Autodesk Revit. Facendo ricorso ai filtri applicabili alle viste tabellari e tridimensionali è possibile associare ad ogni elemento la relativa fase di creazione e demolizione simulando il succedersi dei diversi interventi di trasformazione del manufatto.

L'analisi quantitativa

Solai di copertura 1959

Tipologia	Area
a_Latero Cementizio - 35 cm	841.92 m²
b _Latero Cementizio - 35 cm	583.06 m²
c_Latero Cementizio - 25 cm	334.13 m²
d_Latero Cementizio - 25 cm	2032.46 m²
e_ soletta in cemento - 8 cm	248.45 m²
f_Latero Cementizio - 25 cm	915.10 m²
g_Latero Cementizio - 45 cm	1869.48 m²
h _Latero Cementizio - 35 cm	491.37 m²
i_Latero Cementizio - 25 cm	759.99 m²
copertura lucernai '59	428.09 m²
n_Latero Cementizio - 25 cm	545.83 m²
Soletta cassoni testata	627.17 m²
Area complessiva:	9677.05 m²

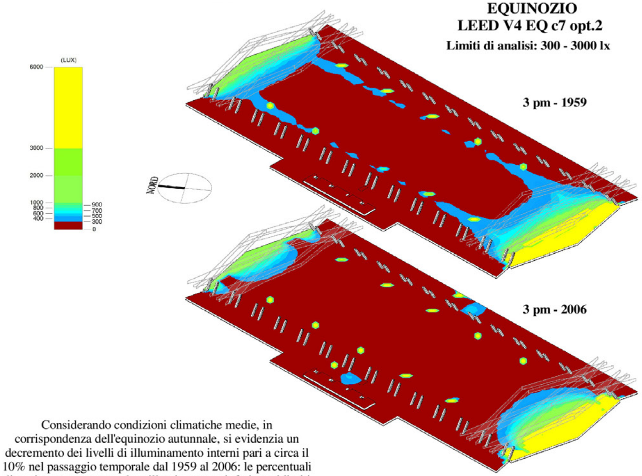
Solai di copertura 1996

Tipologia	Area
a_Latero Cementizio - 35 cm	841.92 m²
b _Latero Cementizio - 35 cm	583.06 m²
c_Latero Cementizio - 25 cm	334.13 m²
d_Latero Cementizio - 25 cm	2032.46 m²
e_ soletta in cemento - 8 cm	248.45 m²
f_Latero Cementizio - 25 cm	915.10 m²
g_Latero Cementizio - 45 cm	1851.73 m²
Griglia calpestabile in ferro zincato	58.73 m²
h _Latero Cementizio - 35 cm	453.58 m²
i_Latero Cementizio - 25 cm	759.99 m²
copertura lucernai bassi '96	199.86 m²
n_Latero Cementizio - 25 cm	545.83 m²
copertura lucernai alti '96	204.44 m²
Soletta cassoni testata	627.17 m²
Area complessiva:	9656.44 m²

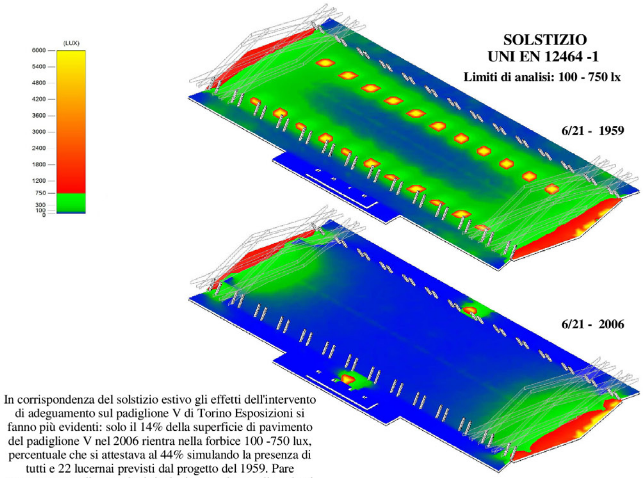
Solai di copertura 2006

Tipologia	Area
a_Latero Cementizio - 35 cm	841.92 m²
b _Latero Cementizio - 35 cm	583.06 m²
c_Latero Cementizio - 25 cm	334.13 m²
d_Latero Cementizio - 25 cm	2032.46 m²
e_ soletta in cemento - 8 cm	248.45 m²
f_Latero Cementizio - 25 cm	915.10 m²
g_Latero Cementizio - 45 cm	1851.73 m²
Griglia calpestabile in ferro zincato	58.73 m²
h _Latero Cementizio - 35 cm	453.58 m²
i_Latero Cementizio - 25 cm	759.99 m²
n_Latero Cementizio - 25 cm	545.83 m²
copertura lucernai alti '96	204.44 m²
Coperture lucernai bassi 2006	186.23 m²
Soletta cassoni testata	627.17 m²
Area complessiva:: 461	9642.81 m²

Lo studio dell'illuminazione naturale



Considerando condizioni climatiche medie, in corrispondenza dell'equinozio autunnale, si evidenzia un decremento dei livelli di illuminamento interni pari a circa il 10% nel passaggio temporale dal 1959 al 2006: le percentuali di pavimento soggette ad un illuminamento inferiore ai limiti d'analisi imposti si innalza dal 74% all' 83%



In corrispondenza del solstizio estivo gli effetti dell'intervento di adeguamento sul padiglione V di Torino Esposizioni si fanno più evidenti: solo il 14% della superficie di pavimento del padiglione V nel 2006 rientra nella forbice 100 -750 lux, percentuale che si attestava al 44% simulando la presenza di tutti e 22 lucernai previsti dal progetto del 1959. Pare opportuno sottolineare che i risultati ottenuti sono dipendenti dalle caratteristiche dei materiali impiegati in fase di modellazione facenti le veci di quelli reali.

scala 1:1000

Figure 1 Comparative analysis of the different configurations of the Pavilion V designed by Riccardo Morandi: the first realization of 1959, the interventions of 1996 and the restoration works of 2006. thematic drawings applied to structures of coverage and quantitative analysis of the natural lighting after the closure of some skylights. Processing edited by Edward Barberis.

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- where data is remotely accessible and understandable even by experts from different disciplines.
The identified phases are the result of reflections on a first experimental action conducted on case studies chosen according to different typologies in order to make heterogeneous and diverse the set of applications.

Phase 1. BIM and legislations on documentation/visualization of Cultural Heritage

Currently, both at national and international level, the guidelines in charge of the identification of protocols, definitions, ontologies within the BIM applied to Cultural Heritage have not yet been defined. Therefore, it is necessary a review of the standards, protocols, and existing guidelines on documentation / display and databases (ICCD protocols and cards; Architectural Survey international Chart; London Chart for digital visualization of cultural heritage; Seville Chart on Virtual archeology, ICOMOS CIPA, UNESCO standards) in order to update them to the international ones on the use of the Building Information Modeling -including proposal for rewriting UNI 11337: 2009 CEN / BT / WG 215, ISO / TC 59 / SC 13 / WG 13 , ISO / TS 12911.

Phase 2. Architectural Survey and data normalization

This phase is very delicate and complex because it embodies two sub- phases seemingly separated that have to be reasoned, organized and co-related. The first one regards architectural survey aimed at a primary definition of goals, of the typology and quality of data to be acquired (by using topographic instruments, 3D laser scanners, photogrammetry and drones). The second, even more critical than the first, concerns the integration, checking and testing of data obtained from surveying in order to get at an appropriate standardization [Lo Turco, 2012].

Phase 3. Parametric digital modeling

Also this phase is divided into two parts, the first concerns the definition of metadata and descriptors to be parameterized in the model obtained from the surveying in order to transform the real continuum in digital discrete (grammar of shapes, procedural modeling, identification of variants and invariants that define the elements and architectural language). The second relates to the construction of parametric models and the integration of heterogeneous data in a 3D environment using connection and relationship of the information system [Casale, Valenti, Calvano, Romor, 2013].

Phase 4. Validation of the integrated model and the interactive data bank linked to it

At this stage we proceed to the analysis and resolution of metadata structural criticalities, testing the infographics system, the validation of the access and interconnection systems with external databases, the development of connections and relation with external data (Big Data).

Phase 5. Communication and Virtual fruition

The last stage involves the representation, sharing and dissemination of the results both in academic and in industry field, as well as the identification of protocols aimed at the repeatability of the scientific process.
The identified steps are the result of the reflections that follow a first experimental action conducted on some case studies selected for different types in order to make heterogeneous and diverse set of applications. The aim, in the long term is the testing of a larger number of types of architectural assets, in order to achieve a methodical and generalized protocol, aimed at the protection of architectural memory, as envisaged in the Charter of the Architectural Survey.
The validation of the integrated model and the Interactive Database (phase 4) is a fundamental step for the purpose of structuring a streamlined workflow that can involve in real time several specialized professionals located remotely.
In order to allocate in the BIM model the heterogeneous recordable information at different stages of the process, you must connect the internal database with the applications designed to record this information on site. With this proce-

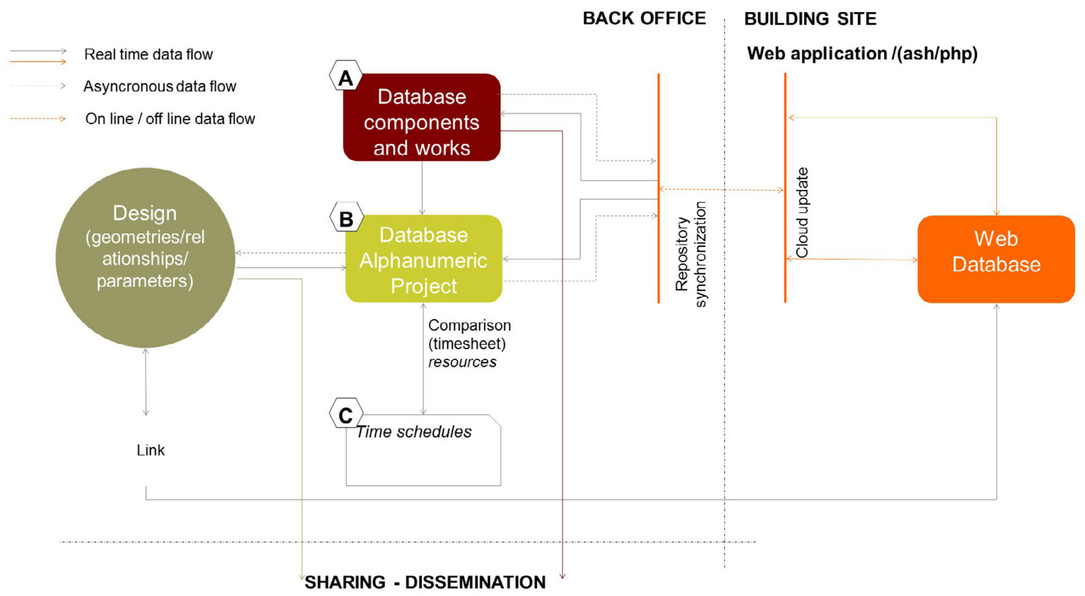

Figure 2 Physical logical scheme of the building information system for the building site management and data flow representation. Processing by Maurizio Bocconcino.

dure, back office times are reduced and a sequential workflow, standardized and implementable is ensured.
In this way, the information system should record not only the number of access, but also the changes made to the data collection by diversifying the functions available for each user profile/ competence.
This is feasible by exporting the database, own of BIM models (by definition formed by alphanumeric and graphical components that can be implemented), and their structuring.
The ability to query in a simplified way the wealth of information collected during the construction phase, and then to produce synthetic and comprehensive report of the work, can become a discriminatory factor for the success of the work. This also facilitates the relationship of communication and transparency towards clients and towards all people involved in the construction process.
To make effective the operational aspects of the intervention, it is mandatory to organically focus these components in a complex of geo-alphanumeric models - three-dimensional and parametric, drawn up by the use of methodologies related to building information systems (BIM technologies indeed) and of the relational database management systems (Database management System, DBMS).
This way it is possible to retain and process geometric / dimensional information, as well as normative, performance, estimate, material, management information. In order that the BIM model becomes the center of intervention information system, it will be enriched with additional elements that can keep track of site activities and of the variants that may involve. The integration of BIM / DBMS technologies with mobile type applications can orient the building process towards cloud-based management where a project information is available anytime, anywhere. The above creates the conditions so that specific applications can be developed in the future for a Field Management optimized and simplified.
The creation of an IT platform - streamlined and integrated with the corpus of the database ofBIM systems - is essential to improve communication between the different actors involved in surveying operations and subsequent intervention; It gains greater knowledge and awareness of the architectural heritage, both in qualitative and in quantitative terms, through unique identification of products and processes, by connecting these to the construction and management information [Bocconcino, Cangialosi, Lo Turco, Serini, 2015].
The integrity and stability of the database, security and data management, in view of a reduction of the loading operation, are fundamental prerequisites for the sustainability of the database.
As for the consultation of BIM data base it is necessary to envision different user profiles, below a possible example:
manager - owner of the database, with the task of updating its descriptors, identifying technicians for updating information, checking data quality;

Figure 3 Building site image. Source: Luigi Ravelli's Private Fund. He was the planning supervisor at Servizio Costruzioni Fiat - at the time of construction of the pavilion [Bruno, 2013].

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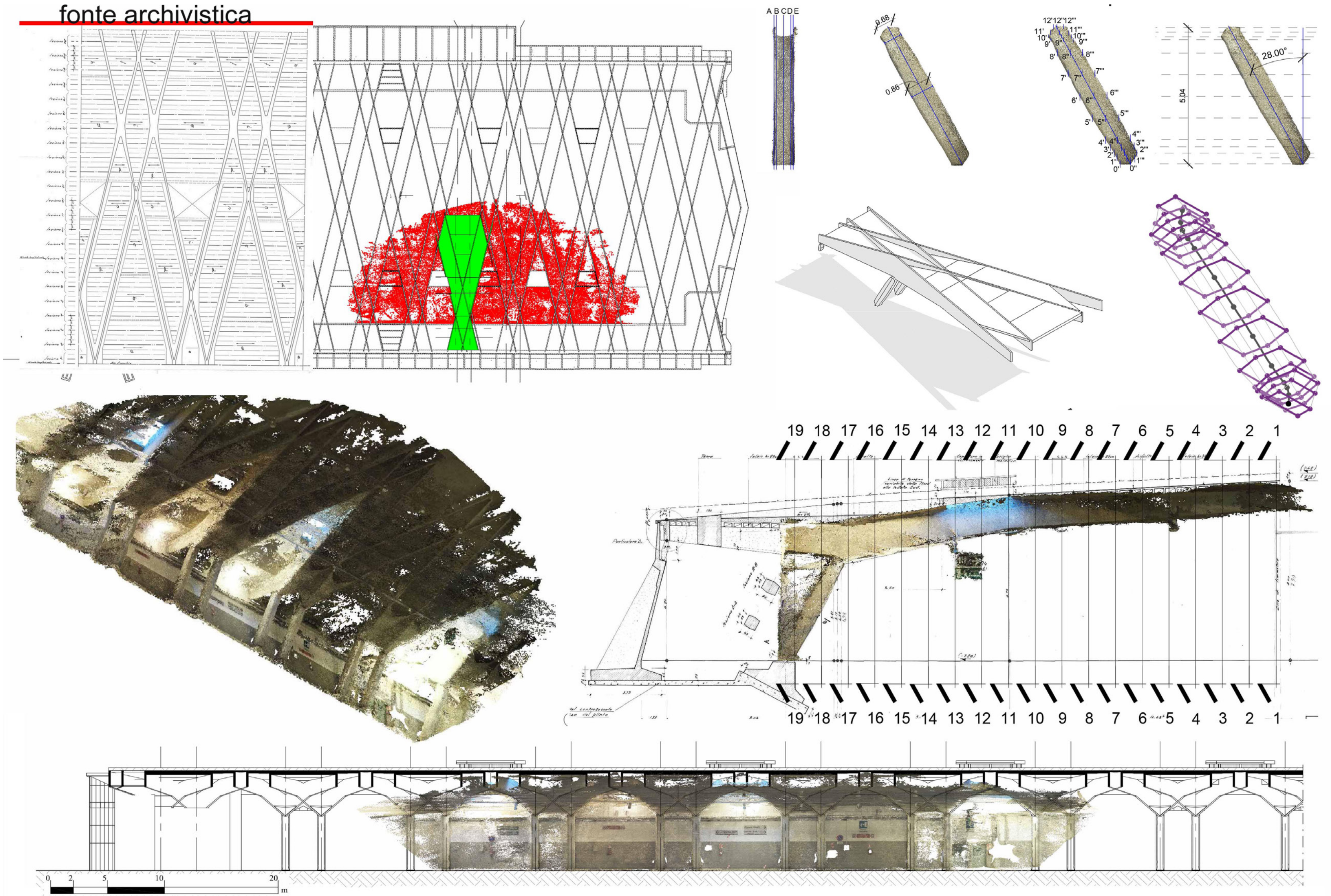

Figure 4 The infographic drawing of Pavilion V. The BIM modeling of the existing condition is the result obtained from the integration of photogrammetric survey, archival researchs and the processing of the geometries extracted from the point cloud. Processing edited by Edward Barberis.

surveyor - employees with the task of updating and control, even in situ, the consistency between the models and the as-built condition;
technical operator - in charge of consulting the technical data / updating the formats that need to be validated by the operator who verifies the reliability;
user - generic user of the database

CASE STUDY: PAVILION V OF TORINO ESPOSIZIONI

As already mentioned, the proposed methodology has been applied to some architectural artifacts typologically different between them. In this paper we give a synthesis of the stages that explain BIM approach application to Pavilion V of Torino Esposizioni, designed by Morandi in the late 60 ' of XX century.
The process aims to assess critically whether the BIM approach of geometric / relational nature, the most widely used in the optimization of the construction process applied to new construction, can contribute to the knowledge and the enhancement of cultural heritage often overlooked and today involved in dynamic upgrading works.
For modeling the as-built condition of the pavilion we considered the symmetry and the modularity of the building, so we surveyed a span of the building type, through digital photogrammetry techniques [Inzerillo, Santagati, 2013; Galicia, Inzerillo, Santagati, 2015]. The resulting point cloud is the spatial reference for modeling [Parrinello, Picchio, 2013]. The images show a synthesis of selection and measurement process of spatial coordinates with reference to the inclined connecting rods of the pavilion V.
The references have been imported on Autodesk Revit where, in correspondence of 12 altimetric elevations with respect to the floor level and the generatrices silhouettes of the volume of the connecting rods have been identified. A similar process involved the modeling of the roof beams.
At the end of the modeling process we have worked on the installation of a database finalized to collect the different found information. All the reports used for modeling, in fact, have been linked to their virtualized components, associating an image parameter to the different categories of objects. In the case study the elements constituting a span type of pavilion were grouped, to which digital copies of archival documents

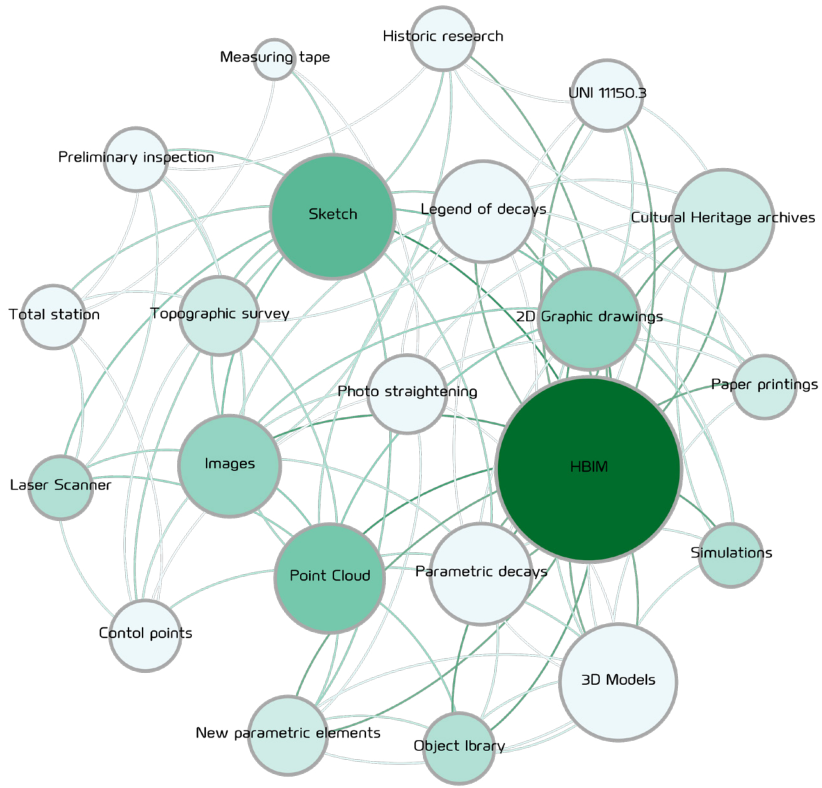

Figure 5 Graphical representation of the reticular and dislocated nature of the actants clouds included in different entities that are involved in BIM processes applied to the Cultural Heritage. The size of the node is defined as a function of the number of connections and relationships that converge in it. Processing by Federico Caputo and Gabriele Fusaro.

have been linked.
This operation was repeated for different spans and the main features of the building, such as skylights and services. This implementation allows you to bring together in one virtual place the different processed discovered, often kept in institutions or funds are not always available.
The reworking of the model allows multiple queries and the production of thematic layouts (such as the identification of the different measurement campaigns, the identification of the types of degradation, the time variable control, ...). The ideal continuation of the research work will help to create a sort of maintenance booklet accessible throughout the building life cycle; in addition, this feature, from next transformation of the pavilion, would allow the creation of an intervention certainly more aware and compliant compared to the experience of the pavilion.
The experiments carried out made it possible to hierarchically and semantically organize the complex graphical-numerical apparatus on the studied architectural heritage that can be made available to the general

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public, the scientific community but also of the professionals involved in future project interventions.
The database has been structured so as to achieve integrated management of the data which make it possible:
- The interconnection between the computer graphics systems and different databases on the cataloging of archives, historical and iconographic sources and documents of archived projects [Marotta, Abello, De Simone, 2010];
- Referencing of the different layers (we consider possible architectural styles, as well as hypothetical restorations, etc.) that have occurred over time, even for a critical assessment of future remedial action and intervention on the existing;
- The production of reports of thematic graphics, designed to qualify the nature and reliability of the metric dimensional data;
- The production of reports of all the functional features of the model, information needed to verify the efficiency and the development of links, immediate, intuitive, between the as-built condition images, documentation, archival, historic images, diagnostic checks, the nature and type of degradation, the point clouds etc.
- The implementation of database management files remotely, increasing the possibilities of control and completion, even in situ, thus saving time re-release of the data in the back office and implementing the database infographic available for different related operations the facility management disciplines.

FUTURE DEVELOPMENTS

The BIM approach capabilities have also sensitized the policy choices taken at the European Parliament: it refers to the approval of the reform of Public Works in July 2014.
The adoption of the directive means that the twenty-seven EU Member States may encourage, require or compel the use of BIM.
The countries that first implemented this legislation were England, Denmark, Finland and Norway. This means that in a little while will be binding deliver not only the elaborations on paper, but also georeferenced three-dimensional digital models, drawn up while respecting the norms and conventions derived from professional practice, related to the degree of reliability of the model.

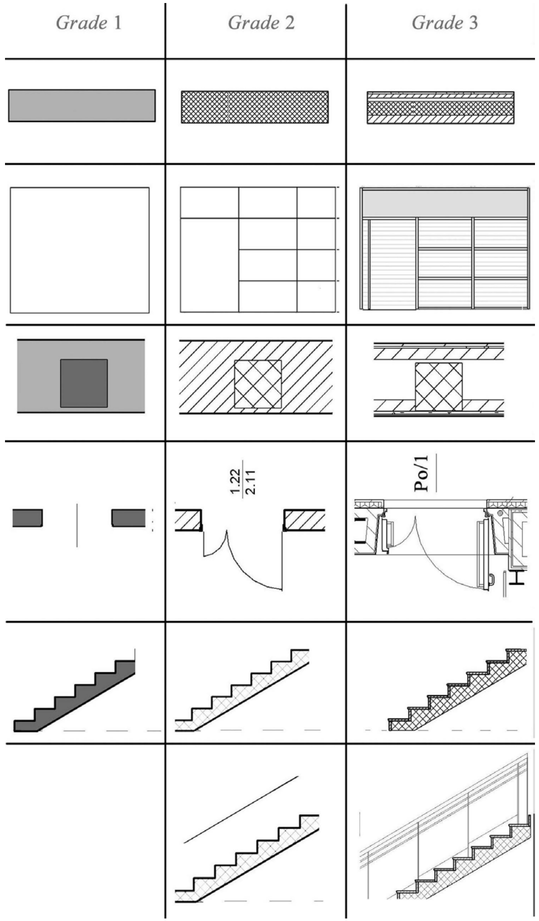

Figure 6 Exemplification of the various GRADE of the main building components (Graphic detail, meaning commonly used in the most diffused guidelines and international best practices to define the graphical content applied to virtual component), which may lead to the preliminary final and executive design according to the Italan Law for Public Works.

On this issue we would comment one topic more, related to different meaning of the word "measurability": if the geometric one is undoubtedly resolved and repeatedly mentioned in different documents that fully define the different metric detection operations, the same thing cannot be said for the ontological meaning intended as a quantitative enhancement of the reliability degree of a survey.
More likely the future trials will led to the preparation of the replicable intervention protocols on a large scale, producing faked knowledge phenomena (in the meaning of Karl Popper) evaluating the possibilities of a critical mediation between the Italian law of Public Works and specification of LOD (Level of Detail, intended as degree of reliability of the model for data) and Grade (GRAphic DEtail, as the control of purely graphical contents) by reducing them to the themes of architectural significance, thinking about possible proposals to measure their pertinence [Lo Turco, 2015].

CONCLUSIONS

We agree in declaring that "knowledge is the first stage of conservation" [AA.VV., 1999] and the conducted research corroborates this assumption. The opportunity to set up database in situ, even by less experienced users, significantly reduces the costs (of survey, drawing, design, construction and maintenance) because the data is not duplicated on the various applications and the information is no redundant, since it is a simple query of a shared virtual space. So, this guarantees a repeatability of the scientific process where the variable element is the data, the fixed one is the process
From a more scientific point of view, the application of these principles will allow to address and define a methodology for the knowledge (and the representation) of the Cultural Heritage that makes the virtual reconstruction, the processing and communication of data more transparent. It is therefore proposed a reflection on the infographic drawing, leading to a new form of design, and expanding the frontiers of our discipline. The concept of cultural dimension is thus a greater formal qualification in a permanent relationship between architectural space and information space.

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