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The knowledge of the architectural heritage in HBIM systems from the discrete model to the parametric model

The application of BIM to architectural heritage and therefore the parameterization of its elements show a certain complexity, because the historical built environment must be subject to systematic readings, in order to detect an information system based on ontologically defined elements, which must be associated with data able to document their material, historical and constructive peculiarities.
With reference to a case study, this paper examines some theoretical implications and operational procedures concerning the transition from discrete three-dimensional model of point clouds to a parametric model.

L'applicazione di una rappresentazione BIM al patrimonio storico e dunque la parametrizzazione di realtà caratterizzate da infinite possibili variazioni presentanotevoli gradi di complessità, riconducibili alla necessità di predisporre letture sistematiche del costruito storico, nell'ottica di individuare un sistema informativo definito sulla base di elementi ontologicamente definiti, a cui associare dati capaci di documentarne le specificità materiche, storiche e costruttive.
In riferimento ad un caso studio, il contributo esamina alcune implicazioni teoriche e procedure operative che investono il passaggio dal modello tridimensionale discreto di nuvole di punti al modello parametrico.

Keywords: BIM, HBIM, ontology, modeling, Architectural Heritage.
Parole chiave: BIM, HBIM, ontologia, modellazione, patrimonio architettonico.

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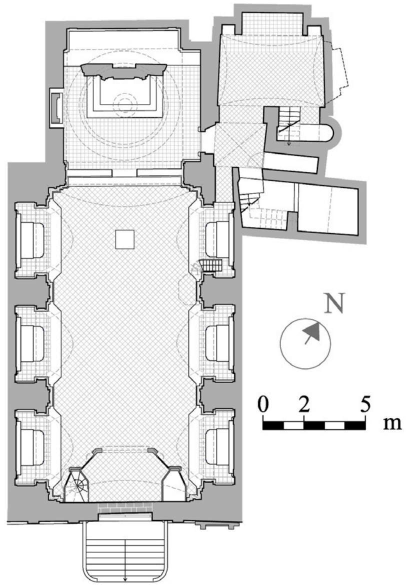
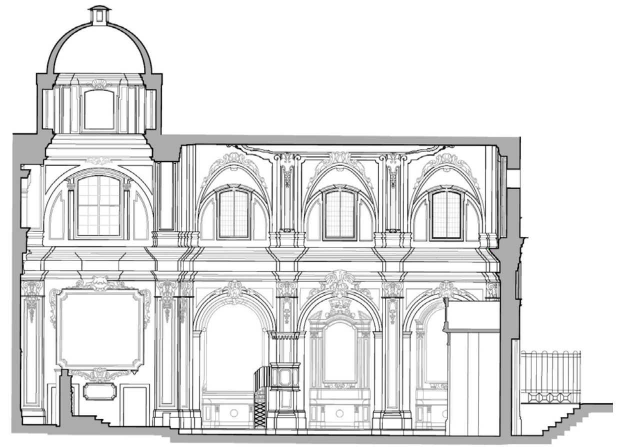
INTRODUCTION TO BIM

For many years the introduction of modeling for built objects (BIM) has caused important modifications in approaching to the architectural project, enabling a real worksharing and the constitution of a digital model which fully replaces reality. In fact it is well known that it is possible organize different information on the basis of a logical system of notions which not only are useful in the operational phase of prefiguration of an idea, but are also available in the entire life cycle of a product.
If it is true that representation implicitly refers to the *construction* of what is represented, this is even more true where the BIM systems replace a system of indistinct lines, ontologically defined elements, not only in their dimensions and functions, but also in their mutual relationship, in their materials and in their intrinsic peculiarities.
Although it seems to be exclusively technological, the problem of modeling for built objects has instead great theoretical implications, particularly where representation concerns the historical built environment and therefore the identification of parts and elements which can be recognised and classified within specific categories. As a matter of facts, not only in its paradigmatic examples, but also in its most common manifestations, historical architecture is not suitable for the standardization of its elements, and not even to solutions and combinations which can be identified a-priori. It is rather a story made of single words which reconstruct its history in its dimensions, materials and uses over time. Therefore the main problem is to make the complexity a system no longer formed by signs, but by ontologically defined elements, whose definition is the function of the cognitive objects.
Modeling for built objects is based indeed on a different way to deal with the architectural project and the study of the existing building, and it provides mutlidimensional models which can be shared with other professional figures through the interoperability between softwares.





1-2. A CAD representation of the plan and of the longitudinal section of the San Pietro in Vincoli Church, in Naples. Made by Giulia De Martino.

HBIM FOR THE MODELING OF HISTORICAL BUILT ENVIRONMENT

There are different application scales of BIM paradigm, ranging from architectural scale to landscape, territory scales and others. Among these, in particular the Historic Building Information Modeling (HBIM) concerns historical architectural heritage and it is the object of the attention of scholars and researchers of Survey and Representation for its complex theroretical and practical implications, because it is extremely important for the study of the built environment, for the purposes of knowledge, enhancement, conservation and management, as well as for any maintenance, renovation, reutilization and restoration.
In particular, HBIM [1] is the application of BIM systems to historical architectural heritage and therefore the arrangement of informative systems based on the parametric modeling of realities characterized by infinite variations.To this effect, representation must necessarily be based on a systematic reading of the single product, in order to document its composition, constructive, historical and materic characteristics. This is a considerably difficult procedure, because it involves the definition of processes identifying the regularity of forms in the built environment, by making easier what is in reality deeply complex and by giving a logical order to the system of knowledge.
Applying BIM systems to the historical built environment means to exploit the potential of parametric modeling and at the same time the precision of reality-based surveys. It is essential to consider HBIM as linked to a data collection through active and passive optical sensors, therefore based on data acquired through laser scanner technologies or photomodeling. These data can be recorded in point clouds providing a cast which is extremely similar to real, with a number of information which is excessive for the simplification required by each representation and whose graphic illustration needs a long processing time and different degrees of complexity. It is clear therefore that to obtain an infographic model which is as complete as possible

and which can always be implemented, this work must be carried out by significantly cultured operators, who must be at the same time competent in the use of the equipment for the acquirement of point clouds (laser scanner and/or digital photogrammetry) and in processing the collected data, as well as in BIM [2] modeling. Starting from point clouds, this process can take place through different devices with specific outputs for the maximization of data: extraction of edges, recognition of features, extraction of profiles to be interpolated with lofting, as well as production of orthophotos from which to extract texture and dimensional values for graphic representation, in any case giving rise to entities providing metric data to be imported in modeling software and to be used as a reference for restitution.
HBIM is aimed at returning the elements mapped on a point cloud to parametric objects, to be associated with multidisciplinary data for the creation of a searchable database, through adequate procedures for translating the complexity of reality, without losing the specific and unique nature of the single examples. So, a generalization is necessary, but, at the same time, the singularity of the specific cases must be taken into account.
In consideration of complex forms which are often irreducible to one another, as concerns the historical built environment it is not possible to refer to existing libraries, but it is necessary to identify new groups of prototypes of parametric objects and to create appropriate libraries of ontologies, correlated with specific structural relations, where each element has a role in the design of the whole and in the relationship with other elements.
It is interesting that parametric modeling gives rise to a fundamental passage *from the form of representation to representation of content*, since it is necessary to create a theoretical scheme a priori and to analyze the objects and the relations characterizing the domain to which the system is applied in order to specify it in its tectonics, within the computer system, for its representation.
In fact, traditional modeling is based on the recogntion of geometries and in its representation it creates systems of signs showing, on the basis of their different evidence, hierarchies of elements and *continuum* of reality can be found in the two-dimensional plane or in the virtuality of digital space, while the identification of parts and their constructive articulation must be carried out through subsequent readings and interpretations. On the contrary, parametric modeling requests *ex ante* the recognition of ontologically defined parts and elements, to be subsequently associated with specific materic and constructive characteristics, thus assuming all the features of the real object in the virtual space.
The formulation of a model does not occur by *form* but by *content* and it does not allow to ignore the ontological recognition of individual parts for its definition, referring to them in the lexicon and semantics who connect them. Therefore ontology is a theoretical tool and formal specification needed for identifying and conceptualizing parts.
Starting from point clouds, the built environment is therefore *surveyed* in its virtual cast, parametric modeling gives a realistic reproduction of it, *increased* by information and data that are connected with it and are its underlying historical, structural and constructive basis.

3. This is a point cloud, got through the laser scanner survey of the San Pietro in Vincoli Church (Naples).

Among the sofwtares based on BIM system (Revit, Archicad, Allplan), Revit by Autodesk allows to import and manage point clouds and to process them so as to obtain sections, profiles, plans and, through modeling with masses, to obtain a rough model to be improved. The recognition of forms is not automatic, neither is the construction of three-dimensional elements which adhere to the points of cloud, but other softwares are needed, from the early stages (ReCap), to simplify the cloud, to segment it into levels and to separate it into small portions, in order to make it easier to model parts.
It is well-known that acquired data have no possibility of a semantic automatic enrichment, but some devices can be useful to transcribe the points of a cloud: in particular *VirtuSurv (Kubit- Faro)* allows to work simultaneously in two three-dimensional digital spaces, on the one hand browsing in panorama pictures of point clouds and, on the other hand, simultaneously creating a model in a modeling software. So, the recognition takes place through the identification of points of

interest displayed in the editor. This process is particularly effective, because panorama pictures are solid projections without overlapping of levels, therefore the elements in the three-dimensional space can be easily and intuitively detected and, at the same time, this guarantees that the process in the virtual contextual survey is correct. *(A.d.L)*

CASE STUDY: THE CHURCH OF SAN PIETRO IN VINCOLI IN NAPLES

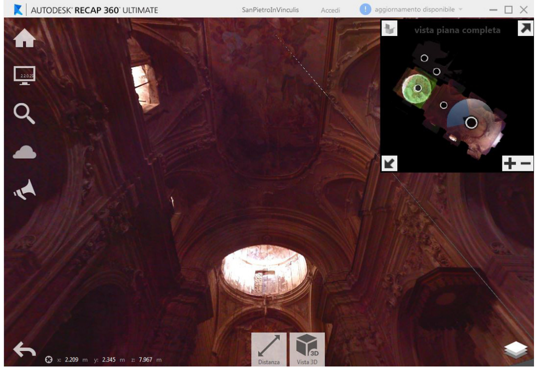
At present, at the Department of Architecture and the Interdipartimental Centre of Urban Eco Research of the University of Naples Federico II, the research team [3] involved in survey and representation of architecture with particular focus on new technologies is carrying out an experimentation aimed at using BIM for the historical built environment [4], especially as regards architectural heritage of Naples.

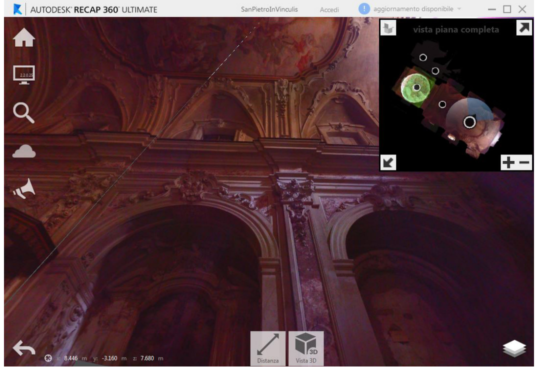
This follows a wider research [5] which has identified and mapped more than 400 churches in Naples, by differentiating them according to their property and present use. Within the most general investigation in the territory, more than thirty churches have been submitted to an architectural survey and an analysis of their state of conservation: among these the church of San Pietro in Vincoli, located in via Sedile di Porto, which has been used as an experimental sample for the parametric modeling of complex forms.

This research had a first phase of field survey through laser scanner technology specifically using the instruments of the Centre [6], thus obtaining a first discrete model for points from which to derive metric and morphological data. This survey was carried out by a limited number of scans thanks to the placement of spherical and chessboard targets and to the structure of the church itself which has a longitudinal structure defined by a single hall without significant areas of shadow.

This survey was followed by data insertion in *FaroScene*, for processing and recording scans in a single point cloud, by carrying out the visualization and elimination of noise, the decimation and filtering of data and the assignment of a reference system.

Although it represents a very realistic cast, at the same time this point cloud is an *unintelligent* model, which does not discretize the survey artifact, but it shows a





4-5. San Pietro in Vincoli Church, detail views in Recap. In the upper right-hand corner we can see the station points of the laser scanner.

series of coordinates producing a 3D model of reality which is fully unaware of what it represents, although measurable and accurately reproduced, in the same way as for a 3D geometric model formed by signs whose interpretation is delegated to the person who reads their articulation, referring to what is represented.

On the contrary, in a parametric model, each element has its precise identity and intrinsecally contains the specific features of this kind of element because it associates to each one diversified data, at the same time ensuring the congruence among the parts of a closely connected system, where every modification necessarily leads to the variation of all elements linked to it.

In order to create the parametric model [8] the cloud can be used as a support base, by utilizing Autodesk Recap for converting formats. In particular the *snap* has been used on the points for a correct placement of views, as well as for a constant and immediate check of the modelled elements, even from the dimensional point of view.

Fully *in place* modeling, that is directly inside the project, was excluded because it has limited management functions and this makes it impossible to record precise parameters for all the parts of the whole.

This project has been geocoded and levels – considered as work plans – have been used as a reference in the decomposition of the artifact and in particular for the horizontal and vertical planes allowing to subdivide space into different default views.

Before defining these planes, it was convenient to reason about space to be represented, by reading its characteristics and articulation, in the perspective of its virtual recomposition with Revit tools.

This church has a longitudinal structure with a single nave covered by a lunetted barrel vault, with three chapels for each side, and it ends with a triumphal arch bordering the presbytery covered by a richly decorated dome. A preliminary analysis of the architectural system was necessary to detect classes of elements to be modelled, rereading the whole in macroelements of the structural system (perimeter walls, roofing system), so as to proceed then to modeling of detail elements.

The collection and the association of data on the stratigraphy of masonry, deduced by the comparison with similar coeval typologies, made it possible to fully exploit BIM potential.

A modular approach was also useful, by detecting the presence of the same composition near the side chaples; these are internally defined by barrel vaults and have beside the hall a step and round arches near which, at the top of the hall, some openings are set within the lunettes in the vault. This system regularly

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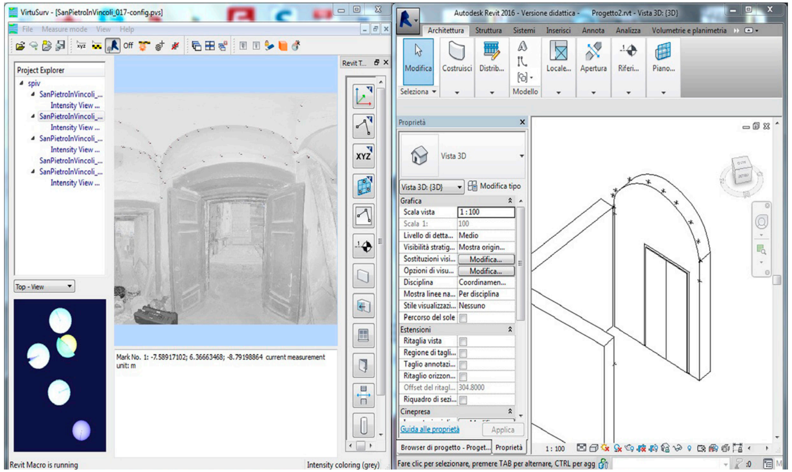
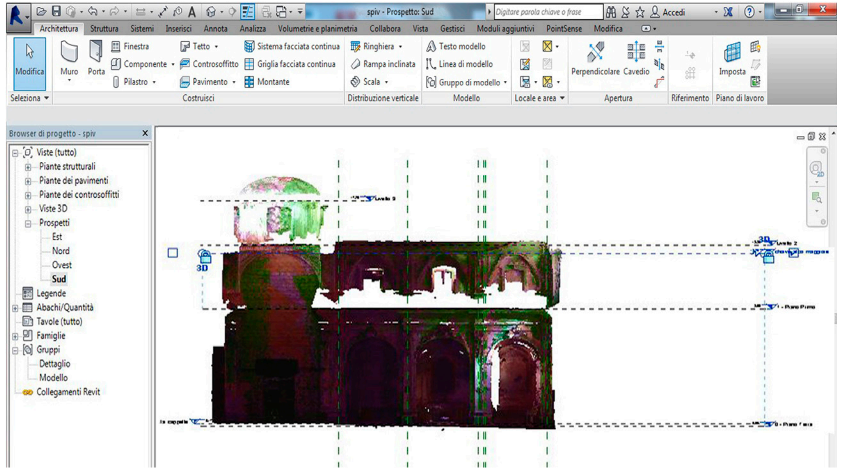


6. A direct identification of points in VirtuSurv on the panoramic picture, and its automatic modeling in Revit.



7. The point cloud is used as a reference point, in order to position the work planes in Revit. This lets you have reference axis for the modeling, work planes and default views simultaneously.

marks the longitudinal structure of the hall and the whole is recomposed in a single design through the profiles of the upper frame and of the skirting board delimiting the church perimeter.
Even the representation of point features was complex, because it required an initial simplification in geometric shapes, subsequently specifying the representation in detail.
It was not possible to refer to *families* of existing objects, but it was necessary to create some new ones and determine their parameters in a coding system of the family itself, to which to link information about materials, situation, geometrical relationships and all what characterizes an element.
In fact, within a single project, *families* represent specific parts, as they have a precise formal, technological and functional identity and many possible forms according to parameters which regulate their identity and they allow to associate them only to predetermined elements.
Modeling started from the floor surface perimeter through the location of walls, by separating them from the decorative structure and virtually retracing the building phases of the artifact.
Once created the floor surface and the main walls (profile walls, walls of separation between chapels and central nave and walls of separations between the chapels), specific *families* were realized for the creation of the vaults and the arches, in particular the family of the *generic adaptive model,* and the barrel vault was built through the parameterization of its *emptiness* and the setting, within the project, of parameters according to the survey data.
A similar procedure was adopted also for creating the triumphal arch and the dome on the presbitery. The realization of the vault covering the central hall was more complex, for the presence of the lunettes requiring a decisively more laborious parameterization.
The detail phase of wall surfaces followed the modeling of *macro-elements,* starting from the pilasters in the chapels, by creating families for each class of element.
On the contrary, for the frames the choice was to model *in place* a mass obtained by extrusion, after the creation of a specific *family* of *metric profile* type for the moled profile, by tracing the profile section through the reference to an ortho-photo and by connecting only geometric and materic information to it.
This procedure was adopted for the arches moulding and for the sidewall base separating the pilasters, because the creation of the profile *family* was appropriate, especially for the possibility to specify the geometric relationships between the many mouldings forming the whole.
This research tested *PointSense* by Kubit-Faro in *Heritage* version, a software which adds many functions for Revit as concerns the interaction between model and point cloud, by producing projections of acquired data for the rapid construction of 3D models.
PointSense was particurarly useful for the functions of *fitting*, which allows the automatic adapatation of the model to the point cloud, through analysis of surfaces measuring their mutual removal, by translating in lines and surfaces portions of point clouds.
In addition, *PointSense* made it possible to simplify the creation of moulded profiles within a specific *family*, as it allows to segment the cloud inside the *editor,* leading to a more precise realization of the profile.
Furthermore, it was possible to create ortho-photos of the cloud directly in the software, so as to quickly read information, and therefore to work by integrating these function with the basic Revit functions. (S.S.)

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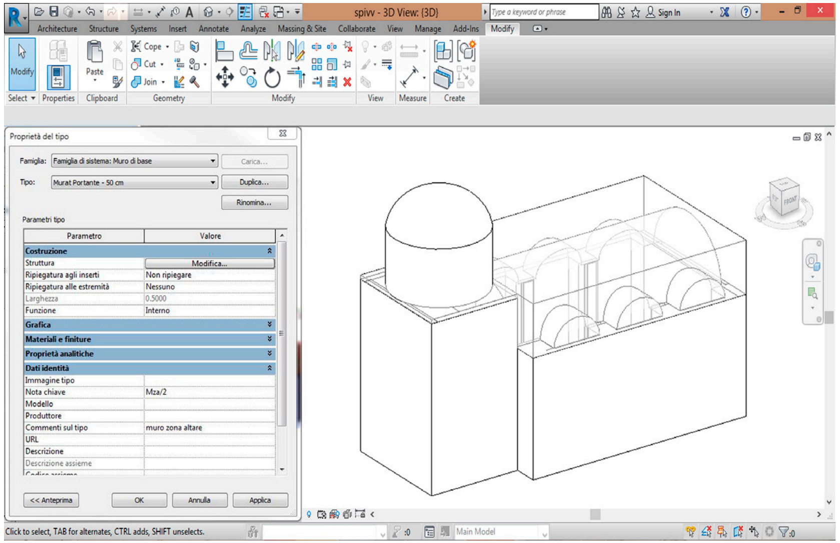
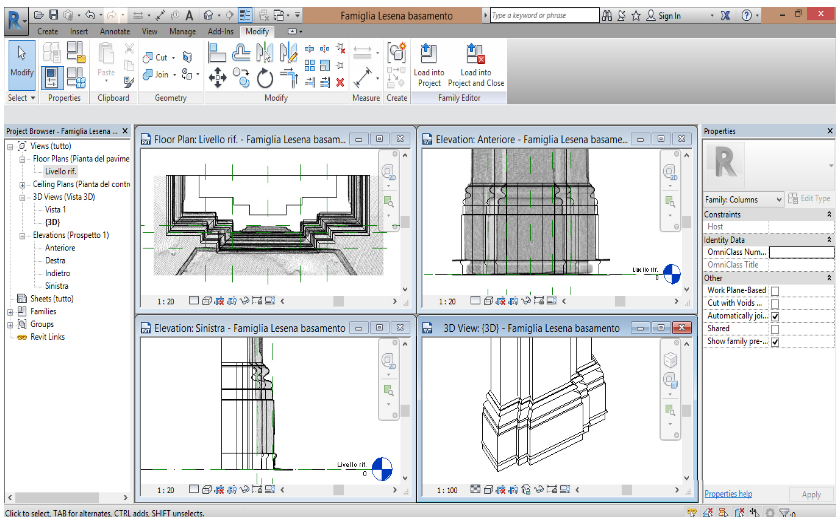


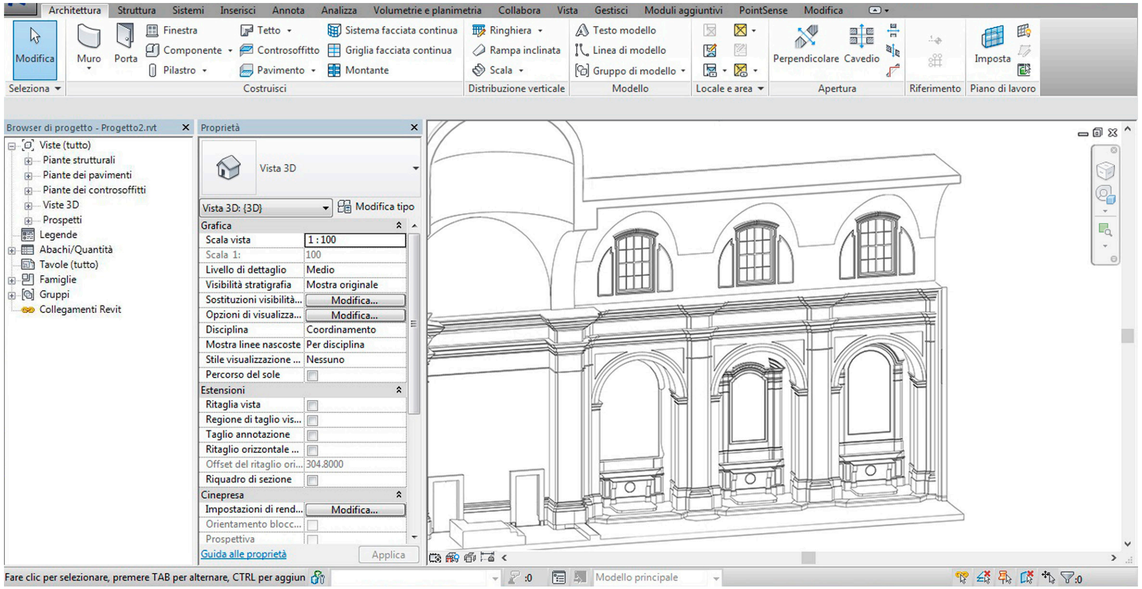
8. A first simple model in Revit. Made by Gabriella Di Dato, Valerio Flavio De Stefano, Simona Scandurra.



9. This moldig has been obtained through the extrusion of the outline, which was previously drawn in a specific family. Ortophotos of the plan, of the elevation and of the section are used as guideline. Made by Gabriella Di Dato, Valerio Flavio De Stefano, Simona Scandurra.

CONCLUSIONS

Unlike geometric modeling which produces an *anonymous* representation only based on the forms into which an architectural work can be decomposed, BIM paradigm leads to take into account the specificity of what is represented, where architecture is a system of parts and elements organized according to precise formal, structural and functional relationships.
Obviously these systems need documentary reliable evidence giving metric and materic determination of an artifact, as well as its state of conservation.
Therefore it is appropriate to apply these systems of knowledge and representation to the historical built environment for its information potential, with the possibility of creating a single digital environment including historical and transformation data and gradually recording the different restoration or maintenance works, thus ensuring a continuous control of the artifact over time and preparing a documentation which can be updated from time to time.
As usual, it is necessary to understand the targets of and therefore its representation, which, in fact, is always the result of a program created with awareness, structured on a precise intention and influenced by the culture of the time.
As such, representation has an important critical implication because it investigates about a complex knowledge, giving different interpretations of it.
If in its theoretical formulation representation is the construction of a mental model, this is even more evident in the application of BIM systems, where the clarity of a model is the result of an analytic and intellectual precision which guarantees the construction of a logical paradigm available in each explicative section.
It is well-known that the knowledge of reality requires a simplification process, because to know and to represent is only possible by logically schematizing the complexity of reality. Therefore it is necessary to find the right balance between mimetic representation of reality and its simplification.
In fact the mimesis and the descriptive richness not always guarantee the transcription of the meanings of reality but, as a pedestrian imitation, they produce a copy of it, by repeating its appearances and by creating information which are not distinguishable for cognitive levels.



10. Infographic model. Made by Gabriella Di Dato, Valerio Flavio De Stefano, Simona Scandurra.

The objective must be an intelligent representation (according the etimology itself of the word, *intus legere*) able to read the formal structure of architecture, its parts and the logical system which connects them, implicitly allowing that architecture becomes aware of itself with a content through which representation is possible.

NOTE

[1] H-BIM, Historical Bim Information Modeling, differs from the traditional bim process because the artifact to be modelled and computerized is already existent and it must be examined in its precise features.

[2] "If, on the one hand, BIM helps to coordinate the different figures of the building process by introducing its competences in models (divided into architeture, structure, plant and maintenance models) so as to prepare their creation and to calculate their quantity for the building site, on the other hand HBIM focuses on survey, on the definition of state of conservation of places and materials, so as to best arrange attentive interventions. (...) BIM models are based on the aggregation of "intelligent parametric components" able to be connected to one another in a semantic way. The models of the existing HBIM involve the exclusive production of these intelligent objects which cannot be found in producers' catalogues or pure geometries, as in the case of the new one" Cfr. S. Garagnani, *HBIM nell'esistente storico - Potenzialità e limiti degli strumenti integrati nel recupero edilizio*, Ingenio, ottobre 2015).

[3] The research team who is working to HBIM applications to architectural heritage is composed by: Antonella di Luggo, Massimiliano Campi, Raffaele Catuogno, Domenico Iovane, Valeria Cera, Valerio Flavio De Stefano, Gabriella Di Dato, Simona Scandurra.

[4] R. Catuogno, A. di Luggo, *Dalla nuvola di punti all'HBIM. Rilievo e modellazione per la conoscenza e la gestione del patrimonio architettonico*, Essay for the 3D Modeling & BIM workshop, Applcations and possible future developments, Rome april 21-22, 2016.

[5] This research was financed by MIUR- Announcement Start up, Line 2 – Culture at increased impact. Title of the research: *GBEY Una piattaforma integrata per la conoscenza, la valorizzazione e la fruizione del patrimonio artistico e architettonico negato nella città di Napoli"*.

[6] For these surveys a Laser Scanner Faro Focus 3d x-130 was used..

[7] The procedures of survey and restitution of data were directed by Prof. Raffaele Catuogno, Department of Architecture, University of Naples Federico II, who coordinates working groups for the experimentation of no-contact survey technologies (range based and image based) and of methods for processing and interpreting data.

[8] Parametric modeling of the Church of San Pietro in Vincoli was fulfilled by: Gabriella Di Dato, Valerio Flavio De Stefano, Simona Scandurra.

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