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Rappresentazione diacronica di edifici antichi: studi sulla basilica di San Giovanni in Conca a Milano

Diachronic representation of ancient buildings: studies on the "San Giovanni in Conca" Basilica in Milan

Questo articolo propone una metodologia per la rappresentazione virtuale di Beni Culturali non più esistenti, che integra l'acquisizione dello stato di fatto attraverso le tecniche di rilievo 3D digitale, con l'analisi delle fonti storiche, letterarie, catastali ed iconografiche. L'uso del dato geometrico oggettivo come griglia interpretativa di partenza consente di costruire un metodo scalabile e riapplicabile su diversi manufatti. Il processo è qui sperimentato con la ricostruzione virtuale delle fasi evolutive di una chiesa emblematica per la sua storia tormentata: la Basilica di San Giovanni in Conca a Milano. Attraverso tale ricostruzione viene proposta una rappresentazione realistica e comprensibile delle storia del manufatto, utile sia per l'analisi critica degli studiosi che per la valorizzazione turistica.

This article proposes a methodology for the virtual representation of lost Cultural Heritage monuments, based on the integration of a 3D digital survey of the remains, with the analysis of historical, literary, cadastral and iconographic sources. By using the objective geometrical data as initial interpretative grid, a scalable method is generated, suitable to be re-used on different artifacts. This approach has been experimented on the virtual reconstruction of different historical periods of a church characterized by a complex architectural development: the Basilica of San Giovanni in Conca in Milan. Realistic 3D digital representations of this monument allow to better understand the lost building changes, useful both for critical analysis of the experts or for touristic valorization.

INTRODUCTION

Explanations and analysis based on the visualization of 3D digital models represent nowadays a possible way for valorization of cultural sites, capable to be aimed at different categories of users, ranging from scholars to simple tourists. The diffusion of these tools depends in part from the increasing interest on digital models as ideal repository for archeological data, conservation records, reconstructive interpretation of lost buildings and web diffusion of cultural 3D contents.

Different solutions based on the use of pre-rendered videos of 3D digital models or direct interaction with them has been successfully experimented so far. Some recent applications in the archeological field have demonstrated the communicative value of this first solution[3,4] and the potentiality of the second ones in terms of interaction and real-time definition of paths and unusual points of view[1], or connection of the model with descriptive data[2].

Given a specific monumental building to be approached, the generation of such 3D models can be obtained according to two different criteria:

on the one hand a faithful representations of the monument at its current condition can be generated, employing advanced digital survey techniques such as digital photogrammetry and laser scanning, with a following modeling and representation processes based on true geometrical data;

on the other hand, a 3D digital reconstructions of the monument can be conceived, starting from historical information and drawings, and with a research approach more oriented to the Humanities.

The first one presents well defined methodologies that allow to create accurate digital representations of the artifacts as is in present time[5]. In the last decade the integration between different survey methodologies were exploited in order to obtain the most accurate digital representation of a real object by improving the features of traditional survey processes[6-11].

Methods for the definition of archetypal digital models present very different possibilities depending on the historical analysis approach. In the last decade experts in Digital Humanities[12-15] have analyzed and discussed about the use of virtual interiors and environments representations as effective instrument for clearer diachronic analysis[16] and therefore as a tool for discovering new archaeological results stacking on the possibility to “see” what in the past was only possible to be imagined through descriptions. This point makes virtual reconstructions a new powerful scientific methodology in addition to the more obvious application for increasing the diffusion of archeological culture among the non experts. Methodologies for defining a coherent and acceptable path aimed at creating digital reconstructions of buildings that at present time are remained only in part, are therefore needed if scientifically acceptable hipoteses have to be proposed.

For this reason the aim of this article is the definition of an integrated methodology that start from an high-resolution digital survey of the remains of an ancient building in order to gain the maximum geometrical knowledge of it, and stack on this for developing a coherent virtual reconstruction through an iterative verification of the different historical sources involved. All the sources, possibly altered by subjective interpretation, metric errors in old surveys, approximations due to rough graphic representations, are therefore adapted and made coherent to each other by comparing them to objective up-to-date geometrical references.

The following visualization of such complex 3D models has the important role to render them clear, understandable, intelligible, exploitable to common users, and with a certain level of interaction[17]. For this reason some research projects in the literature dealt with different approaches and problems, from the study on 3D reconstruction and simulation of real monuments[18] to the different type of interaction between users and 3D models[20,21].

The process of designing an interactive 3D model representation of a Cultural Heritage monument presents different aspects of complexity. This is why this research deals with two crucial aspects for the whole pipeline: the definition of a methodology that integrate geometrical information extracted from 3D survey and historical data, with the main purpose to identify an optimal process of 3D reconstruction of lost buildings and the relative representations of their different historical phases, improving the comprehension of the artifact evolution by a diachronic model.

The 3D acquisition and modeling project of San Giovanni in Conca was promoted by the regional government in order to define a reliable methodology for generating 3D digital models of ancient monuments hidden under the surface of Milan and nowadays, with very few exceptions, almost completely lost. For this purpose the application of virtual reality for the visualization of lost architecture in a realistic way was taken into consideration as a mean for giving new life to such hidden patrimony, expecially interesting for the approaching EXPO 2015, that will be held in Milan.

By this point of view San Giovanni in Conca represented a very significant test for its complex historic evolution.

At last it became essential the definition of a non common instruments of valorization of an artifact that combines an evident historic value with an invisible presence inside the city.

HISTORICAL BACKGROUND OF THE BUILDING

The rests of the Basilica of San Giovanni in Conca are defined by a little apsidal portion and a crypt located in the center of Piazza Missori in Milan.The reduced ruin dimensions and their particular setting give few importance to this particular ruin despite the well-know role of Basilica during the Romanic period.

Different historic sources place the beginning of the church foundation in the first century B.C.[23-25,1] while is supposable its conclusion around the V-VI century B.C. The relevance of the church in that period is demonstrated by the presence of its name in the list of the eleven Matrici churches and ten chapels served by the citizen mission.

In XI century different decorative and constructive Romanesque alterations were introduced in the church and the addition of the crypt.

While there are few historical sources that describe the thirteenth-century partial destruction of the building by Barbarossa, for sure it was appointed by the archbishop Ottone as church for the daily indulgences of the Lent period in 1284.

In the XIV century the ecclesial complex was enlarged and adorned with sculptures and frescoes thanks to Bernabò Visconti’s patronage.

In XVI century Francesco II Sforza lended the church to Carmelitani Fathers of Mantova congregation and some architectural modification were produced for the official visit of Carlo Borromeo. Beside the church there was a high 24 meters massive bell tower. The period of foundation is not exactly known, but it’s well-known that the Carmelitani Fathers increased the height of this part of thirty ells (18 meters) in 1596. In the next two centuries different modifications and enlargements were brought for the achievement of lateral chapels and architectural restoration.

From XVIII century began some troubles of the building: in 1782 the church was taken away from Carmelitani Fathers as a consequence of the abolition of religious orders. Starting from 1808 the church was used by the Corona institution as barracks for Napoleon recruits and in the same year the bell tower was used as astronomic observatory. At the end of this period the deconsecrated church was rented to private customers for warehouse destination.

In 1876 Carlo Alberto route was built and in 1879 the

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town council decided to pull down the front spans of the building and sold it to the Waldensian community who was obliged to rebuild the facade and arrange the residual part of the complex. Colla was entrusted with the restorations that ended in 1881; the new facade was distorted to fit the actual oblique plan while the bell tower, at that point isolated in the middle of an empty square, was demolished in 1885.
During the Albertini’s Regulating Plan the complete demolition was realized until 1952 saving only the present apsidal ruins and the crypt. The facade was dismantled and reassembled on the new Waldensian church in Francesco Sforza Street.

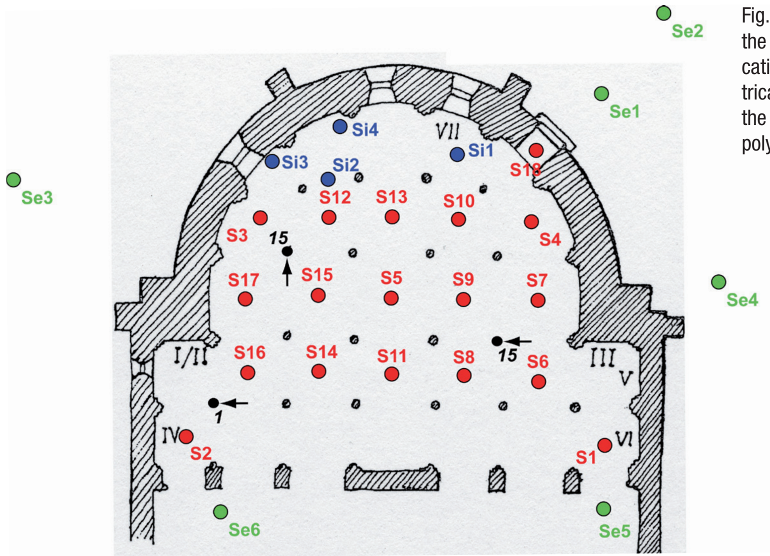
3D ACQUISITION AND MODELING OF “SAN GIOVANNI IN CONCA”

Instruments

Different instruments were employed to gain enough information about the artifact for supporting the historical and architectural analysis.
For acquiring the ruins geometry a 3D Time of Flight scanner (HDS3000) and a triangulation 3D laser scanner (Vivid Minolta 910) were used, and two digital reflex cameras (Canon 5D and Canon 400D) for getting textures of the real construction materials employed. The instrument integrations allowed acquiring different level of details of the architecture and materials.
For the historical analysis several literary sources were integrated, mainly defined by the description of artistic, historic and architectonic evolution, and cadastral and ichnographical sources that completed the historical overview. The presence of ancient maps, period plans, drawings and paintings of the church allowed verifying the reliability of the historical sources providing the best interpretation of the past aspect of the building. In this step the pictures of the past period have assumed the crucial role of objective data.
All these sources converged to one historic evolution of the artifact characterized by few verified architectural phases.

Data acquisition

The 3D survey considered a 20x20 meters area composed by a middle-complex hypogeal portion with many columns and capitals and a less-complex external portion without sculpted elements.
During the survey project it was decided to use the bigger part of the 3D acquired model as a reference base



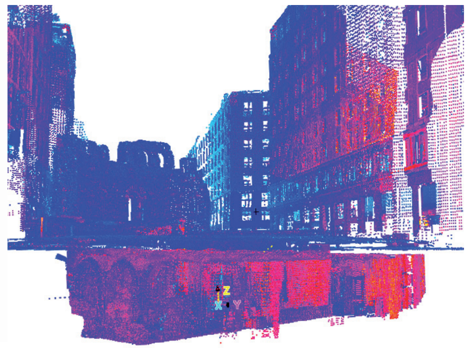


Fig. 1. Laser scanning of the crypt, the absidal ruins and part of the surrounding environment of San Giovanni in Conca: a) locations of the laser scanner for properly acquiring the geometrical data taking into account the high number of occlusions in the crypt; b) final aligned point cloud, used for generating the polygonal model of the monument.

for CAD modeling and only the little remaining part as direct information source.
This assumption required the definition of a dynamic resolution step in 3D acquisition, starting from 2 cm for architectural portions up to 0.4 mm for the sculped ones. Reference targets were not positioned in the survey scene for the evident presence of recognizable three-dimensional features in the environment that were used for aligning the range maps through an Iterative Closest Point (ICP) process.
During the 3D survey the TOF laser scanner HDS3000 was used for the massive 3D acquisition of the architectonic portions of the apse and the crypt while the Vivid 910 instrument was applied in the 3D detailed acquisition of the most interesting capitals in the crypt.
A complex network of acquisition points was defined in order to obtain redundant data, avoiding both the geometrical lack due to the shadow effect of the columns and reaching a good precision in the alignment step.
The base of 3D acquisition grid was composed by 4 scans from the corners of the crypt (stations S1 to S4, with reference to figure 1) to maximize the field of view in relation with the column presence and one high resolution central scan (S5). Starting from these five scans, others 12 scans were acquired from every important crypt span (S6 to S17) and aligned with the residual 4 scans (Si1 to Si4) dedicated to the Roman foundation ruins.
The connection between crypt and apse was allowed by a crucial range map (S18) that linked some detailed portions of the internal part with the external ones. At the end 6 different range map were acquired (Se1 to Se6) to survey the external apse from different point of view. Side by side to this activity were acquired three different capitals using 25 different detailed range maps for each one. At the end of the ICP alignment a final point cloud of 9 x 10^6 points was obtained and resampled with different resolution steps in relation with the historical, architectonical and artistic relevance of the real model, from 20 cm step for the urban context to 2 cm for detailed portions; this solution allowed an optimal reduction of the point cloud for the creation of the polygonal model. All data process was carried out inside the Cyclone software (Leica Geosystem).
At the same time a photo reportage was completed in order to integrate geometric information useful for the CAD reconstruction step and for the definition of a material repository necessary for the texturing phase. The color and dimension data were post-processed to optimize the projection phase of the texture and the realtime visualization of the entire 3D model *(Fig. 1)*.

Fig. 2. Texturized polygonal model (reality based 3D model) of San Giovanni in Conca crypt

Creation of the reality-based model

Only a little part of the acquired architectural data were processed to obtain a coherent resolution with the real geometric characteristics: the roman foundation ruins, the complex of vaults in the crypt and the closing portions of the apse wall, parts of the real artifact that couldn’t be represented in properly with CAD tools. The others parts were reduced 40 times from the original data in order to generate a simplified model suitable for the CAD re-modeling phase. From the detailed 3D acquisition three high resolution polygonal models of the capitals were defined each one by 80000 polygons. Every polygonal process was carried out inside Rapidform (INUS Technology) and Polyworks (Innovmetric) software.

Starting from the real sections of the reality-based model, a sequence of simple geometrical shapes were defined inside the Rhinoceros software (McNeel) in order to define the reference framework for the creation of a new archetypal geometry. The use of simple mathematical primitives and surfaces simplified the digital data management, supported the interpretation of the model by the use of simple data as reference for the historical reconstruction, allowed to create a flexible digital model suitable for the iterative reconstructive interpretation that imply frequent geometry modification. During the digital modeling the distance between the new CAD geometry and the reality-based model was verified never above 5 cm. The final model defined by 210000 polygons was used as base for the application of the texture contained in the materials repository. For the definition of an actual environment of the church an up-to-date urban map was used as reference for the creation of simple building shapes, integrating the space and elevation map information with the 3D data acquired by 3D laser scanner *(Fig. 2)*.

Interpretative 3D model generation

The first step of the historic reconstruction process started from redesigning the past iconographical and cadastral representations with CAD instrument. These historic data lack in objectivity and mutual coherence, due in part for the representation style and the graphical instruments used, in part for the introduction of errors in survey and measurement restitution, the low precision of the designer and the unsuited data preservation. The lack in objectivity requests a complex step of “translation” and “mediation” between the rough graphic output of the traditional representation technique and the precise CAD geometries construction, trying to obtain a coherence between the drawing dimensions and the

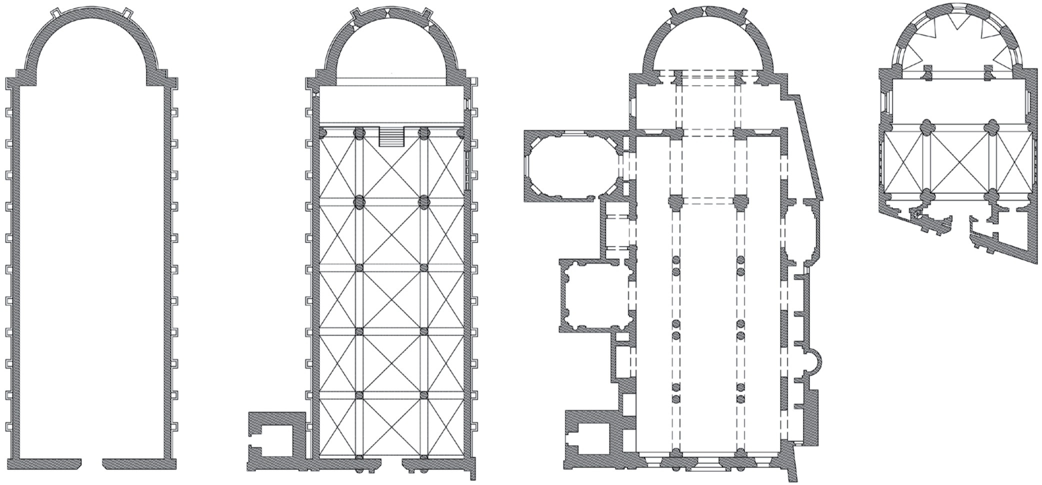


Fig. 3. Maps of the church at the different historical periods, normalized through the real 3D data: a) VI century; b) XIII century; b) XVI century; c) XIX century

hypothetical past architecture. The presence of non coherent variation in dimension e proportion between historical plants, fronts and sections belonging to the different historical period can be avoided by an iterative comparison between the traditional representations and the real relative dimensions coming from the reality-based 3D model *(Fig. 3)*.
In this case different sections extracted from the reality-based model were used to rescale the iconographical sources and to verify their correct representation. Starting from the XII century Basilica plant as reference, a complex inspection process of all the other plants, fronts and sections has started in order to reach a sequence of 2D representation acceptable from the geometrical and historical point of view *(Fig. 4)*.
The 3D digital model reconstruction of the bell tower has followed only the facade information and proportion contained inside the few historical pictures, due to the lack in other form of representation. At last the integration of historical data coming from period drawings and the geometrical measurements contained in the real “revisited” facade of the Waldensian church played an important role for the 3D reconstruction of the ancient church facade *(Figg. 5-6)*.
From 2D digital data started the process of 3D modeling of the different periods of the church. The combination between the complex level of 3D representation and the interpretation of reconstructive hypothesis, respecting the constructive and aesthetical rules of the period, represented the bottleneck of this step. A 2D drawing represents a form of incomplete spatial representation, effective for the geometrical description of a particular portion of the architecture but unsuited for the global knowledge and representation of the entire building.

Fig. 4. Inverse perspective reconstruction of the bell tower from an ancient photography taken before its demolition. Starting from the definition of three Accidental Points and the Rectangular Trihedron, the Principal Point (V0), the Distance Points and Circle were defined. The real architectural dimensions were extracted from the Horizontal (AB) and Vertical segments (ACD) obtained from the lines passed by Measure points (M) an image points and intersected with the Fundamental Line

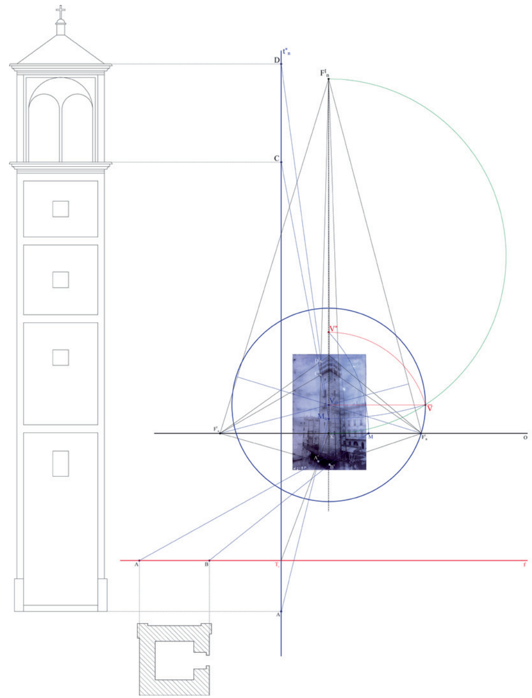


Fig. 5. Façade of the church in the different periods

Fig. 6. Sections of the church in the XVI version

Instead of this in a 3D representation every single element have to be geometrically described since every portion of the digital model is connected with the others in a complex network of shapes. The type of interpretation that involve both the principal shapes, the simplified details and the connections between these network of shapes with the lack in historical descriptions define a more complex level of visualization *(Fig. 7)*.
The modeling process if not supported by historical and iconographical sources is founded on constructive logics supported by an architectural vocabulary and local culture, defined in relation with the formal rules present in other churches nearby San Giovanni in Conca.

FINAL RESULTS
From historical analysis four different evolutive phases of the architecture evolution have been defined. Starting from the architectonic information extracted from different sources and 2D drawings began the procedure of 3D modeling. For the early Christian version of the church (VI century B.C.) the redesign process of the walls and roof started from the apsidal portion, using the surveyed model as initial reference. The definition of the second Romanesque version of XII century B.C. period began from the first reference structure of the early Christian Basilica with the addition of a little bell-tower and the introduction of some important constructive elements like a nave, two aisles, a transept and the crypt; the definition of this last element obliged to raise the apsidal floor and to introduce a stairs to reach the most sacred area of the church. In the third evolution step of XV century B.C. some different architectonical and aesthetical modifications were inserted both in the bell-tower and in the Basilica. The last significant pas-

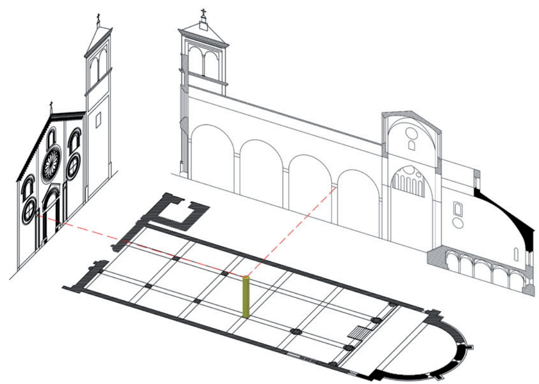


Fig. 7. Modeling process starting from the 2D reconstruction driven by historical sources integrated by 3D real data

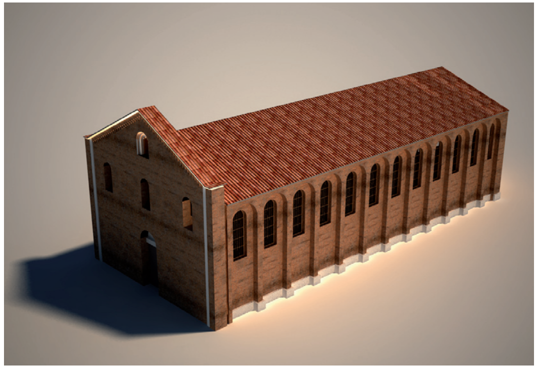


Fig. 8. Reconstructed models of the various periods: a) VI century; b) XIII century; c) XVI century; d) XIX century. It can be noticed that the reconstruction of the most ancient version has been generated without any reference to the surrounding area, while the other version has been rendered within a flattened version of the current building fabric in order to have a clearer idea of the chuch extention in comparison with the actual sctructure of the city.

sage of the XVIII century B.C. presented the building in a maimed version preserving only the final part of the nave and aisles and the apse. The materials used to texturize the models considered both the preserved materials of the ruins and some materials acceptable for the period, in relation with a comparative material research present in similar churches in local context. All the CAD models were generated in Rhinoceros software (McNeel) and visualized in 3D Studio Max (Autodesk) *(Fig. 8)*.

The sequence of 3D models of different period visualized in the same environment suggests a clear instrument of representation of the architectonical evolution of the building. The level of information of the 3D models, the geometrical variation of the global structure and the details, the materials and light sources analysis allow both a careful evaluation and a base for discussion between experts about the interpretative choices and the variation introduced during the modeling step. In addition this kind of visualization represents a clearer and more involving instrument of communication for the comprehension of lost Cultural Heritage.

Experts can use 3D models as data repository, exploiting the interactive capacities and real-time visualization of the results for critical discussion or analyzing the effects of the dynamic variations of materials and light parameters.

The extraction of simple measures or 2D thematic tables from the 3D model can always be implemented as support for discussions or research in different fields. Texturized sections represent an example of information that can be extracted from a 3D texturized model and a hybrid but clear type of visualization of the final results, because it combines the detailed information of

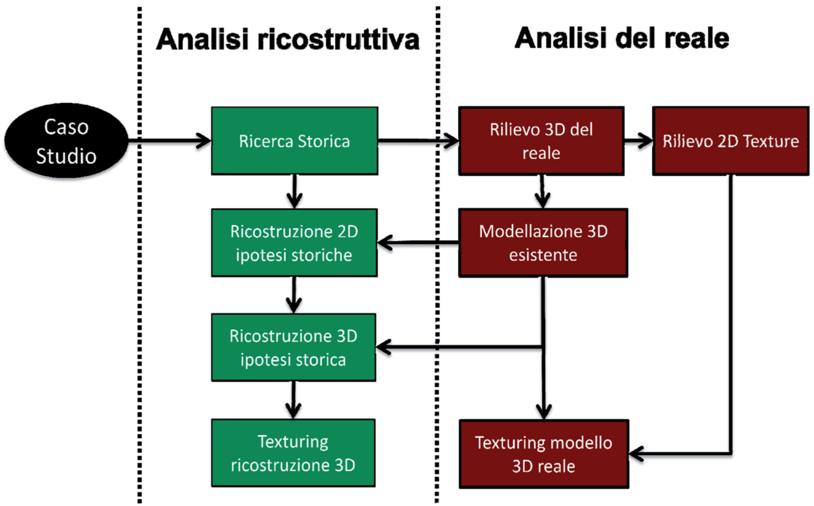


Fig. 9. Block diagram of the reconstruction process based on the integration of 3D measurements and historical analysis

material and ambient with a clear and simplified interpretation of the whole aspect of the architecture *(Fig. 9)*.

CONCLUSION

The main goal of the article regards the definition of a diachronic digital model of a lost Cultural Heritage. Starting from a real example representative for its construction history, the church of San Giovanni in Conca in Milan, a method of survey and critical analysis based on the integration between bibliographical and iconographical sources and 3D geometrical survey is suggested, in order to obtain a complex system of knowledge about the building. Starting from this approach the critical aspects that can affect the whole 2D and 3D interpretation process of the church were exploited.
The final results demonstrate that this kind of diachronic visualization represents an interesting "medium" of communication suitable at different levels for experts that can use 3D models as a common field for discussion and analysis about the interpretative choices.
In addition virtual reality offers an effective instrument for communication and knowledge transmission suitable for the tourist valorization of the church, based on a clearer comprension of the historic evolution of the fabric and a more realistic and involving representation of the ancient aspects of the external Basilica and the interior ambient.

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