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Digital reconstruction of a lost heritage: the San Geminiano's church in San Marco's Square in Venice

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***Abstract* – Very often our Cultural Heritage deals with several cases of lost monuments or part of them, due to destruction, replacement or radical changes caused over time. Today the documentation of intangible because lost heritage can be supported by virtual reconstruction, based on a multidisciplinary approach, for both scientific and cultural-leisure applications.**
Currently, the use of 3D digital acquisition techniques represents the most popular means for the documentation and digitization of our Heritage. The advantage of recreating a detailed virtual model of an invisible place can, on one hand, support scholars in their associated studies, to better understand urban or architectural transformations for example; on the other hand, improving the spread of Cultural Heritage artefacts by using different medium of visualization reaching a wider public directly.
To this purpose, geomatics techniques and survey data processing provide a very powerful tool, extracting both geometric and descriptive information.
The paper deals with a virtual reconstruction of the San Geminiano Church in San Marco's Square in Venice, a masterpiece of architecture by the great master Jacopo Sansovino, demolished during the Napoleonic domination of Venice. This is a particular case of today intangible heritage, as part of the artworks, such as statues, altar, paintings, that belonged to this church are now preserved and relocated in the other buildings, distributed over the Venetian territory.
Point clouds coming from laser scanning and photogrammetry of the current San Marco's Square and of the various artworks, distributed in several places of the city, integrated with historical analysis and iconographic sources are the rigorous starting point for the virtual reconstruction of the today invisible Church, by using tools of modeling, of computer graphics up to the creation of 3d printed physical models. These can be considered as an augmented replica, meaning the interaction between digital fabrication (3d printed model), rendering of the digital models, videos and video-mapping just to support communication and disseminating the results and the hypotheses we made about the Church reconstruction, with the most appropriate tools

I. INTRODUCTION

Documentation of Cultural Heritage (CH) should be a high priority because it has an essential and irreplaceable part of the preservation cycle. It's critical that CH should be documented accurately and constantly prior to any physical harm or loss that might impair its integrity, to keep detailed records of any cultural asset that contains all the proper data and information for understanding the object in question and leads to the adoption of the best practices for safeguarding it.
Nowadays, documentation of CH is achieved by using digital tools and the evolution of digital sensor technology has changed the way we document our heritage, in terms of application methods, software, and hardware tools. The technology of digital sensors has expanded the range of applications, introducing new products [1,2]. In the last few years, geospatial technologies have achieved great results, mainly due to technological, economic, environmental factors. Geomatics has developed new image- based and range-based techniques and strategies for digitalizing Cultural Heritage (CH) in order to answer to this need of accurate documentation and allowing not only to analyse the shape, geometry and position of any artefact, monitoring it over time, without necessarily coming into contact with it, but also understanding and explaining its history and relating it to the traditions of a place [3]. Innovations in photogrammetry and image-based modelling have also been influenced by the amazing developments in Information and Communication Technology (ICT) and computer vision.
This influence can be seen in a widely use of 3D reconstructions of lands and cities or monuments and statues, by creating complex models. Their complexity comes from both the high number of acquired and processed geospatial data and the description given by available sources.
Today digital tools allow the reconstruction of no longer visible CH based on different sources and testing various processes for manifold purposes [4]. Different goals

inevitably influence the results, but the use of 3D digital reconstruction is adopted in different disciplines to support various analyzes and considerations: hypothetical reconstruction of never realized projects from original drawings, mean to support restoration in case of destruction, diachronic visualization of lost constructive phases of urban heritage [5,6,7].

The work was carried out under the GAMHer (Geomatics data Acquisition and Management for landscape and built Heritage in a European perspective), which is a 3-year project financed under the Italian PRIN 2015 framework (Progetti di Ricerca di Rilevante Interesse Nazionale), a collaborative project that aims at exploiting and validating Geomatics algorithms, methodologies and procedures in the framework of new European regulations, which require a more extensive and productive use of digital information, as requested by the Digital Agenda for Europe as one of the seven pillars of the Europe 2020 Strategy [8]. GAMHer aims at exploiting some research and practical challenges in those disciplines devoted generating 3D models for objects related to both landscape and built heritage. It focuses on the need of a certified accuracy for surveying and monitoring projects with photogrammetry and laser scanning technologies, especially when used in a multiscale approach for landscape and built heritage documentation, conservation, and management.

Within this context the study on San Geminiano's church was developed, because it represents a lost heritage of Venice and it needs a rigorous process to provide validation of the virtual reconstruction.

The proposed workflow of the case study can be divided into three phases: a first phase of study of the history and analysis of the artworks, a second phase of survey campaigns and data processing and the third phase of reconstruction through modelling and creation of the "lost" place.

II. FIRST PHASE: NOTES ON THE HISTORY OF THE CHURCH

It is believed that the Church has origins dating back to the Sixth century, making it one of the oldest in Venice. In 1106 the Church was destroyed by fire. It was then rebuilt in 1173 at a different point in the Square which at the time had been enlarged.

In De' Barbari's perspective view from the year 1500 we see the Church in its previous guise with a gothic facade and a bell tower. In 1505 a renovation of the Church was begun by Cristoforo dal Legname. The building works were interrupted but in 1557 they were completed by Jacopo Sansovino. The Church was demolished in 1807 for the construction of the Napoleonic Wing as a seat of royal representation with a monumental staircase and ballroom [9-14].

Thera are some fundamental graphic documents representing the Church, done by Diedo, Cicognara, Selva and by Antonio Visentini as well as interior sections by Vincenzo Coronelli.

Figure 1. Canaletto, View towards San Geminiano, 1735

One of this drawing represents an overlap of the plan of the Church with one of the reconstruction projects and only in this drawing is represented the corner solution that once existed between the Old Procuratie and the connecting wing to the Church.

Based on the texts by Francesco Sansovino and Cesare Zangirolami, an analysis of all the artworks once present inside the Church was undertaken. These included frescoes, statues, paintings, including those by Tintoretto, Paolo Veronese and many others. Then organ doors, altarpieces and their respective altars.

Stone pieces from San Geminiano were used for the construction of the Church in the Name of Jesus on the Fondamenta Santa Chiara in Venice.

Among all the artworks some of those have been found and relocated, such as the first is the High Altar which is now located in the San Giovanni Battista Church belonging to the Order of Malta in Venice.

The documents kept in the archives of the Order confirm that this is the original Altar from the Church of San Geminiano and that it was purchased in 1842 from the Magazzini di Santa Margherita, where it was temporarily relocated, waiting to be resold.

Then a second Altar, a minor one, now present in the National Museum of Villa Pisani in Stra, a village close to Venice.

Even in this case it's confirmed from archival documents regarding the origin of the artwork. It is a marble altar with a bas-relief representing Jesus crowned with thorns and two angels on the sides.

There are also two marble busts from the demolished Church, one representing Matteo Eletto and the other Benedetto Manzini. Both are located at the Giorgio Franchetti Gallery at the Ca' d'Oro in Venice.

Moreover the organ doors by Paolo Veronese have also been relocated, today in the Gallerie Estensi of Modena and represent: San Giovanni Battista, San Menna and Saints Geminiano and Severo.

Then, another painting representing Sant'Elena is now conserved in the Gallery of the Academy of Venice.

From these few notes on the history of the church, it is clear that the virtual reconstruction process does not only concern the architecture, totally lost, but also its decorative apparatus.

Figure 2. Laser scanning survey of the High Altar in the Church of San Giovanni Battista in Venice

Figure 3. Photogrammetric survey of the Altar of Villa Pisani (Stra)

III. SECOND PHASE: SURVEY CAMPAIGNS

The latest available technologies and methods in the field of 3D CH data acquisition take advantage of two approaches: active sensors such as the well-known terrestrial laser scanning (TLS), and passive methods such as digital photogrammetry (close-range) that nowadays are connected with the automatization of the computer vision approach using structure-from-motion (SfM) techniques [15-17]. Particularly the development of new photogrammetric computer vision technologies and the improvements in image- matching algorithms allow to achieve 3D models with a very high level of detail, furthermore the opportunity to generate a high-resolution photographic texture allows to document also the consistency of the modelled object making this technique very suitable for digitization of museum collections. The aim of the work was define an integrated methodology, starting from an high resolution survey in order to gain the maximum geometrical knowledge of it for the development of a coherent virtual reconstruction trough iterative verifications of the different historical sources involved [18]. Obviously, the survey concerned those elements still survived and preserved in the various places mentioned: such as structures and works of art, which then served as integration in the digital reconstruction of the Church.

The elements that have been surveyed, by photogrammetry and laser-scanning, , are the two altars: the High Altar, today in the Church of San Giovanni Battista of the Order of Malta in Venice, belonging to the Sovereign Order of the Knights of Malta, while the the minor altar is located in one of the rooms, used as a chapel, on the first floor of the National Museum of Villa Pisani in Stra.

The laser scanning survey of the High Altar required the use of FARO FOCUS CAM 3D, to also acquire the environment in which the altar is kept. A total of nine scans were carried out to obtain a sufficiently dense and detailed cloud. Scans were aligned by topographic GCPs, surveyed in a local frame.

To integrate the laser scanning survey data, we proceeded with a photogrammetric survey. In particular, two sets of photographs were captured: a set using a full frame Nikon D800 with a fixed lens at 20mm, positioned on a tripod. Given the unfavorable lighting conditions, we opted for taking advantage of long exposures at low ISO levels and with the aperture closed at the same time for uniform sharpness throughout the depth of field in the shots.

The second set was made with a high-performance compact camera, SONY RX100 Mark 4. We opted for the use of this camera as it is small in size and weight, remotely controllable and easily installed on an extendable pole up to 10 meters. This set was used to obtain photographs from above, impossible to reach with a tripod from the ground. Even in that case, the photographs were taken with a small aperture to keep the sharpness of the shots high throughout the depth field.

The survey of the Altar of Villa Pisani consisted only of the photogrammetric acquisition. Images were taken by using the SONY RX100 Mark 4 camera. Also, in this case, as for the previous altar, it was necessary to use the extendable pole to obtain the images from above. In addition, before taking the photos, six targets were positioned, four of which on the horizontal plane and two on the wall on the left and right sides of the altar for the orientation of the models.

Two marble busts from the Church were also surveyed by photogrammetry, always with the SONY RX100 Mark 4 camera, now preserved in the Galleria Giorgio Franchetti at the Ca 'd'Oro. They are busts of: Matteo Eletto and Benedetto Manzini.

Two other elements were also surveyed, even if they do not come directly from the Church but, for a stylistic

comparison, were characteristic of the Republic of Venice whose very similar copies were present inside the Church, referring to Visentini's drawings. These are two winged lions, one is a bas-relief installed just outside the door of the Arsenale in Venice that looks more like the one found in the upper part of the facade, represented in Visentini's drawings, while the other is a round installed on the left side of the entrance to the Scuola Grande di Misericordia in Venice, this too, similarly, resembles the "tondo" represented inside the Church as a decoration of the tomb of Tommaso Rangone.

A laser scanning survey was also carried out on the eastern part of Piazza San Marco, obtaining three point clouds for a uniform coverage of the wing for subsequent elaborations and scaling of the elaborated models, representing the final reference system for the reconstruction.

Regarding the photogrammetric surveys, all the objects were processed with the use of the Agisoft Metashape software, one of the major commercial SFM-DMVR representatives currently available, processing object by object separately, first masking the parts of the photographs that should not have been taken into the final model, then aligning the photos and obtaining scattered point clouds, developing dense point clouds, subsequently obtaining the mesh (ie polygonal mesh defined by triangles having the points of the dense point cloud as vertices) and finally the texture.

The three-dimensional models obtained by photogrammetry were then processed individually in the Geomagic Studio software which allows the processing of polygonal meshes.

In the case of the two busts, the work was limited to cleaning the surface and possible decimation in order to avoid having extremely heavy models in terms of polygons that did not have better definition characteristics than a reduced - decimated model.

The most complex processing was that of the altar data. The 3D polygonal model of the Minor Altar of Villa Pisani was undefined and noisy in the lateral parts of the tympanum because of two red curtains that lean on the side of the tympanum. This, despite the masking of the photographs in the first phase of processing, did not eliminate the problem and the model was noisy and incomplete in the upper and lateral parts. So, the missing parts were remodeled, that is, directly processing the mesh in Geomagic Studio.

The work on the High Altar was also complex as historical data confirm the repositioning of the three statues when the Altar was installed in the Church of San Giovanni Battista. How it looks today and how it was surveyed is not exactly like the original version. The statues during the survey couldn't be moved from their original position, as they are extremely delicate objects, so it was a matter of taking them back in the best possible way from more physically possible angles and then fixing any imperfections in post-production. In fact, in the subsequent processing of the statues, once detached from the rest of the altar, digitally in the software, the rear part clearly did not exist, in fact never physically detected due to the impossibility of access, as well as the lower part of the pedestals. Even the protruding details of the statues, such as the decorations, the crucifix, the spear, and three halos, were seen not to have come in much detail from photogrammetry. So we proceeded to the three-dimensional reconstruction of this object starting from the original visible shapes and based on the individual photos.

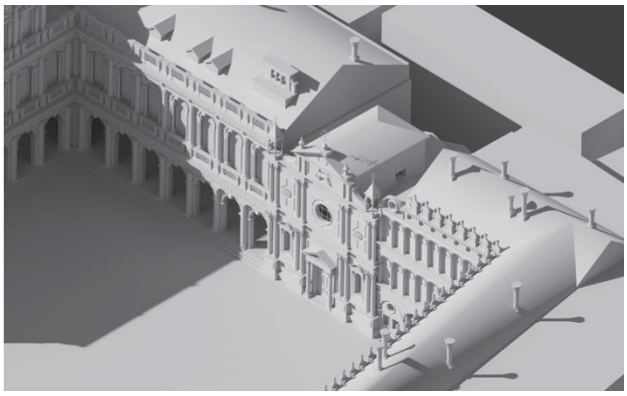

Figure 4. The virtual reconstruction of the church and of the square

Figure 5. Photorealistic rendering of the texture model

IV. THIRD PHASE: MODELLING THE HYPOTHETICAL RECOSTRUCTION OF SAN GEMINIANO

The final three-dimensional modeling of the interior of the Church, its facade and parts of the Old and New Procuratie, based on archives documents and survey data, was done using two Autodesk softwares - AutoCAD and 3DS Max.

Initially it was decided which drawings to use for the reconstruction and the final choice fell on those of Antonio Visentini, as they come from the same historical era, made in the same period, by the same person and consistent with each other.

For the reconstruction process, drawings by Antonio

Visentini were mainly utilized, because were made before the demolition of the Church and are, therefore, considered to be the most reliable source material.
The drawings were referenced and scaled according to the graphic scale in Venetian feet (1 Venetian foot is equal to 34.7735 cm)
The profiles of the pedestals, the columns and of the moldings were redesigned, both internally and externally using all the archives documents at the same time to obtain a complete description.
All the structural elements of the Church were modeled, piece by piece, starting from the mesh (by photogrammetry or laser scanning) and integrated with the basic operations of three-dimensional modelling.
Once the modeling of the church was finished, the artworks were also re-positioned after having been previously surveyed.
Next came the texturing phase or, more specifically, the creation and application of photorealistic materials.
To obtain these materials, some textures of different marbles were applied. Also, different photographs of some facades on various Venetian churches were taken.
Three different versions of the façade were developed, based on the design by Visentini, on the painting by Bellotto and on that of Canaletto.
Particular attention was given to render process, i.e. materials, texturing and unwrapping of the meshes' texture. The obtained results are particularly interesting, not only from the point of view of the rigorous process adopted to virtually reconstruct San Geminiano, but also the highly mimetic effect reached during the photorealistic renderings. The model, once inserted in the Venetian real context, that is San Marco's Square, provides an excellent example of virtual reconstruction in order to communicate both the history of the Church and of one of the most famous Square in the word.
Besides the views and the animations, the project went on with the creation of a prototyped physical model (3d printing) of the palace which took the interpretation gained from the comparison of the actual form and the historical documents, into consideration [19,20].
The use of printing processes based on metric surveying enables production of objects that replicate the true shapes or, as in the case of San Geminiano's church, they reproduce situations, i.e. places and architectures, that are no longer visible today. Researchers often use three-dimensional digital models and printed ones for purposes of data collection and analysis, thereby avoiding physical contact with sensitive objects or to implement an exhibits experience. As noted, the most rapid and extensive diffusion of 3D technologies, within the overall area of CH, has been in museums, where the concept of "usability" has always been manifest: a reality that relates well the potentials of 3D technologies for the attraction and engagement of a very wide public, including even those who would not be regular visitors. The aim is to move the traditionally conceived museum exhibit towards a multi-level and multi-sensory experience, offering new ways of interaction. Monitors, projectors and physical models or replicas are used to add information, but also to transform the way in which the user approaches art itself [21,22].
The production of the physical model requires machine operations which are themselves characterised by different levels of accuracy. Different printers utilise different methods and materials to translate the virtual model into a physical one, as suggested by their names: computer numerical control (CNC), sterolithography apparatus (SLA), fused deposition modelling (FDM), selective laser sintering (SLS). These different choices imply different accuracies and resolutions. The technology used for the prototype of San Geminiano's church was the SLS of polyamide powder because it ensures a high level of detail and the surface is also suitable for any video mapping installations to make the model "augmented". The "augmented model" want to mean the interaction between digital fabrication (3d printed model), rendering of the digital models, videos and video-mapping just to support communication and disseminating the results and the hypotheses we made about the reconstruction of the church and of a part of San Marco's square, with the most appropriate tools.

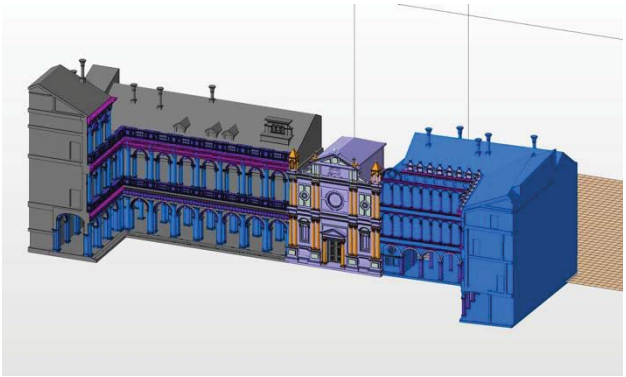

Figure 6. preparing the model (STL) for 3D Printing

Figure 7. The printed model

V. CONCLUSIONS

The experience of the digital reconstruction of the lost church of San Geminiano presented in this document highlights how geomatics, when applied to cultural

heritage, enhanced by equipment from different disciplines and fields of use, can provide the necessary applications to integrate the information on the city's history and architecture into a coherent whole entity, even when deriving from different sources, often not connected to each other. These processes are however closely linked thanks to the transversal contribution technologies give us: the diachronic process of 3D modeling for the recreation of lost or partially lost monuments should be developed through the integration and interpretation of historical and real data.

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Figure 8: The Ala Napoleonica in San Marco's Square in Venice today

Figure 9: the virtual reconstruction of the Church of San Geminiano in a photorealistic rendering