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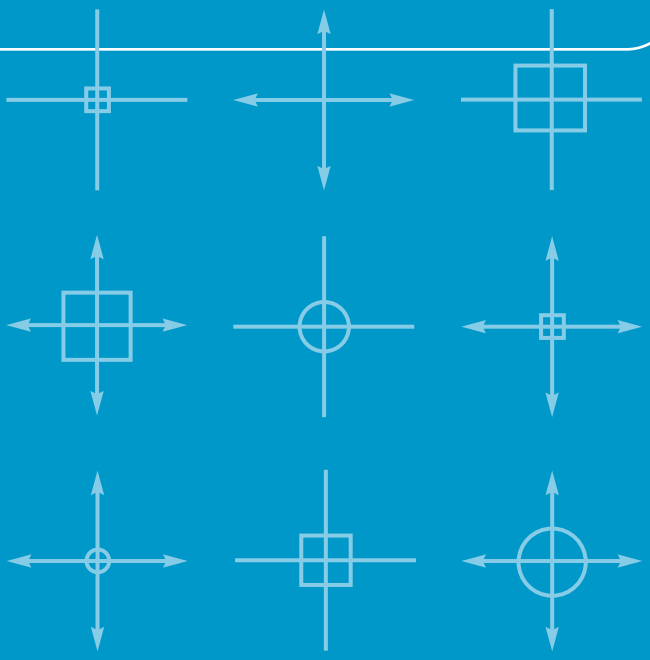

STADT ARCHÄOLOGIE WIEN

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SfM digital survey and modelling

for the Museum of the sculptures of the Basilica of St. Silvestro, Catacombs of Priscilla in Rome

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Abstract: The basilica of St. Silvestro, at the catacombs of Priscilla in Rome is a recent construction, it was built in the early XX Century, but it was constructed over the foundations of a structure developed in different times during the Late Antiquity. It is now at the end of a meaningful restoration. The South-East part of the original building was conceived as a space for burials. Currently this area is used as storage for the archaeological materials found during the excavations of the past century. The new museum of the sculptures will contain 405 pieces of sarcophagi dated between the beginning of the III Century A.D. and the first half of the IV Century A.D. One of the most important pieces in this collection is a well preserved marble sarcophagus, dated around the III Century A.D., engraved with scenes from everyday life, agriculture and sheep-herding. This piece is the object of this paper, quite a challenge for a digital survey, because of the complex characteristics features of the sculptures and it's fine details. And last but not least due to the difficulties linked to the light subsurface dispersion of the marble. For these reasons the survey was based on the Structure from Motion process, using a digital SLR camera and a specific SfM software. The main advantages of this choice are the reduction of the instrument costs and their practical management: all was done with a good quality camera, a tripod and some studio lights, while a single, middle price, software was used to produce the final digital 3D model. The final results, edited and optimized in different solutions for multimedia presentation and prototyping were soon ready for further use, like the implementation into a multimedia database of the details. (under development).

Keywords: sarcophagus, 3D modelling, photo-modelling, database, Structure From Motion.

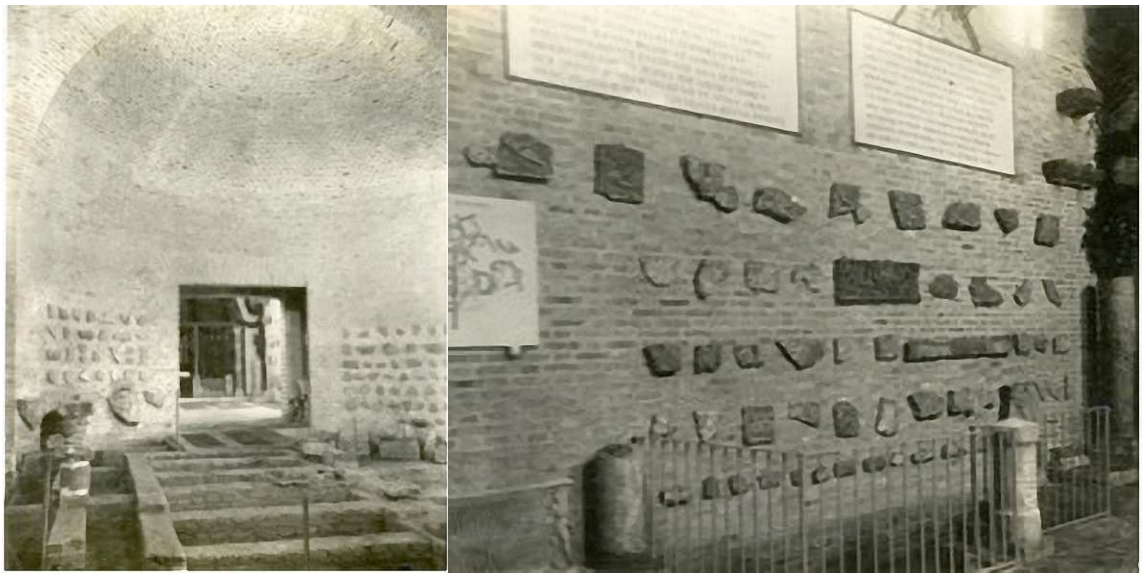
Introduction

In our time the use of new technologies in Cultural Heritage subjects is an important step for analyzing the patrimony of humanity and enhancing its documentation. In the last years the digital surveys made with 3D laser scanner technologies brought on numerous case studies aimed to digital representation and interpretation, while the digital and multimedia solutions have renewed and expanded the range of communication tools available for the dissemination and even for the protection of Cultural Heritage. The main problem connected to the production of meaningful innovation and important contents is often the fact that this kind of technology requires high costs, often beyond the intentions of institutions and the possibilities of a single researcher or scholar. And this is not only about the cost of the tools, while they can be found for rent at reasonable prices, but regards the meaningful investment required in post-production of the contents and development of the final products. It is enough to think about the passage starting from a

point cloud to generate high quality 3D model and 2D drawings to understand the complex -and time consuming- process needed to develop versatile multimedia contents.
Nowadays there is a well-known and very popular method to operate an efficient digital survey: the use of photogrammetry based on the Structure from Motion (SfM). These procedures are now in a great moment, based on very well working software, their main vantages are: the good exploiting of the digital camera features, interesting perspective of development, well working freeware software tools, a quite short workflow for producing usable 3D textured models. The result is a sort of “return” in the Cultural Heritage subjects of the photogrammetry techniques, with a more than ever “immediate” and “easy to use” logic, which can be translated in a sort of “it’s easy to play, it’s hard to be a champion”. But the fact is that this is a low cost procedure and is thought to work with standard photographic equipment. Some online solutions, like the Autodesk 123Dapp website, offers the possibility to produce model virtually but also physically, selling 3D print-on-demand physical copies of the model generated from the uploaded pictures.
The classical process to produce a 3D model out of a set of pictures consists in a photographic survey of the object (from the building to the small element, like a sculpture), made with a good illumination, and a subsequent software operation, with a final generation of a textured 3D model of the object.
The process of development of these processing was quite long through time, but it has reached a meaningful acceleration in the last five years with the production of important and well working software solutions like Agisoft Photoscan and freeware software package like Autodesk 123D Catch, Microsoft Photosynth and Visual SfM, just to name the more popular. The case studies about Cultural Heritage themes surveyed using SfM solutions are right now really numerous, and this is due to the simple approach of the software solution and the very portable set of tools needed to work in this way.
An important fact of this processing is that a lot of the possible accuracy and the whole quality of the final result depend on the quality of the shooting: not completely focused photos, micro-blurred images and lighting conditions, can reduce or even invalidate the possibility in obtaining a good quality model. So any high quality model starts, in this case, from a high quality set of pictures. It is possible to consider this solution as a very powerful tool, balanced between traditional and innovative features and available for multiple purposes and needs but with the option to be efficiently inserted in the general workflow of any research about Cultural Heritage subjects. Is the case study presented here, the need to produce a high quality model of an important and well preserved element found a good and economical solution in the use of these photogrammetric procedures.

The Basilica of San Silvestro and the Priscilla’s Museum

The Basilica of Saint Silvestro is a small church in Rome, it has the particular characteristic of rising above the catacombs of Priscilla, the church in itself is a quite recent realization, while it was built in 1907 over the remains of two ancient constructions from the third and the mid-forth centuries.



Figs. 1-2 – Early 1900: the museum at the time of its first opening (from the PCAS archives)

The original buildings were incorporated in a funerary enclosure and probably they were surrounded by numerous mausoleums. Inside the church, the floors of both buildings were tapped in time with the insertion of tombs some graves were placed also in the walls. In the fourth century, in the oldest building, there was the transferring of the bodies of two martyrs: Felice and Filippo and the realization of the burial of pope Silvestro (who died in 335 A.D.).

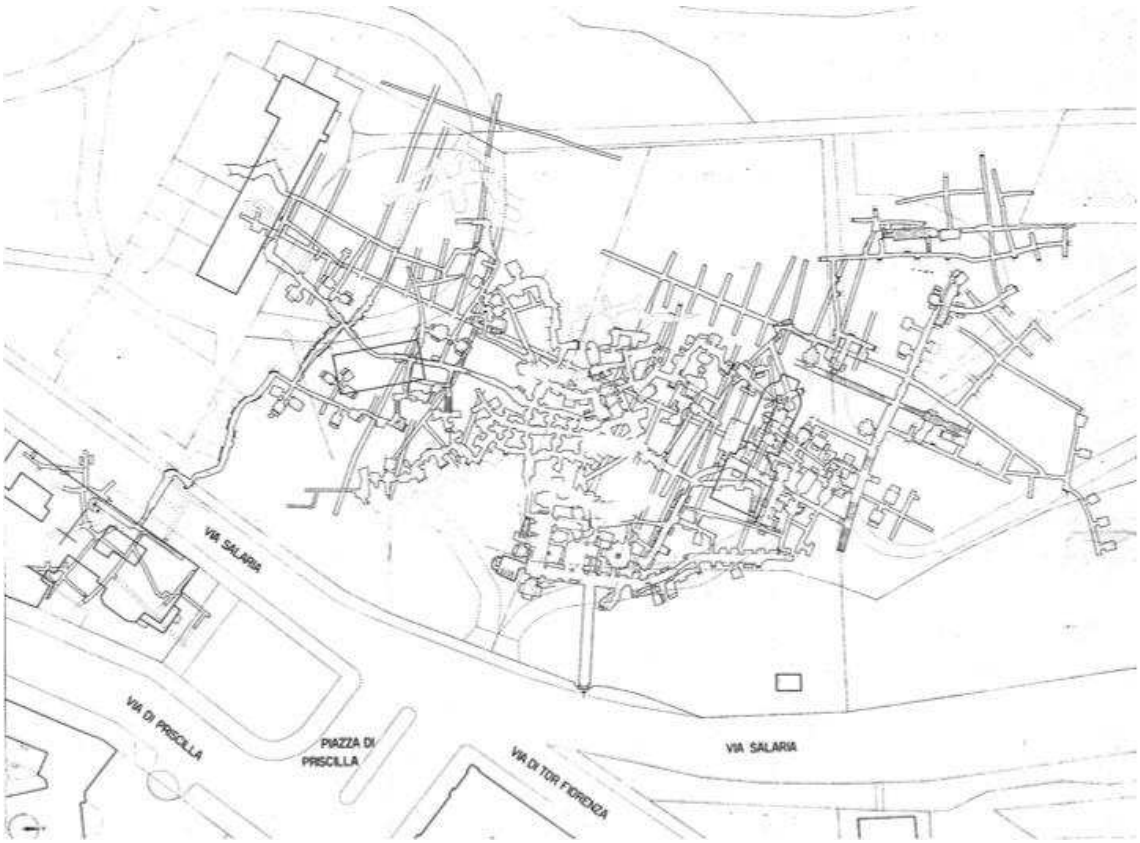


Fig. 3 – The plan view of the system of the Priscilla's Catacombs

In the funerary area many sarcophagi were placed, but in time they get lost, fragmented, stolen, their parts falling on the ground and mixed. All these artefacts were found during the excavations operated at the beginning of the XXth century. At that time the choice has been to display them directly in place, so the marble fragments were hung on the walls of the reconstructed building. The museum of the sculptures of the basilica of Saint Silvestro collects almost five hundreds of sarcophagi pieces, dated between the beginning of the 3rd century and the first half of the 4th century. Two entrances connect the basilica to the underground tunnels of the catacombs. The underground micro-climate strongly influences the above environments creating significant phenomena of condensation and humidity problems. A monitoring system was added during the restoration works to better verify and manage these conditions.

The basilica is property of the Vatican, and any intervention on it is coordinated by the PCAS (*Pontificia Commissione Arte Sacra*). With the articulated operation of reorganizing the whole basilica as a new museum, the importance of this ancient building became very important. The new museum has a double role: it exists as a physical space, and it now exist as a virtual space, both the version can collide during the visit on the place, creating enhanced experiences for the visitors. The whole intervention is oriented in obtaining an efficient modern museum, and so the digital effort becomes an important part of the whole work, enriching the quality of the visit and reducing the need of panels and writes. It was chosen to maintain the pieces in their original context through a project and a web-application based on the ISEE software. This software has been developed by Laura Pecchioli and an international research group at the Technische Universität in Berlin starting from 2009. Its intuitive interface allows the user to navigate in the model and retrieve the information when he/she is looking.

The basic idea of the ISEE is to enable information retrieval by simply viewing inside a 3D environment, since moving and looking in the real world are basic modes which all viewers use. ISEE ranks the relevant information by means of its position/orientation in 3D space as a viewer, proposing them to the visitors during the visit, checking their positions and pushing the available information about the objects nearby, in this way it is possible to read the suggestions without the need to move in strange position (like it happens when the visitor is asked to walk around looking through a tablet) and fully appreciate the characteristics of the place without having excessive overlaps between the virtual apparatus and the real museum.

Figs. 4-5 – Fragments of the sarcophagi (from the PCAS archives)

The restoration of the sarcophagus

The archaeological investigations allowed the recovery of hundreds of fragments from the sarcophagus once buried in the basilica and in its surrounding areas. In the winter of 2009, the Pontifical Commission for Sacred Archaeology has decided to proceed with the restoration of the stone materials.

In the course of the cleaning of the findings it has been realized the opportunity to reconstruct a large number of fragments giving back the unity of the sculptures. The high quality of materials and the variety of typologies testify a sculptural production extended in time for a period around four centuries. The sculptures were restored and archived following the standard of the ICOM-CIDOC (International Committee for Documentation of the International Council of Museum).

Fig. 6 – One of the restorers at work during the interventions of the 2009 (from the PCAS archives)

The aim of these operations

The goal is to rebuild the historical identity of this architecture through a permanent exhibition, where the fragments of the sarcophagi can be highlighted. The museum has been thought and developed using digital technology since the beginning.

To allow the correct realization of the whole new asset of the glass floor and to preserve the remains of the burial area at the best, all the rooms of the basilica have been digitally surveyed using a phase shift 3D laser scanner (a Cam/2 Faro Photon 120 unit).

This well working solution allowed to obtain a detailed digital 3D model of the ancient level of the tombs, giving to the designer all the measurements and the references needed to define the new floor with accuracy.

The large number of fragments does not allow an easy presentation of an adequate set of information directly in the exhibition, the typical use of panels should result in an “invasion” of the collection, compromising the general aspect of the place.

For this reason, the digital system, fully integrated in the real museum, allows the user to be able in retrieving detailed information connected to each fragment, using a QR-code (or an URL) placed *in situ* the visitor is able to reach additional information connecting to a local server through the WiFi network of the Basilica. At the same time, the 3D web application for a virtual visit and QTVR (QuickTime Virtual Reality) movies will be available on the Internet to help people understanding the context of the basilica before, during and after the visit.

The sarcophagus and its survey

One of the most important piece in the collection is a well preserved marble sarcophagus, dated around the III Century A.D., graven with scenes from the everyday life and from agriculture and sheep-farming activities. This piece is a challenge for the digital survey and representation, because of the complex characteristics of the sculptures, the small size of the details and last but not least the difficulties linked to the light subsurface dispersion of the marble.

Fig. 7 – The sarcophagus after the restoration (picture by Mirco Pucci).

For these reasons its survey was based on the Structure from Motion process, operating using a digital SLR camera and a specific SfM software. The main advantages of this choice are the reduction of the instrument costs and their practical management: all was done with a good quality camera, a tripod and some studio lights. A single software was used to produce the final digital 3D model. The final results, edited and optimized at different resolutions for multimedia presentation and prototyping were soon ready for further usages, like the implementation in the multimedia database of the fragments, still under development at the time of the survey.
The survey was made directly inside the Basilica, because of the fact that the sarcophagus is very weighty, fragile, and obviously difficult to be moved.

Figs. 8-9 – The survey of the sarcophagus (pictures by Alessandro Blanco).

Consequently it was necessary to organize a shooting set inside the Basilica. This was done with three artificial lights, with continuous lighting and a temperature around 3200° Kelvin, the quite dark conditions of the room helped in balancing the artificial light, because of the digital nature of the shooting session the camera was easily set to compensate this typical photographic kind of lighting. A first quick photo survey was made in form of test and allowed to realize a first SfM process to analyse the quality of the lighting and to reorganize them reducing the shadows and giving a smoother result to improve the quality of the calculated digital model.

The SLR camera was placed on a tripod to reduce the risk of shaking blur in the photos and to allow a full exploitation of the image qualities: the exposure time was very slow because of the stopping down needed to extend the depth of field, and because of the low ISO setting chosen to reduce the digital noise caused by high sensor speeds.

The photos were taken with a Canon 450d 12.2 mega pixels digital SLR camera with a 200 ISO setting and an exposure time from 15 to 30 seconds, the lens was a Canon 18-55mm zoom (used at 18mm focal length) with the stop set at F11, the camera was placed at a distance around 1,6 meters from the sarcophagus. In these conditions all the elements between 0.61 to 2.87 meters from the focal plane of the camera were fully in focus, allowing 2.26 meters of DoF, a perfect condition to have all the elements on the sarcophagus in focus while the elements from the background were blurred. The whole shooting session took care about the three main sculpted sides, using the same settings. From the whole photographic campaign a set of 80 shots were then selected to enter the 3D creation process.

The generation of the 3D surface

The first step of this process was the generation of a 3D model with a high level of polygons (commonly named “high poly mesh”) to describe every possible detail of the sarcophagus.

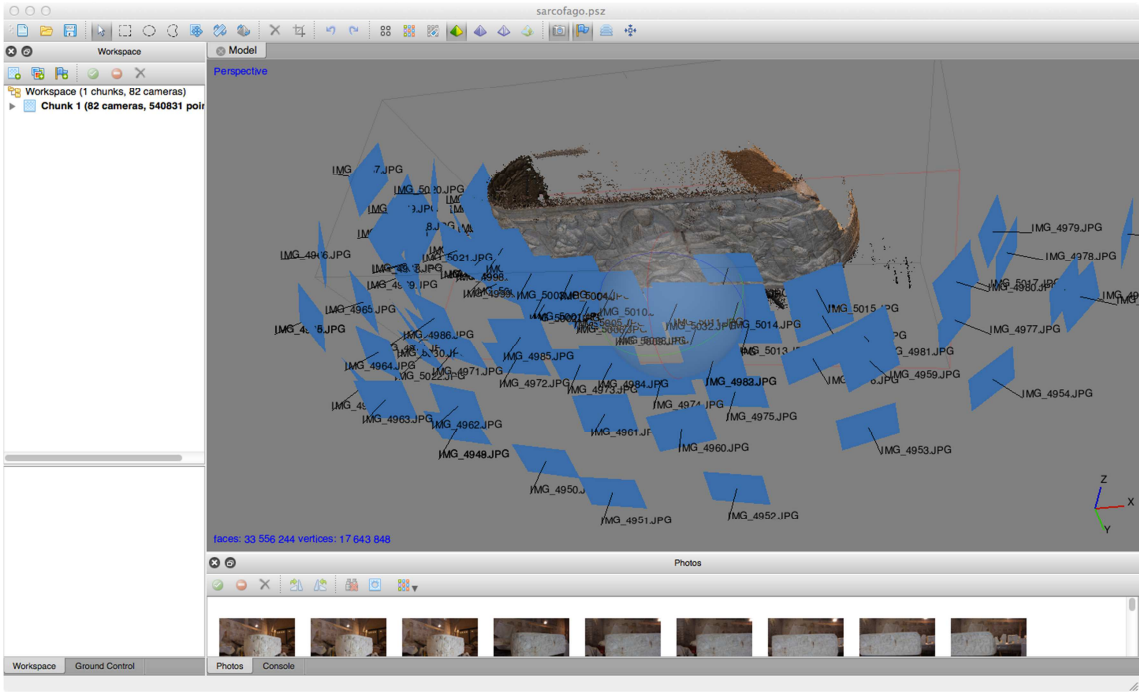


Fig. 10 – The generation of the 3D model in Agisoft Photoscan.

The process was made using Agisoft Photoscan and the workflow was the typical one for this kind of software: a first step based on automatic calibration and positioning of the photos in the 3D space, and the consequent generation of a pointcloud with chromatic features of the object. After these first couple of operations it was possible to calculate the high poly mesh, this first resulting model came out from this processing made of seven millions polygons, but this result has some critical factors and it was not directly usable for multimedia because of its “weight”, otherwise it represents the first starting point of the model processing. The first post processing was the mesh editing, resolving all the difficulties in managing the surface with operation of filling the holes and correcting small and medium mistakes produced by the automatic surface creation. It can be very hard to identify and select the holes in a high poly mesh and It’s possible to have some risk in making improper corrections on the surface, so a great attention must be paid to this phase. A similar condition happens for the texturing operation, because it’s practically impossible to manage an UV map with a very high number of faces. A high poly model has problems of any editing with most of the commercial hardware, it makes necessary to operate using high performance workstations. In the end, it is worth to be said that, every multimedia system supports the use of only “light” model, because the web application (for example the applications developed using Unity) doesn’t run high poly models, being created for a fast data transmission and to be used with basic performance hardware like home computers, tablets and other personal devices.

Fig. 11 – The original mesh as produced at the end of the photogrammetric process (reference scale in centimeters) .

For these reasons it’s necessary to produce an optimized 3D model, with the generation of a surface made by a reduced number of polygons (commonly named low poly mesh), with a normal map and a chromatic texture derived from the high poly mesh to enhance the visual appearance of the final result.
The simplification process can be made within the Agisoft Photoscan or even with other surface editing software. The final result for the sarcophagus was a mesh made by 150.000 polygons. The resulting surface required some extra editing process to fill some minor holes and to filter some residual noise in the mesh.

After this process was done it was possible to generate an UV map, necessary for the subsequent operations of baking and texturing aimed to produce the final model for the multimedia use.

Fig. 12 – The decimated 3D model after the editing operations (reference scale in centimeters).

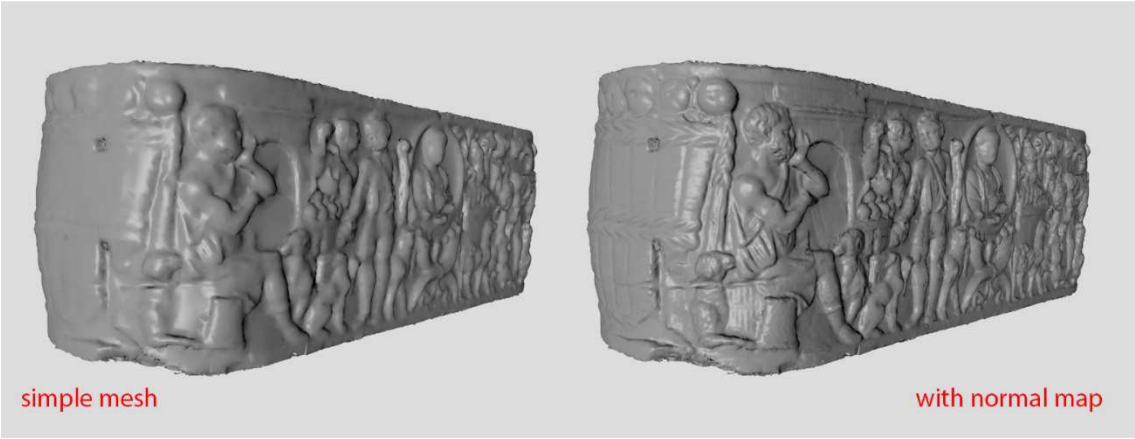


Fig. 13 – The same 3D model with and without the normal map applied .

Fig. 14 – The textured final digital 3D model (reference scale in centimeters).

The UV map is a bijective correspondence associating the coordinates X, Y, Z of the mesh to the UV coordinates of an image. The UV map of the low poly objects can receive, after a baking process the normal map, the texturing and even other kind of maps, coming from the high poly mesh. With this procedure the low poly mesh will show the geometrical characteristic of a high poly model, with a virtual increase of the numbers of polygons and a meaningful visual enhancement.

Figs. 14-15 – The virtual museum in progress: the hall, the exposition structures and the model of the sarcophagus.

If an external software is used to reduce the complexity of the surface, the final texturing process can be made after re-importing the low poly mesh into Agisoft Photoscan. In facts, the edited result will be positioned in the same place of the original high poly model, then the software will automatically generate the chromatic texture of the object and the process will be completed.
At the end of this process an optimized 3D model usable in the multimedia solutions is made, the new model is “lightweight” and fully compliant for exporting in one of the many possible/needed digital formats, and can be easily imported into other software to complete the preparation of the multimedia product.
The high poly model remains as a higher quality documentation of the object, usable for specific analysis needs or for further studies/uses.
It can be even used in the future to update the multimedia product in itself if there will be the option to use more complex models in the online presentations.

Conclusions

The interdisciplinary collaboration has been a contribution to try innovative solutions to be operated for accessing and managing the information about the basilica of St. Silvestro and all its ancient findings and remains. After the opening of the Museum, in November 2013, the completion of the 3D virtual museum started its advanced phase. All the rooms, like the main hall, are generated and modelled with a process similar to the one used for the polygonal mesh of the sarcophagus, but using the data produced by the 3D laser scanner survey. After a fast modelling of the interior museum setup, it’s now in progress a series of model constructions about the various fragments located all around the museum. The aim is to produce a good quality 3D digital model of the whole museum optimized for multimedia use. This process will surely results in a quite economic and satisfactory workflow for this kind of work.

Acknowledgment

The Priscilla's Museum website can be found at the following URL: http://www.mupris.net/

The coordination of the whole intervention is cured by Barbara Mazzei from the PCAS (Pontificia Commissione Arte Sacra) . The digital concept and the design of the new physical and virtual Priscilla's Museum is a work from Laura Pecchioli. Digital solution for multimedia and communication are developed by Mohamed Fawzi. The digital survey work of the Basilica of St. Silvestro has been done by Alessandro Peruzzi (Area3D S.r.l. Livorno) and Mirco Pucci under the coordination of Giorgio Verdiani and Laura Pecchioli. A great thank you to all the people from the PCAS for the chance, the challenge and the interest demonstrated in time to each new proposals. A special thank you to Barbara Mazzei for her efforts and her involvement in this work.

References

GUIDI, G., REMONDINO, F., RUSSO, M., MENNA, F., RIZZI, A., ERCOLI E. (2009). A multiresolution methodology for the 3D modelling of large and complex archaeological areas, in "Special Issue in International Journal of Architectural Computing" (IJAC), Vol.7, pp 39-55.

KULITZ, I., FERSCHIN, P.(2013). Im Schatten der Pyramiden. Von der Grabung zur virtuellen Präsentation, catalog Im Schatten der Pyramiden. Die österreichischen Grabungen in Giza (1912 - 1929), ed. by S. Haag, R Hölzl, P. Jánosi, Wien.

LOCATELLI, M.P., RINALDI, D. L., SIMONE, C., VIZZARI, G.(2012). Supporting Valorization of Cultural Heritage Documentation: The TIVal Portal Approach,18th Internationale Conference on Virtual Systems and Multimedia, Virtual Systems in the Information Society,

MANFERDINI, A. M., REMONDINO, F. (2010). Reality-Based 3D Modeling, Segmentation and web-Based Visualization, in Proceedings of EuroMed 2010, 8-13 November, Cyprus, Limassol.

PECCHIOLI, L., MOHAMED, F., PUCCI,M., MAZZEI, B.(2012), Browsing in the virtual museum of the sarcophagi in the Basilica of St. Silvestro at the Catacombs of Priscilla, in Rome,18th Internationale Conference on Virtual Systems and Multimedia, Virtual Systems in the Information Society, IEEE VSMM, 2-5 September 2012, Milano, Italy.

PECCHIOLI, L., YULE, P., MOHAME,D F. (2012). (ZVM) Das durch ISEE kreierte Zafar Virtual Museum, in «Forum Archäologie» 61/XII/2011, http://farch.net, Zeitschrift für klassische Archäologie 1605-4636.

PECCHIOLI L. et al. (2011), ISEE: Information access through the navigation of a 3D interactive environment, Journal of Cultural Heritage.

TOLOTTI, F.(1970). Il cimitero di Priscilla, Studio di topografia e architettura, Città del Vaticano.

VERDIANI, G., DI TONDO, S., FANTINI, F., PUCCI, M. (2011). "Il ritorno all'immagine, nuove procedure image based per il cultural heritage", Lulu, USA.

PECCHIOLI, L., MOHAMED, F., PUCCI,M., MAZZEI, B.(2013), Museum of the sculptures of the basilica of Saint Silvestro integrating the visit at the catacombs of Priscilla in Rome,Built Heritage 2013 Monitoring Conservation Management, 18-20 November 2013, Milano, Italy.

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